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Svenska Elektromekaniska Industriaktiebolaget, Hälsingborg.

R 2056 Wiew of the Factories at Hälsingborg.

In 1918, Svenska Elektromekaniska Industriaktiebolaget—"Elektromekano" for short—was formed for the purpose of taking over the engineering business of Hälsingborgs Mekaniska Verkstad. This firm was founded towards the end of the 18th century, and at first produced chiefly cooking ranges and sundry commercial castings. During the subsequent 150 years, the business kept pace with the progress of mechanical engineering, and was eventually extended to include also the building of railway engines and trucks, steam-engines, etc.

The manufacture of electrical machinery and transformers was taken up in 1916 and soon grew to be of considerable importance, the whole production programme thus assuming an electromechanical character. Since taking over the old company, Elektromekano has considerably enlarged the plant and factory buildings, the electrical manufactures have been standardized, and now comprise practically every description of high tension appliances, e. g. threephase and D. C. motors and generators, motor generators, synchronous converters, induction voltage regulators, and all kinds of transformers. Considerable changes in and additions to the original factory have been made for this purpose. A view of the plant is reproduced on p. 18. In course of time, a large number of appliances etc. have also been manufactured in connexion with complete electrical equipments for power stations and factories.

R 2057

L. DE LA COUR.
Managing Director of
Svenska Elektromekaniska
Industriaktiebolaget.

The increasing production of electrical machinery led to the establishment in 1918 of a drawing-mill for copper wire, to supply all the copper wire required in the works and so make these independent of outside sources of supplies. This mill was considerably enlarged in 1922, when a modern copper wire rolling mill was added. In 1925 several new roll stands were added, and down to 6 mm round copper wire can now be rolled in this mill, which is the only one in the Northern Countries capable of rolling copper wire to this small gauge. The wire mill therefore does not now supply rolled and drawn copper wire for the needs of the factory alone, but large quantitees are also sold to other firms.

The company does extensive business in all the Scandinavian countries, and is also represented in many European and extra-European countries.

From the beginning of 1931, it is entirely controlled by Telefonaktiebolaget L. M. Ericsson.

General Theory of Disturbances in Communication Lines, Caused by Power Lines.

By Professor *H. Pleijel.*

Introduction.

Reciprocal disturbances in parallel conductor systems are usually divided into two kinds, viz. those caused by "influence"/"static action", and those caused by "induction". As a rule, each effect is determined separately.

The electric field arising from the charges in the power system causes the "influence", and the strength of this field is determined from the Maxwell relations of potential differences and charges in the two systems.

The induced EMF, on the other hand, is equal to the product of the mutual induction coefficient per unit of length and the negative derivate of the current with regard to time. Corrections are made for the effect of occurring earth currents.

It is generally possible to use the conceptions potential- and induction-coefficients, as long as the distance between the lines is small in comparison with the parallel length of the lines and the wavelength. This is usually the case when investigating the reciprocal effect of the several wires of a power-line system, as well as of a grouped number of telegraph and telephone lines. But when the disturbance caused by a power system in a line of the latter description has to be determined, the distance between the two systems is frequently so large that the conceptions induction- and potential-coefficients can no longer be used in the calculations.

To bring problems of this kind back into the sphere of parallel conductors in which certain definite EMF:s are acting, the author in 1925 propounded, proved, and made use of the following general theorem: If a conductor system A acts on a conductor system B, the currents which then arise in B can be determined by introducing in the B-conductors fictitious EMF:s, in size and direction equal to the electrical field which would have obtained in the points of the B conductors if the conductivity of the B conductors had been = 0. If the permeability of the conductors in the B-system is 0, this system may be considered removed when determining the fictitious EMF:s.

Premising a neutral condition, the charges in B are obtained directly from the currents. The same is the case in the final stationary/static state, e. g. when simple sinusoidal EMF:s act in system A.

The potential difference in system B is obtained by adding to the voltages corresponding to the currents in this system the voltage which would be caused by system A at the corresponding points if the conductors of system B were removed.

No assumption has been made in the above theorem regarding the configuration or mutual situation of the two systems. If the theorem is applied to two parallel systems of conductors and earth, the power system and earth may be taken as system A, while the conductors of the communication lines, with any possibly occurring earth connexions, are called system B.

When computing the currents in system B, it is necessary to take into consideration the presence of the system A conductors. Frequently, however, this effect may be disregarded, e. g. when, on account of the distance between the two systems or on account of the conductors of system B being balanced, the reciprocal effect of the two systems is small.

Our general problem would then be divided into two, one to determine the field caused by system A when system B is removed, and the other to determine the disturbing currents by means of the fictitious EMF:s acting in B thus obtained when system A is assumed to be removed. The last named problem is discussed in a separate paper, and we need therefore now only deal with the first problem, viz. the determination of the EMF:s appearing in system B on account of voltages and currents in system A.

Voltages and currents in the power system are mutually independent. The current in a system of conductors with varying voltages can be equalized by means of transformers.

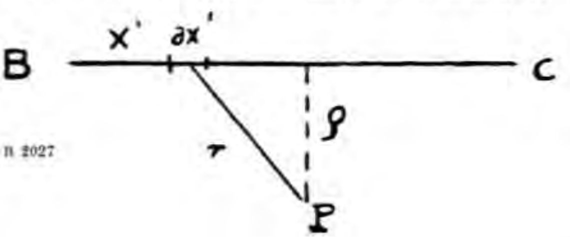
The obvious course is therefore to divide the forces acting in the communication line conductor into those caused by the voltage and those caused by the current. They may further be divided into longitudinal EMF:s acting, as indicated by the name, in a direction parallel to the line, and transverse EMF:s acting in conductors joining or earthing the wires of the system, consequently in conductors lying in planes at right angles to the parallel direction.

On examination, the transverse forces prove to depend on the voltage in the power line system.

As regards the longitudinal EMF:s, we have first the electrical field corresponding to the "induction", i. e. equal to the product of the mutual induction coefficient and the negative derivate of the current with regard to time. This longitudinal EMF is conditioned by the current. But we have still another longitudinal component, namely that corresponding to the voltage drop in the power line. The voltage drop being a function of the current, this longitudinal component will also depend on the current, and not on the voltage. These two components being directed in almost opposite directions, their resultant will, as we shall find later, be proportionate to the ohmic voltage drop.

But we get a longitudinal force also dependent on the charges at the ends of the power line section under consideration. In points at a distance from these ends, this residual component may generally be disregarded. It is, however, a function of the voltage, and can therefore as a rule be grouped with the transverse EMF:s.

To illustrate the above, we will consider the conditions arising when the A-system conductors are ideal conductors, i. e. have no resistance. If



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sinusoidal EMF of high frequency be fed to the system, we get strong "induced" EMF:s. Nevertheless no longitudinal EMF will arise, as the electric field is at right angles to the ideal conductor. The reason for this is that the longitudinal field caused by the voltage drop will completely neutralize that caused by the "inducing" force. Naturally, conditions cannot be materially altered if the conductors of the A system are not perfectly ideal, but have a slight ohmic resistance. In that case, we thus get a longitudinal EMF proportionate to the ohmic voltage drop which is small in comparison to the "induced" EMF, and also unaffected by the frequency.

In this connexion we may mention that measurements taken in 1915 along the electrified railway Kiruna—Riksgränsen gave almost the same EMF per 100 ampere-kilometre aat $16\,^2/_3$ cycles as at 25 cycles.

Measurements in 1929 on the telephone lines running parallel to the Stockholm—Uttran power lines showed an EMF of 1.74 volt per 100 ampere-kilometre at 25 cycles, and 1.70 volt per ampere-kilometre at 50 cycles.

The Electrical Field caused by a Straight Conductor.

The results of these measurements caused the following investigations to be undertaken.

The electrical field at a certain point in the vicinity of a live conductor is generally assumed to depend solely on the current and voltage at the base of the perpendicular to the conductor from the point in question. This assumption is correct as long as the distance to the conductor is small in comparison with the parallel length and the wave-length.

In order to obtain formulas of a more general applicability, however, we will assume the electrical field at a point outside the conductor to be determined by all the elements of the power line.

We assume BC to be one of the conductors in a power line system, and select an element dx' situated at a distance x' from the end B. The current in this element is assumed to be $i(t,x')$, and the charge per unit of length at the point x' $q(t,x')$. The current is positive in the direction of an increasing x'. We consider a point P in the field outside the conductor, and call the distance between P and the element dx' r. The coordinates of the point P, with origin in B, we will call x, y, and z, of which the coordinate x is parallel to the longitudinal direction of the conductor. The directions of the y- and z-axes will for the present be left open, except that their origin is in the point B. The distance from P to the conductor we designate ϱ. The formula will then be:

$$r^2=(x-x'^2)+\varrho^2.$$

As we know, the field in the point P is determined by the vector potential $\overline{A}$, which is parallel to the direction of the current, and the potential function φ. These two are determined by the formulas:

$$\left|\begin{array}{l} :\overline{A}=\int \frac{e}{r}^{-p\frac{r}{u}} i\,(t,x')\,\overline{dx'} \\ \varphi=\int \frac{e}{r}^{-p\frac{r}{u}} \frac{1}{\varepsilon} q\,(t,x')\,\overline{dx'} \end{array}\right|$$

$\overline{dx'}$ is here a vector element directed from B towards C:

u is the velocity of propagation in the medium surrounding the conductors, and ε is the dielectric constant of this medium in absolute electromagnetic units.

The expression

$$e^{-p\frac{r}{u}} i\,(t,\ x')$$

is the equivalent of

$$i\,(t-\tfrac{r}{u},\ x'),$$

which is directly deduced by developing $e^{-p\frac{r}{u}}$ in a power-series in p or $\frac{d}{dt}$.

The integral extends along the full length of the conductor. We introduce the abbreviation

$$\psi=\frac{e}{r}^{-p\frac{r}{u}}$$

The components of the electrical field along the conductors and at ringht angles to them we call E_x and E_ϱ respectively.

We then get
$$\left|\begin{array}{l} E_x=-p\,A-\frac{d\varphi}{dx} \\ E_\varrho=-\frac{d\varphi}{d\varrho} \end{array}\right|$$

Here we have

$$A=\int \psi\ i\ dx'$$

$$\varphi=\int \psi\,\frac{q}{\varepsilon}\,dx'$$

We may now write

$$\frac{d\varphi}{dx}=\frac{d}{dx}\int \psi\,\frac{q}{\varepsilon}\,dx'=\int \frac{d\psi}{dx}\frac{q}{\varepsilon}\,dx'=$$
$$=-\int \frac{d\psi}{dx'}\frac{q}{\varepsilon}\,dx'=\left(\psi\,\frac{q}{\varepsilon}\right)_B-\left(\psi\,\frac{q}{\varepsilon}\right)_C+$$
$$=\int \psi\,\frac{d}{dx'}\left[\frac{q}{\varepsilon}\right]dx'$$

and

$$pA=\int \psi\,\frac{di}{dt}dx'$$

If we substitute these expressions, we get

$$\left|\begin{array}{l} E_x=\left(\psi\,\frac{q}{\varepsilon}\right)_B-\left(\psi\,\frac{q}{\varepsilon}\right)_C-\int \psi\left[\frac{1}{\varepsilon}\frac{dq}{dx'}+\frac{di}{dt}\right]dx' \\ E_\varrho=-\frac{d}{d\varrho}\int \psi\,\frac{q}{\varepsilon}\,dx' \end{array}\right|$$

In computing the field outside the conductor we may consider the current i as well as the charge q concentrated in the centre line of the conductor.

If we choose the point P on the surface of the conductor, we may disregard the effect of any line elements dx' the distance of which from P are large in comparison with the radius of the conductor. With the wavelengths usually occurring, we may consequently disregard the effect of elements far enough away for the strength of the current or the charge to have altered. When the point is on the surface of the conductor, we can therefore write:

$$\left|\begin{array}{l} E_x=-\left(\frac{1}{\varepsilon}\frac{dq}{dx'}+\frac{di}{dt}\right)\int \psi\,dx' \\ E_\varrho=-\frac{q}{\varepsilon}\frac{d}{d\varrho}\int \psi\,dx' \end{array}\right|$$

Before discussing these formulas further, we will define what is meant by the potential of a point in the field. All currents being parallel to the direction x', the lines of the magnetic field will lie in planed at right angles to the length of the conductors. The line integral of the electric field between two points in one of these planes will therefore be independent of the distance. We can therefore define the potential of a point as the line integral of the electric field from this point to infinity, if the integral is taken in a plane at right angles to the conductors passing through the point in question.

An integration thus gives us the potential value ν:

$$v = \int \psi \frac{q}{\varepsilon} dx'$$

Similarly, if the point P is on the surface of the conductor, we get:

$$v = \frac{q}{\varepsilon} \int \psi \, dx'$$

We will now introduce the symbols:

$$C = \frac{\varepsilon}{\int \psi \, dx'}$$

$$L = \int \psi \, dx'$$

On the surface of the conductor we thus get:

$$q = C \cdot v$$

C is the capacity operator per unit of length of the conductor. Further, at the surface of the conductor, we may write:

$$E_x = -\frac{L}{\varepsilon} \frac{dq}{dx'} - L \frac{di}{dt}$$

or, as $L\,C = \varepsilon$

$$E_x = -\frac{1}{C} \frac{dq}{dx'} - L \frac{di}{dt} = -\frac{dv}{dx'} - L \frac{di}{dt}$$

L corresponds to the external inductance of the conductor. According to the definition of the resistance operator and the operator of the internal inductance of a conductor, we have:

$$E_x = \left[R + pL' \right] i,$$

where R is the resistance operator, L' the internal inductance operator, and E_x the field strength on the surface of the conductor and the total current in the conductor.

Equalling the two expressions for E_x we get:

$$-\frac{dv}{dx'} = \left[R + p\,(L + L') \right] i,$$

R and L' are even functions of p.

If we now pass on to an arbitrary point P, we have:

$$E_x = \left(\psi \frac{q}{\varepsilon}\right)_B - \left(\psi \frac{q}{\varepsilon}\right)_C - \int \psi \left[\frac{1}{\varepsilon} \frac{dq}{dx'} + \frac{di}{dt} \right] dx' =$$

$$= \left(\psi \frac{q}{\varepsilon}\right)_B - \left(\psi \frac{q}{\varepsilon}\right)_C - \int \frac{\psi}{L} \left[\frac{dv}{dx'} + L \frac{di}{dt} \right] dx'$$

Substituting the previously obtained value for $\frac{dv}{dx'}$, we get:

$$E_x = \frac{\psi_1}{L} v_1 - \frac{\psi_2}{L} v_2 + \int \frac{\psi}{L} (R + pL') \; i \; dx'$$

or, if we disregard the internal inductance:

$$E_x = \frac{\psi_1}{L} v_1 - \frac{\psi_2}{L} v_2 + \int \frac{\psi}{L} R \; i \; dx'$$

Index *1* here refers to the B end, and index *2* to the C end of the conductor:

The formula obtained shows that the longitudinal field consists in two parts, the first caused by the potentials at the ends of the conductor, and the other depending on the ohmic voltage drop in all the conductor elements. This last part of the longitudinal field will thus not be dependent on the frequency except by consequent change in the resistance R. On the surface of the conductor the part of the field caused by the voltage drop will be

$$\frac{Ri}{L} \int \psi \, dx' = Ri.$$

This agrees with the theory.

At points P, at small distances from the conductor in comparison with the distances to the end points, we may disregard the first two terms of E_x. We have assumed nothing with regard to the distribution of charges along the conductor. At the ends of the conductor, however, these may, on account of the great conductivity of the conductor, be expected to be so distributed that the lines of the neighbouring electrical field will be at right angles to the conductor. By a first approximation, we may therefore assume the longitudinal EMF:s caused by the first terms to be localized to the vicinity of the ends of the conductor.

The formulas obtained show that *the longitudinal field caused by the current, and consequently the longitudinal EMF in a parallel line, is independent of the frequency.*

Note. An exception must, however, be made for the cases where the inductance of the inducing line is increased. This inductance will appear in our formulas as internal inductance, and the complete formula for the longitudinal field will be:

$$\int \frac{\psi}{L} \left[R + p\,L' \right] i \; dx'$$

At high frequencies the resistance will increase with the square root of the frequency, and the internal reactance will more and more equal the resistance. We cannot then disregard the internal reactance, and the longitudinal field will be practically proportionate to the square root of the frequency.

When the distance between the two systems of conductors is of approximately the same length as the distance for which the lines run parallel, we can no longer disregard the effect of the end charges when computing the longitudinal EMF in the communication lines.

We now pass to the transverse field of the EMF:s arising in conductors connecting the wires of the communications lines to one another and to earth.

According to the above:

$$E_{\varrho} = -\frac{d}{d_{\varrho}}\int \psi \frac{q}{\varepsilon}\, dx' = -\frac{dv}{d_{\varrho}};$$

The integral is extended over the full length of the conductor.

Is we assume a connexion between two wires in a system of parallel telephone or telegraph lines, and assume this connexion to be wholly in a plane at right angles to the parallel lines, we get an EMF $= E_l dl$ in each element dl. As the distance between the wires generally is small in comparison with both the length of the parallel lines and the wavelength, it is permissible to regard the EMF in the connexion local, and to put it equal to

$$\int E_l\, dl.$$

But

$$E_l = -\frac{dv}{dl}.$$

The transverse EMF acting in the connexion will consequently be equal to the potential difference in the field between the two ends of the connexion.

In the same way, the transverse EMF arising in a conductor connecting a wire to earth will be equal to the potential difference to earth in the wire at the point where the connexion is fixed.

We will now consider the total longitudinal EMF in the conductor of a communication line, obtained from the expression:

$$E_x = \frac{\psi_1}{L} v_1 = \psi_1 \frac{q_1}{\varrho}$$

If we extend the integral over the communication line conductor, we get

$$\varepsilon_x = \int E_x\, dx = \int \psi_1 \frac{q_1}{q}\, dx.$$

E_x will thus equal the voltage which would arise at the end of the power line if the charge along the whole length of the communication line conductor were q_1 per unit of length.

We will call the transverse EMF E, and the transverse EMF which would be obtained if the power line were of infinite length E.

If power line and communication line are earthed at the same point, we get approximately

$$E_{\varrho} = \frac{E}{2}, \text{ and } E_x = \frac{E}{2}.$$

In this case, the total EMF:s caused by the voltage will thus be

$$E_{\varrho} = E_x = E.$$

But if the power line continues far beyond the earthing point of the communication line, we have:

$$E_{\varrho} = E, \quad E_x = O,$$

the last because the end point is so far away. In this case also the total will be approximately equal to E.

If, finally, the communication line stretches far beyond the end of the power line, we get

$$E_{\varrho} = O.$$

Here, however, we get a longitudinal EMF in the line which will be equal to E opposite to the point where the power line ends. The total will consequently still be $= E$.

When the communication line is earthed, we consequently always get an EMF equal to E and determined by the power line voltage. When the distances between the conductor systems are comparatively small, these EMF:s may be regarded as being local.

If the power line stretches far beyond the communication line, and the latter is insulated at its end point, no EMF will be caused by the voltage.

Today's Knowledge of High-Tension Cables and Fittings.*

By *Bernhard Ell*, Chief Engineer with the Sievert Cable Works, Sundbyberg, Sweden.

Cables for super high voltages are insulated with layers of impregnated paper. Despite the fact that many attempts have been made to find a more suitable insulating material, which at the same time possesses the requisite pliability, as well as adequate electrical homogeneity, no positive results have been arrived at.

Even though all manufactures of high-tension cables have this experience in common as regards insulating material, there is a great deal of divergence of view as to the nature of the raw materials in same. Thus, for example, one finds some manufactures maintaining that it is absolutely necessary to use Manilla paper for wrapping the cables, whereas others regard cellulose paper as the only satisfactory material. Some manufacturers use only a light mineral oil for the impregnation, while others have found it considerably more advantageous to mix resin in the oil for making it better capable of withstanding the electrical strain. Viscous mineral oils are used in some cases, and it seems as if in the United States even oils of a vaseline nature, with comparatively firm consistency have been used for the purpose in question.

As to the choice of paper, it has recently been ascertained that it is of absolutely no importance whether Manilla or cellulose paper be used, provided that it contains no ingredients, or that no ingredients are formed during heating which might contribute to setting up electrolytical conduction in the insulating layer. It is a matter of extreme importance, on the other hand, that the grinding of bibrous material, and the hardness and thickness of the paper, should comply with certain demands. The resistivity to the flow of oil in the insulating layers, for example, is in a high degree dependent on the hardness of the paper, and the break-down voltage will also be higher with a harder paper, because the ions during ionization impinge against the fibres, which therefore provide a muchneeded protection against puncture, especially at low pressures. The thickness of the paper tape must also be considered in order to prevent the formation of voids at the wrinkless or the edges of the tape.

It is hardly possible to consider any other oils for the impregnation than well refined mineral oils, free from ingredients that can be electrolytically dissociated, and in that state possess conductivity which makes the oil unfit for insulating purpose. The properties of oils of decisive importance are the viscosity and the effect of the temperature on the volume, because the formation of voids in the insulating material is dependent on these properties.

Attention has furthermore in recent years been directed to so-called x-formation in the insulating layer. This phenomenon represents polymerization or condensation of the oil, and is produced by bombardment of electrons due to discharges in the voids. The oil is thereby subjected to a considerable alteration of consistency, although the electrical properties are not noticeably changed. The alteration of consistency is certainly assumed to have some bearing on the quality of the cable, but most manufacturers are nowadays of the opinion that this phenomenon is not in itself of decisive importance in regard to the serviceability of the cable.

The manufacturing of the insulation layer is a very important process, and the application of the paper and insulation of the conductor, as well as the drying and impregnation, comprise many phases of high quality work. It is well known that certain points or sections of a cable-length are liable to become hot during continued electric tension, although the temperature in the cable as a whole may not have increased to any appreciable extent. These heated sections, know

* Paper read at the World Engineering Congress, Tokyo, 1929.

as "hot spots", are characterized by the formation of carbon in the insulating material owing to partial discharges. Generally these carbon formations appear most frequently in the middle of the insulating layer, and not, as one would expect, next to the conductor, where the voltage gradient is the strongest, nor next to the lead sheath where voids and absorbed moisture might be apprehended. This fact makes it plain that "hot spots" have their origin in the manufacture, as there can hardly be any variation in the electrical properties of the oils or paper which are used. The insulating paper is wrapped on in the form of a thin tape, which in all probability ensures good continuity, and the careful stirring of the oil before the impregnation should also obviate heterogeneities of the kind in question.

The service demanded of a cable, however, must be gauged by the strength of the weakest point, and it is therefore an indispensable condition that the manufacturing equipment should make it possible to produce cables which are of an absolutely homogeneous character throughout.

Dielectric losses and Ionization.

For determining the quality of a high-voltage cable one must ascertain how the angle of loss is affected by the voltage, and it is then possible to differentiate between 3 principal ranges or divisions; see Fig. 1.

At voltages within the range A to B in the figure there is no ionization, and the measured development of energy is derived only from the solid and liquid insulating material.

At voltages from B to D there is added the loss of energy owing to ionizing shocks among the gas molecules in the layer. The discharge current in a gas space may of course be expressed as

$$i = k \cdot (E - E_0) \quad . \quad . \quad . \quad . \quad . \quad . \quad 1,$$

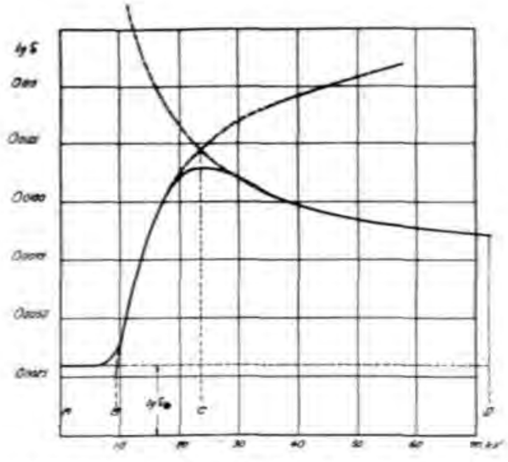
in which k is a constant dependent on the gas pressure, the nature of the gas, and the geometrical dimensions of the space, E being the voltage at the gas space, and E_0 the ionization voltage.

The power loss will then be

$$W = E i = k E (E - E_0) \quad . \quad . \quad . \quad 2$$

and the angle of loss at this ionization power, assuming the capacity of the cable to be constant, will be

$$\operatorname{tg} \delta_{ion} = k \left(1 - \frac{E_0}{E}\right) \quad . \quad . \quad . \quad . \quad 3.$$



R 1971 Fig. 1.

In the voltage range B—C the resistance in the ionized gas spaces is relatively high, and E will at first be proportional to the voltage gradient

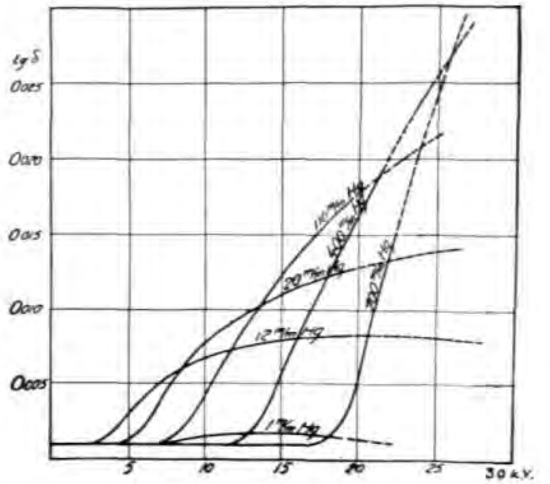
$$\operatorname{tg} \delta_B = \operatorname{tg} \delta_0 + k' \left(1 - \frac{V_0}{V}\right) \quad . \quad . \quad 4,$$

in which V_0 is the ionization voltage of the cable, and V the applied voltage.

In the voltage range C—D the resistance in the gas spaces falls so much that voltage on these will no longer be proportional to the stress. Instead, the discharge current in the spaces begins to approach a value which is proportional to the charging current in the insulating material, and one can then write

$$\operatorname{tg} \delta_D = \operatorname{tg} \delta_0 + k'' \left(1 + A \frac{V_0}{V}\right) \quad . \quad . \quad 5.$$

The limitation lines obtained from the equations 4 and 5 have been drawn up in Fig. 1, and from these it can be concluded that under certain conditions, when the ionizing limit has been considerably exceeded, the spaces will be practically short-circuited, and the energy developed at the discharge then becomes comparatively small. This has been proved by a series of measurements at different gas pressures of the angle of loss in an unimpregnated cable. The measured values are graphically reproduced in Fig. 2, and from a study of these curves it would seem that the maximum value of the angle of loss stands in a certain proportion to the pressure. The fact that the total angle of loss is so much larger than that obtained in impregnated cables naturally depends in this case on the very large volume of gas in the material. One finds further from Fig. 2 that the ionization limit is dependent on the gas pressure.



R 1966 Fig. 2.

Connection between Gas Pressure and Ionization.

The impregnation substance contains dissolved gas corresponding to a certain gas pressure. If the cable cools off the volume of the impregnation substance is diminished, reducing the pressure on the insulating material. If the outside pressure falls below the pressure of the dissolved gas, it will result in the formation of voids with a gas pressure equal to the pressure of the dissolved gas.

At a given electric field strength in the insulating layer there is a corresponding pressure in the voids or, in the most unfavourable circumstances an ε times higher pressure owing to the higher dielectric constant of the solid material. One can apply Paschen's law for the gas space, thus

$$V = f(p \times l) \quad . \quad . \quad . \quad . \quad 6.$$

in which V is a function of the number of gas molecules between the electrodes. One will then find that the ionization voltage is dependent on both the gas pressure and the size of voids, see Fig. 3. What size of voids and which pressure are then to be found in the cables?

For a dried but unimpregnated cable the ionization voltage has been determined at different pressures, which has given as result a function according to Fig. 4. The cable insulation in question consisted of 0.18-mm thick cellulose paper with $^1/_3$ lap. At pressures between 150 and 760 mm Hg the curve corresponds to the function

$$E_{eff} = 1200 + 1.5\,p \text{ volt/mm} \quad . \quad 7.$$

There is naturally a higher voltage gradient in the actual gas and for this one can put down

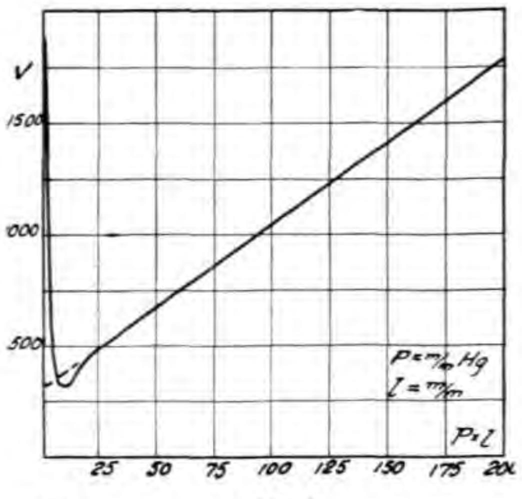
$$E_{Air} = \eta\,(1200 + 1.5\,p) \quad . \quad . \quad 8.$$

One can assume with a high degree of probability that the spark length has no higher values than about 0.3 mm, and that thus $p \times l$ = from 45 to 250, the function in Fig. 3 being applicable for this range. One can therefore approximately for this curve use the equation:

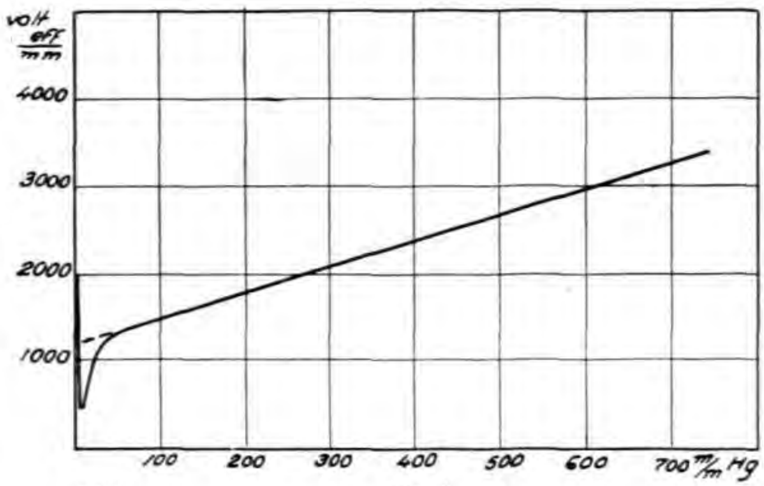
$$V = 260 + 3.8\,p.l. \text{ volt eff.} \quad . \quad 9$$

By putting together the equations 8 and 9 it is possible to calculate that the spark length

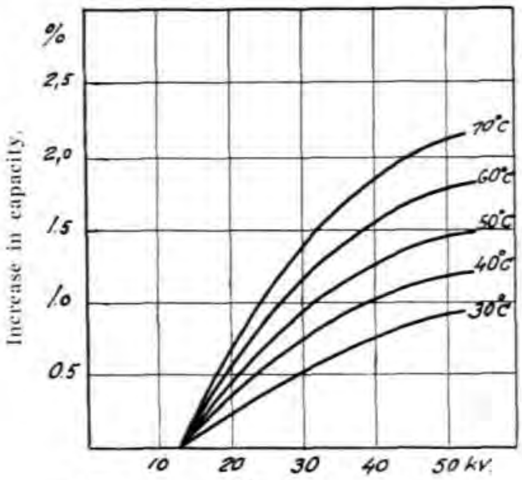
$$l \leq 0.087 \text{ mm.}$$



R 1968 Fig. 3.



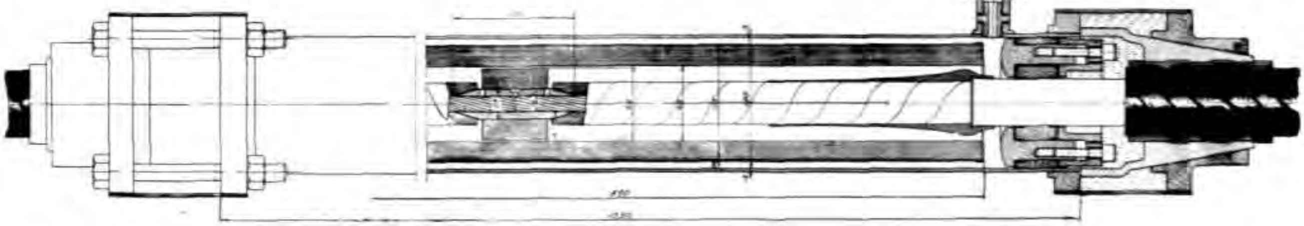
R 1965 Fig. 4.



B 1967 Fig. 5.

be constant, seeing that the ionization voltage is constant. The greater capacity-increases are plainly due to the greater number of voids formed as a result of the higher temperature to which the cable has been heated. The measured capacity-increase can be regarded as being in proportion to the number of short-circuited voids, and one comprehends from this circumstance that the volume of voids at low temperature, after the cable has been heated once or a few times to a comparative high temperature, may amount to several per cent of the insulating volume. The difference in the volume of the oil amounts to from 0.05 to 0.01 % per °C, which corresponds to from 1.25 to 2.5 % void volume at

One might object to this that the size of voids need not be the same if the cable is impregnated. It goes without saying that the total volume of voids will be only a fraction in the impregnated cable of what it is in an unimpregnated one, but there are nevertheless possibilities that the stretch

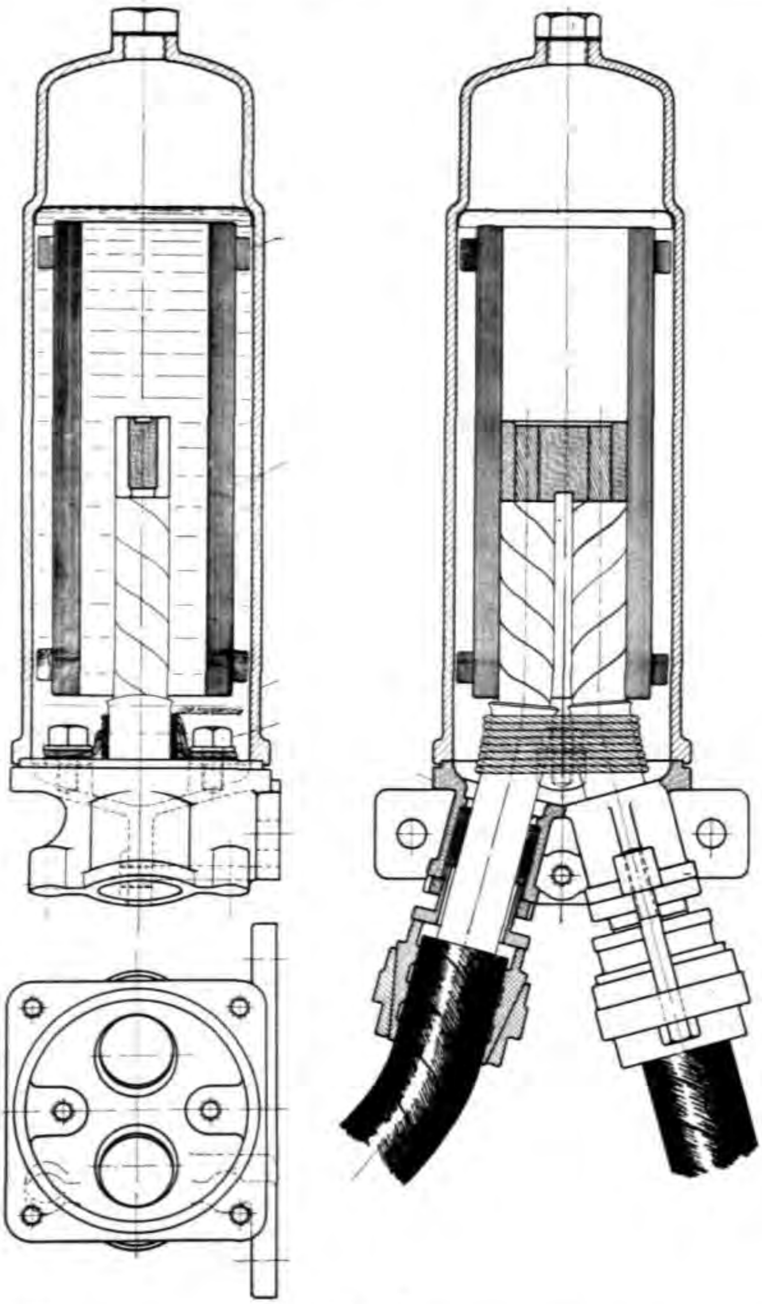
B 1969 Fig. 6.

of voids in the line of the field can be as large as above after a sufficiently strong rise of temperature, and certain tests indicate that such is the case. The ionization voltage has been determined in one and the same cable sample, and at the same temperature, namely after heating the cable to 30, 40, 50, 60 and 70° C during 2 hours, and cooling it down to 18° C after each heating. The measured increases of capacity are in Fig. 5 represented by ordinates, and the pressure by abscissas. It will be seen that the capacity increase, and thus also the ionization, begin at exactly the same voltage, despite a considerable difference in the amount of capacity increase.

Corresponding similarities are also present in respect of the dependency of the angle of loss on the tension. One finds thus that, in as much as the pressure in the voids must be constant, the size of voids in the line of the field must also

a temperature lowering of 25° C. These conditions are frequently encountered in practical working, athough they do not always cause trouble.

It has been found that cable installations have functioned quite satisfactorily when subjected to a voltage gradient of from 4000 to 6000 volts per mm., and where the measured ionization gradient has been between 1300 and 1600 volts per mm. Experience has also taught that a cable with a very low gas pressure is better able, in spite of its lower ionization gradient, to sustain a considerably higher voltage than a cable with a higher gas pressure. At a lower pressure the ionization voltage will be lower, but the flash discharges are softer, and occur without causing carbon formations. Another lesson taught by experience is that the ionization losses are not necessarily a criterion of the serviceability of the



R 1970 Fig. 7.

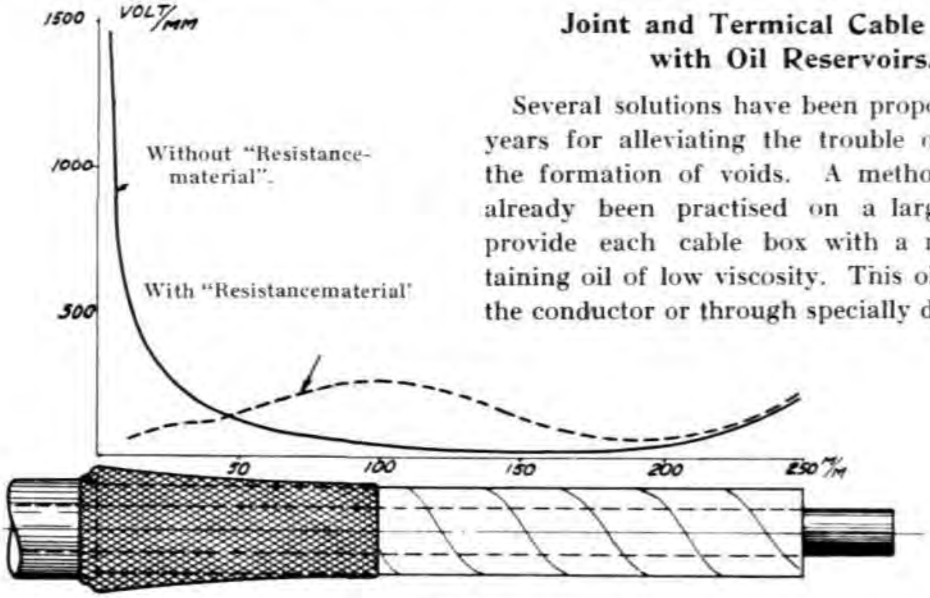
cable. This is reasonable enough, too, because the amount of loss for the insulation thickness in use cannot prevent the establishment of a thermal equilibrium, and one is furthermore justified in assuming that the great losses under such conditions are mainly due to a large number of small voids, and there is thus no cause for any partial carbon formation.

It may further be mentioned that the thermal stability is hardly affected by the ionization losses because, owing to the heat generated, the temperature will rise in and around the void, and the expansion of the oil will cause the void to disappear.

Physical Condition of Insulating Material while Cable is in Use.

The conclusion may easily be drawn from what has been said in the foregoing that the electrical properties which a cable may possess immediately after manufacture need not necessarily be permanent, and that they therefore play a subordinate part in judging its serviceability. The question of what changes the cable is subjected to in service will then be all the more important and the following exposition is offered as an elucidation of this problem.

Owing to the heat generated by the current in the conductor, dielectric losses in the insulating material, and temperature increases around the cable, the latter will at times be heated up to a relatively high temperature. The impregnation substance, which in comparison with copper, paper and lead has a high coefficient of expansion, will be pressed out through the paper insulation and expand the lead sheath. At the subsequent lowering of the temperature from reduction of the load or lowering of the outside temperature, the outer layers are cooled off first, and on account of the increasing viscosity of the oil in these layers the oil cannot re-enter at that prevailing slight difference of pressure. The inner and middle insulation layers thus contain less oil than the outer ones. At a low temperature, voids are first formed in the middle layers, while the layers nearest the conductors are as a rule kept slightly warmer, and are therefore not to the same extent exposed to the formation of voids.



R 1964 Fig. 8.

Joint and Termical Cable Boxes with Oil Reservoirs.

Several solutions have been proposed in recent years for alleviating the trouble occasioned by the formation of voids. A method which has already been practised on a large scale is to provide each cable box with a reservoir containing oil of low viscosity. This oil flows along the conductor or through specially designed ducts through the whole length of cable. Fig. 6 shows a cable box with oil reservoir. Partly in order to obtain better communication between the reservoir and the oil ducts in the core of the cable, and partly for obtaining a better joint, the cable boxes are now made by certain manufacturers as shown by Fig. 7.

This style of box is very simple, but cannot without special provisions be used for higher tensions than 30,000—40,000 volts. Special devices must be made for preventing flash discharges at the contact surface between the cable insulation and the oil in the cable box. The voltage at which flashing occurs in boxes of this kind may, for normal voltages, be calculated with

R 1961 Fig. 9.

sufficient accuracy from a formula by Toepler, viz.

$$E_{eff} = \frac{1.335}{c^{0.44}} \cdot 10^{-4} k\,V \quad . \quad . \quad . \quad . \quad 10.$$

$$C = F/\text{cm}^2.$$

Toepler has also given a very simple explanation of these flash discharges. He thinks that the "running-spark" phenomenon is established by the collection of ions and electrons on the surface of the solid insulating material. The sparks are plainly due to these ions and electrons in the electric field being projected forward and backward in the line of the field.

With the object of preventing these axial running sparks certain devices have been introduced for regulating the axial reissance at the surface. It this resistance is kept sufficiently low, the formation of sparks can be prevented, and by regulating the resistance at the surface in an axial direction per unit of length, the axial voltage gradient may also be regulated, eliminating the action from the edge of the lead sheath. A practical solution of this problem is afforded by the Swedish Patent Nr. 61848, demonstrated by the joint illustrated in Fig. 8.

It is proved that with this arrangement it is possible to raise limit of tension for the joints from 2¼ to 2½ times in comparison with ordinary cable joints. In Fig. 8 the axial strain in joints with and without regulating device is depicted by a diagram, drawn in accordance with measurements carried out with a probe, and furnish ample proof of the improvement achieved with this type of box.

Fig. 9 illustrates the effect on the cable insulation exerted by a tension of 55,000 volts during 36 hours when the box has not been provided with this safety device. It will be seen that the insulating layers have been completely cut up by running sparks.

Single-phase Cables for Alternating Current.

It is plain enough that the heavier the insulation of the cable the more difficult it is to endow the material with sufficiently good properties, and the greater will be the beforementioned changes during service. It therefore becomes necessary to design cables for super high voltages as single-phase cables, and it is owing to this design that supplementary losses occur from the electromotive force induced into the sheaths.

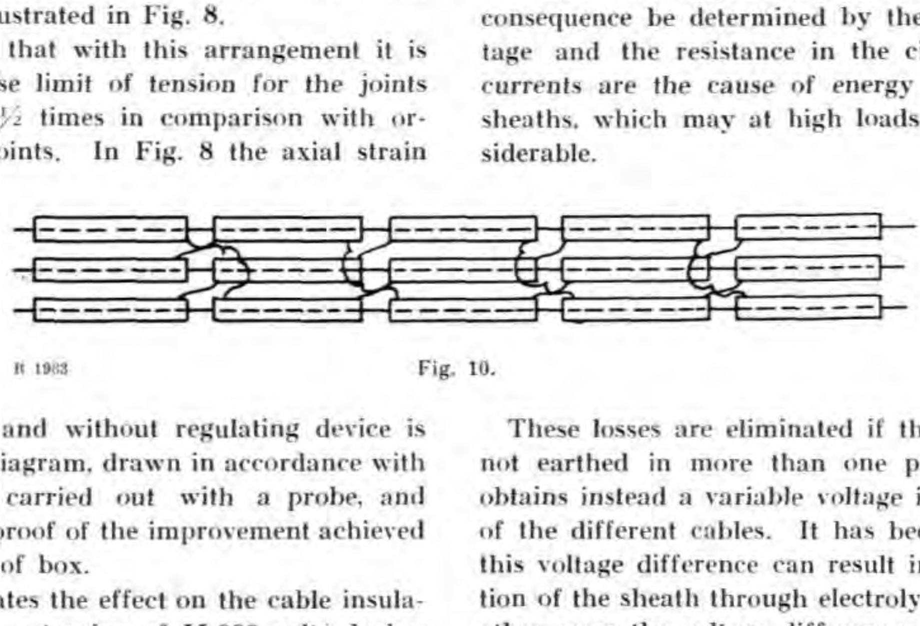
If the different phases are laid with a distance from centre to centre of a cm, and if the diameter of the conductor is d cm, each conductor is surrounded by a magnetic field having an induction coefficient of

$$L = \left(0.05 + 0.2\, ln \frac{2a}{d}\right) \text{mH/km}.$$

If the average diameter of the sheath is D, this field will induce an electromotive force into the sheath, and the mutual coefficient of induction may be expressed

$$M = 0.2\, ln \frac{2a}{D} \text{mH/km}.$$

If the lead sheaths are short-circuited in more than one place there will be a current in the sheath, and the magnitude of this current will in consequence be determined by the induced voltage and the resistance in the circuit. These currents are the cause of energy losses in the sheaths, which may at high loads be very considerable.



R 1983 Fig. 10.

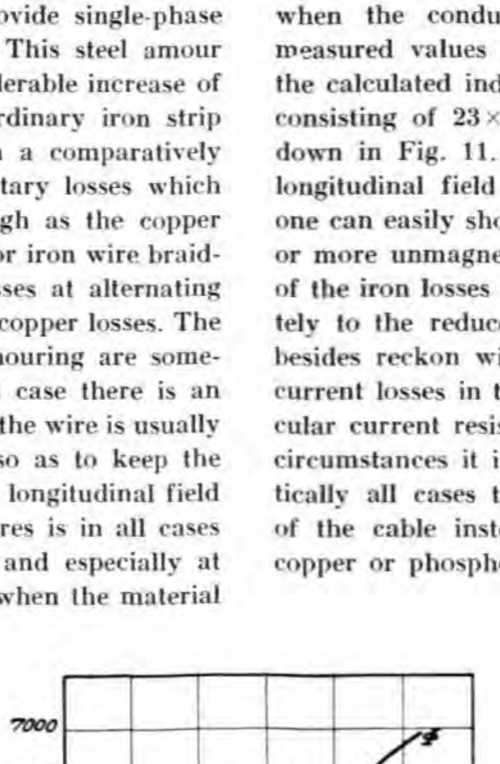
These losses are eliminated if the sheaths are not earthed in more than one place, but one obtains instead a variable voltage in the sheaths of the different cables. It has been found that this voltage difference can result in the destruction of the sheath through electrolytic action. In other cases the voltage difference at high short-circuit currents has been so great as to cause serious burns in the sheath.

As the induced voltage is proportional to the length of cable, these voltage differences are small for short cable lengths, and do not become serious except in case of long lengths of cable. For this reason a method of cross connecting the cable sheaths at the joints is practised by some firms. The lead sheath is insulated on one side of the joint from the sheath on the other side, and cross connections are made from the sheath of one phase to the sheath of another phase in the manner shown by the Fig. 10.

At every third joint the potential will be zero, and these points of the installation are therefore earthed. It must, however, be regarded as preferable under all conditions to place the cables so near each other that the circular current losses become insignificant, in which case the sheaths can be shortcircuited at each joint. The same potential will then be obtained through the whole length of cable.

It is furthermore necessary, for certain kinds of installation methods, to provide single-phase cables with steel armouring. This steel amour is always the cause of a considerable increase of the supplementary losses. Ordinary iron strip armour, which is wound with a comparatively low pitch, sets up supplementary losses which are from 5 to 20 times as high as the copper losses. A double wire armour or iron wire braiding will also increase the losses at alternating current from 5 to 15 times the copper losses. The effects from a single wire armouring are somewhat more favourable; in this case there is an air gap between each wire, and the wire is usually wound on with a high pitch so as to keep the induction in the iron low. The longitudinal field established in line with the wires is in all cases of rather great importance, and especially at comparatively high loads and when the material possesses high magnetic permeability. The iron losses are thus mainly dependent on this longitudinal field and the permeability of the iron. The radial field, on the other hand, is fairly independent of the permeability of the iron, being in the main limited through the air gaps between the wires, and the iron losses of this field component become relatively small. This field, however, in common with the field in the air, induces an E. M. F. into the sheath and the armour, which causes an increase of the circular current in the short-circuited sheaths.

The longitudinal field can easily be measured if one provides the cable with a coil of winding, and measures the voltage induced in the coil when the conductor carries a current. The measured values for the longitudinal field, and the calculated induction in an iron-wire armour consisting of $23 \times 6 \times 1.4$ mm iron wires are put down in Fig. 11. The iron loss caused by the longitudinal field is as a rule the largest, and one can easily show that the introduction of one or more unmagnetic wires produces a reduction of the iron losses corresponding only approximately to the reduced weight of iron. One must besides reckon with an increase of the circular current losses in the same proportion as the circular current resistance is lowered. Under these circumstances it is no doubt preferable in practically all cases to increase the conductor area of the cable instead of inserting one or more copper or phosphor-bronze wires in the armour.



R 1962 Fig. 11.

THE L. M. ERICSSON'S ORGANIZATION FOR SELLING AND INSTALLING

Interlocking and Safety Signal Plants for Railways.

It is now seventeen years since the Telefonaktiebolaget L. M. Ericsson took up the manufacture in Sweden of material for electric interlocking and safety signal plants, its manufacturing capacity for this line of material as well as for completely installed plants having experienced a steady development, while the working out of new systems and the application of the most modern principles for installations of this description have given it a leading position in this branch. In consequence, the company is able to view with satisfaction a steadily growing market for its output of railway safety and signalling devices. This led to Telefonaktiebolaget L. M. Ericsson establishing, a few years ago, a separate organization for the sale and installation of these products, which was designated the *"L. M. Ericssons Signalaktiebolag"* (L. M. Ericsson Signal Company Ltd.)

Finally, in 1929, the increasing turnover necessitated the provision of enlarged accommodation for this branch of manufacture. The whole production, with the exception of the purely electrical parts and the assembling work, was therefore in 1929 transferred to specially equipped workshops in the AB. Alpha factories at Sundbyberg, which company was then amalgamated in the Ericsson Concern, and is wholly controlled by Telefonaktiebolaget L. M. Ericsson.

Extensive plants on L. M. Ericsson's system have been manufactured by them and installed in Sweden, Norway, Denmark, Finland, Esthonia, Russia and Poland.

These plants are of various kinds, a number of them being mentioned in the following.

A. Interlocking plants for railway stations, with electric interlocking machines for the control and manoeuvring of points, semaphores, day-lightsignals, scotch blocks and crossing gates. Points and scotch blocks which are not manoeuvred from the interlocking machine but are set locally, may be locked and supervised from the interlocking machine with the aid of electric locking devices. Points, scotch blocks and crossing gates which are manoeuvred from the interlocking machine may be locally set and manoeuvred with the aid of patented devices whithout affecting their relation to the interlocking machine. Also, with Ericsson's latest type of central electric interlocking machine, all locking and interdependence between signal and point levers are electrically accomplished. The traffic and train movements in a station yard are easily supervised by means of the illuminated track plan with repeater lamps for the light signals (mounted in the signal cabin) and the track system, consisting of insulated track sections, thereby permitting a much wider area to be covered by a single central interlocking machine.

B. Manual lock-and-block apparatus for station and section blocking.

C. Apparatus for automatic section blocking, by means of which the signals for the different sections are automatically set by the trains and show "clear" only when the following section is clear.

D. Automatic signal plants for level crossings.

E. Electric crossing gate installations.

F. Equipment for the electric locking of points controlled by a mechanical interlocking machine, for the purpose of preventing the setting of the points during the passing of a train.

G. Telephone installations for announcing the arrival of trains.

R 1835 Interlocking Frame, Gothenburg C station.

Electric Locking Frame with All-Electric Interlocking Gear.

By *E. G. Windahl*, Managing Director of L. M. Ericssons Signalaktiebolag.

When points first began to be operated electrically, the interlocking of the levers was arranged on the same system as in mechanical signal cabins, the mechanical locking gear being retained. As all the connexions between a lever and the points, signals, etc. operated by it—including requisite control that points, signals, etc. follow the movements of the lever—are exclusively electrical, the next step was obviously to make all the interlocking of the levers in the signal cabin also wholly electrical. This is a natural development, and in no way reduces the reliability of the interlocking plant from the safety point of view.

The system has already been used to some extent in electric interlocking plants where two cooperating interlocking machines are employed, i. e. where some of the points of a train-route are operated from the one machine, while the signals for the route are set by the other. In that case the interdependence between the point levers of the one machine and the signal levers of the other is wholly electric.

In the new interlocking plant with all-electric interlocking gear, the positions of the levers and their movements when operated are controlled by locking and indicating magnets on each lever, the circuits of which are led over contacts on all levers with which connexion is required.

Points are controlled by SS-relays, which are set differently in normal and in reversed position of the points, and the signal- and control-currents are led over the contacts of this relay.

Signals are operated by relays which are not energized to set the signals to "clear" until all the points for that particular train-route are laid correctly.

For each of its two directions of movement, a signal lever can be combined with a group of conflicting routes and signals. This will reduce the number of signal- and route-setting levers, and also the length of the interlocking machine, to a minimum.

The system is flexible and easily operated, particulary for laying alternative train-routes in complex and extensive station yards, or for arranging new train-routes in plants already completed.

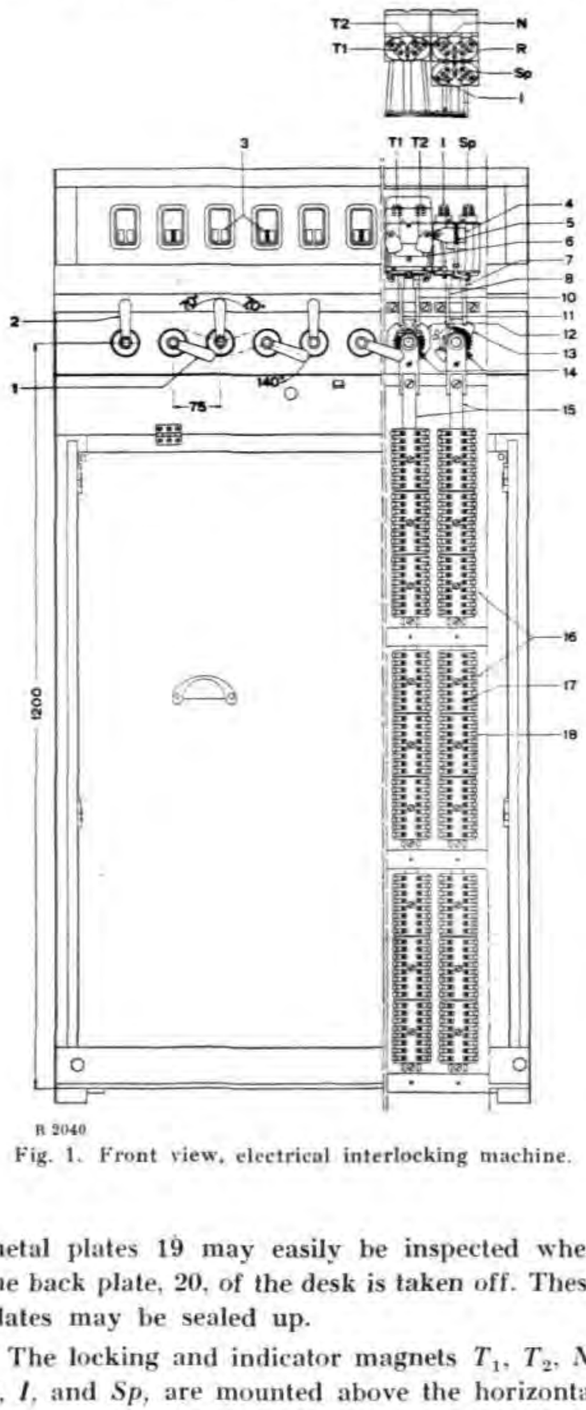
The levers (figs. 1—3) are mounted in a sheet metal desk provided with a steel frame, and are arranged 75 mm. apart in a horizontal row 1 200 mm. above the floor. The desks are made in two standard sizes, viz. for 16 and 24 levers, and can consequently be combined in plants holding multiples of 8, e. g. 32, 40, 48, etc. The length of the 16- and 24-lever desks is 1 354 and 1 954 mm. respectively. Their width at lever height is 650 mm.

The levers have a horizontal shaft 22, and a vertical shaft 15. The lever handle, 1 and 2 respectively, is placed directly on the former. Every second lever handle is directed upwards and every second downwards. The downward handles project slightly more than the upward ones. Each lever handle is provided with a locking stud, 24, which must be pressed in before the lever can be moved. This stud also acts on a latch contact 23.

The vertical and the horizontal shafts of the lever are joined by a bevel gear, 14, which is very accurately made, to give practically no play in transferring the turning movements of the horizontal shaft to the vertical. Contacts, 16, are arranged on the vertical shaft. Contacts, 21, used exclusively for operating the motors, are also fitted on the horizontal shaft of the point levers.

These contacts are carefully made, and separated by insulating flanges to prevent short circuits. Up to 72 independent contacts may be fitted on each vertical shaft. If more should be needed, the shaft is lengthened downwards.

The contact spring terminals 17 are easily accessible by removing the front plate 25, and the



B 2040

Fig. 1. Front view, electrical interlocking machine.

metal plates 19 may easily be inspected when the back plate, 20, of the desk is taken off. These plates may be sealed up.

The locking and indicator magnets T_1, T_2, *N*, *R*, *I*, and *Sp*, are mounted above the horizontal shaft. The armatures of the locking magnets are provided with locking bars, 7, 8, 9, 10, 11, acting on locking plates 12, 13, fixed in groups on the shaft.

Coloured discs 4, 6, or hand 5, fixed on the magnet armatures, are visible in a small window, 3, above each lever.

Point levers.

A point lever (figs. 1 and 2) is provided with the following four magnets:

One normal magnet *N*, to lock the lever in normal position or in normal indicating position,

one reverse magnet *R*, to lock the lever in reversed position or in reverse indicating position,

one indicator magnet *I*, to show if the position of the points corresponds to the position of the lever, and

one interlocking-control magnet *SP*, to show if the lever is interlocked or free to be moveed.

The normal and reverse magnet circuits are determined partly by the latch-contact 23, which is closed when the locking stud 24 is pressed in, partly by the contacts on the vertical shaft of the lever, and partly by contacts on other levers or devices with which the particular point lever is interdependent. The magnets can only be energized when all levers or devices involved are in positions permitting the point lever to be moved.

The indicator magnet circuit is controlled by contacts on the point lever, and by contacts either actuated by the point machine or guided by the indicating SS-relay of the point machine.

The interlocking-control magnet circuit coincides with the normal and reverse magnet circuits, except that neither the latch contact and contacts of the respective point lever nor the control contacts of the point machine are connected in it.

The end positions of the point lever handle, 1, are downwards to the right (normal position) or downward to the left (reverse position). The total angle of movement is 140°. The point lever handles can also be directed upwards, when the normal position will be upwards to the left.

Fig. 4 shows a point lever connected to its points *V*.

The lever is indicated as follows:

handle, 1, and locking plates, 13, on the horizontal lever shaft,

normal magnet *N*, with locking bar 8,

reverse magnet *R*, with locking bar 9,

indicator magnet *I*,

interlocking magnet *Sp*,

latch contact 23,

contacts 52/53/54 and 55/56/57 on the horizontal lever shaft, for operating the motor, and

contacts 43/44/45, 46/47/48, and 49/50/51, on the vertical lever shaft.

26 is the point machine, and the position of

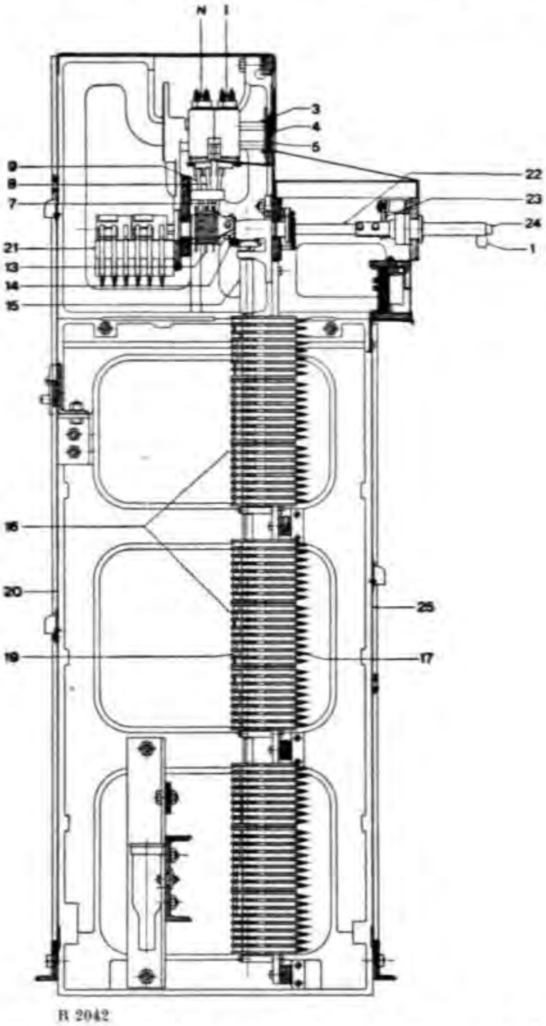


Fig 2. Section of electr. interlocking machine, point lever.

the points is controlled by relay SS, provided with the contacts K+ and K—. The former is closed in the normal position of the points, and K— in the reverse position of the points.

ST is a relay for protection against outside currents. Its contact *Kst* is closed when the relay is energized.

42 is the contact for a signal lever depending for its movements on the position of the points. When the signal lever is in normal position, contact 42 is closed.

Normal position.

When the points are in normal position, the motor is short circuited (circuit M-L_7-a-53/52-L_6--37/38-M). The SS-relay is energized (circuits S_1-L_{10}-SS-L_9-S_2, and S_1-L_3-L_1-35/34-L_5-41-L_4--32/33-L_2-S_2).

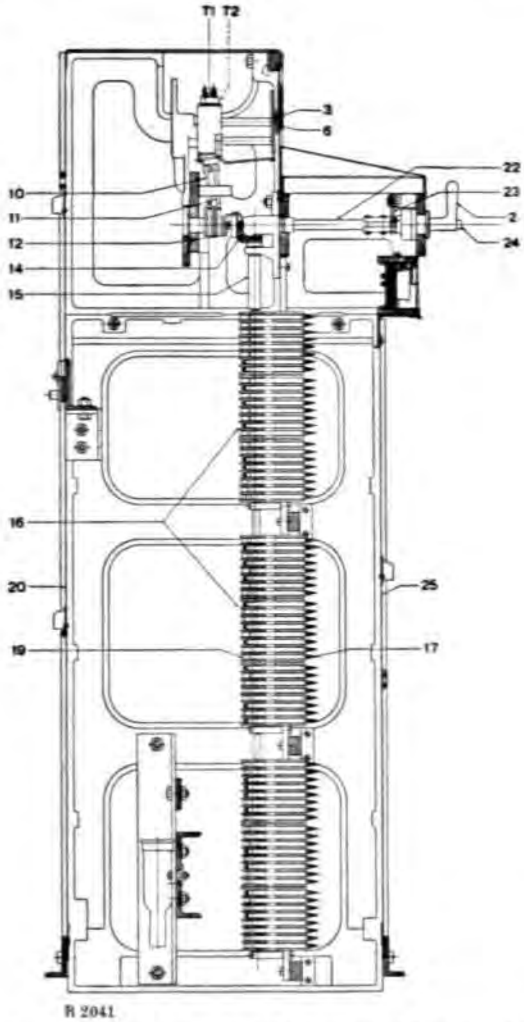


Fig. 3. Section of electr. interlocking machine, signal lever.

The contact K+ on the *SS*-relay is closed and the indicator magnet I energized (circuit S_4-L_{15}--L_{17}-K+-L_{18}-44/43-I-L_{12}-S_5), a white disc is visible in the lever window 3, fig. 1, indicating that the positions of the points and point lever correspond.

The interlocking-control magnet *Sp* is energized (circuit S_4-L_{12}-St-42-L_{13}-Sp-L_{12}-S_5), and its hand 5, fig. 1, is therefore not visible in the lever window, which means that the point lever is free to be moved.

Contact 42, fig. 4, is closed (signal lever in normal position).

The normal and reverse magnets (N and R respectively) are de-energized. The locking bar 8 of the normal magnet is in the same plane as catch 59 of locking plate 58.

Moving the points from normal position.

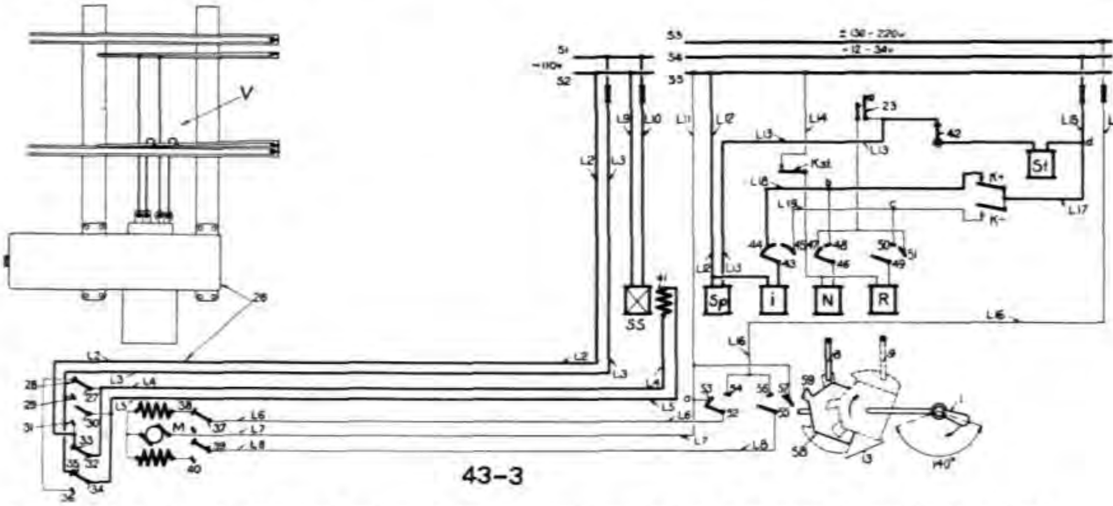
The locking stud on the handle is pressed in, which closes latch contact 23 and energizes the normal magnet N (circuit S_4-L_{15}-St-42-23-47/46-N-Kst-L_{14}-S_5), see fig. 5. This moves the locking bar 8 to one side, so that catch 59 of locking plate 58 can pass the locking bar when the lever is turned. But if the normal magnet N remains de-energized, the lever can only be turned 30°, in which position catch 59 meets locking bar 8. This position is called *normal locking position.*

When the lever is turned 35°, contact 47/46 is broken, de-energizing the normal magnet N. Simultaneously contact 53/52 is broken, breaking the short circuit of the motor.

When the lever is turned another 10°, a circuit is closed through the normal magnet over the contact 46/48 (circuit S_4L_{15}-$L_{17}K+$-b-48/46-N-Kst-L_{14}-S_5), which circuit is again broken when the lever is turned 65° from its normal position. This function, however, is only of importance when the lever is moved in the opposite direction.

When the lever is turned 65° from the normal position, contact 43/44 is broken and the indicator magnet I is de-energized, causing the lever window to show red.

When the lever is turned 85° from normal, contact 52/54 is closed, switching current to the points motor (circuit S_3-L_{16}-54/52-L_6-37/38-M-L_7-S), which lays the points over — fig. 6. In this lever position, which is called *reverse indicating position,* contacts 43/45 and 49/50 are also closed.

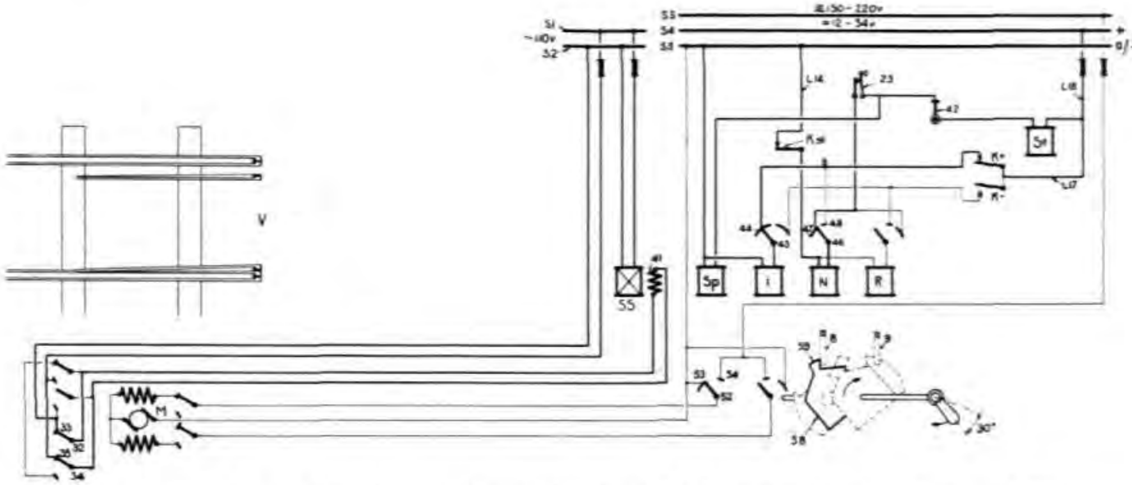


B 2039 Fig. 4. Point lever and points in normal position; indicator magnet I energized; normal and reverse magnets N and R de-energized.

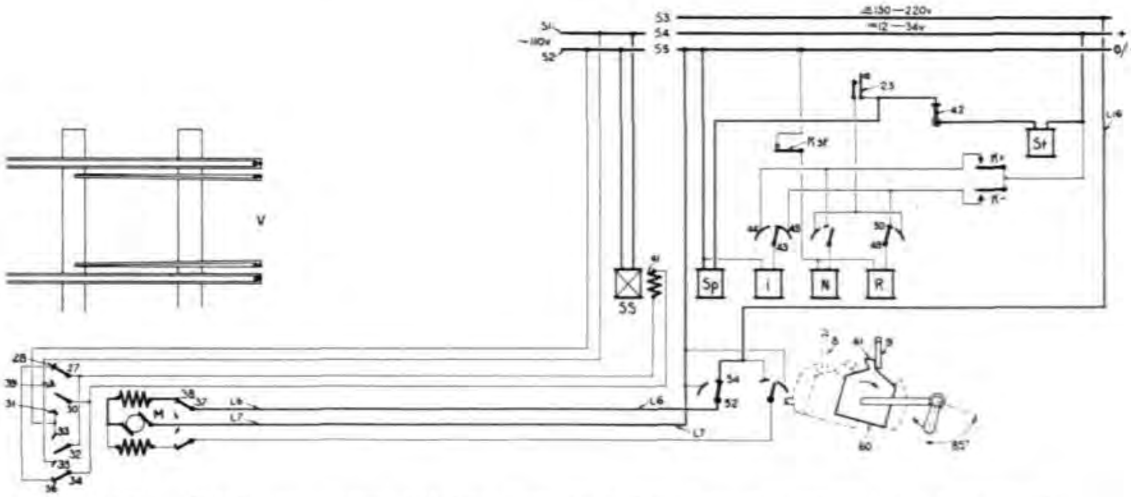
Further turning of the lever is prevented, as locking bar 9 of the reverse magnet is up against catch 61 of locking plate 60.

When the motor is switched on and begins to lay over the points, contact 32/33 is broken, and contact 34/35 is switched to 34/36 in the point machine, which breaks and short circuits winding 41 of the SS-relay. The SS-relay then takes up an intermediate position, breaking contact $K+$. When the points are completely laid over to the other side, fig. 7, contact 27/28 is switched to 27/29, and contact 30/31 in the point-driving machinery is closed, which again connects winding 41 of the SS-relay (circuit S_1-L_3-29/27-L_4-41-L_5-30/31-L_2-S_2). The SS-relay then takes up its other end position, closing the K- contact and re-energizing the indicator magnet I (circuit S_4-L_{15}-$L_{17}K$— -c-L_{19}-45/43-I-L_{12}-S_5). White disc then re-appears in the lever window. Simultaneously the reverse magnet R is energized (circuit S_4L_{15}-L_{17}-K— -c-50/49-R-Kst-L_{14}-S_5), and moves its locking bar to one side so that catch 61 can pass it, thus enabling the lever to continuë its turning movement to the end position, which would not be possible if magnet *R* were de-energized and catch 61 held by locking bar 9. If the normal magnet *N* were energized, the turning tion as locking bar 9 in figs. 6 and 7 in changing from normal to reverse position.

When the lever is moved still further from normal position, contact 49/50 is broken, de-energizing the reverse magnet. If this does not happen, the turning of the lever to the end posi-



R 2038 Fig. 5. Point lever turned 30° from normal — *normal locking position* —; latch contact 23 closed; indicator magnet I and normal magnet N energized.



R 2037 Fig. 6. Point lever turned 85° from normal position — *reverse indicating position;* point motor receives current and lays the points over; indicator magnet I de-energized; normal magnet N again de-energized.

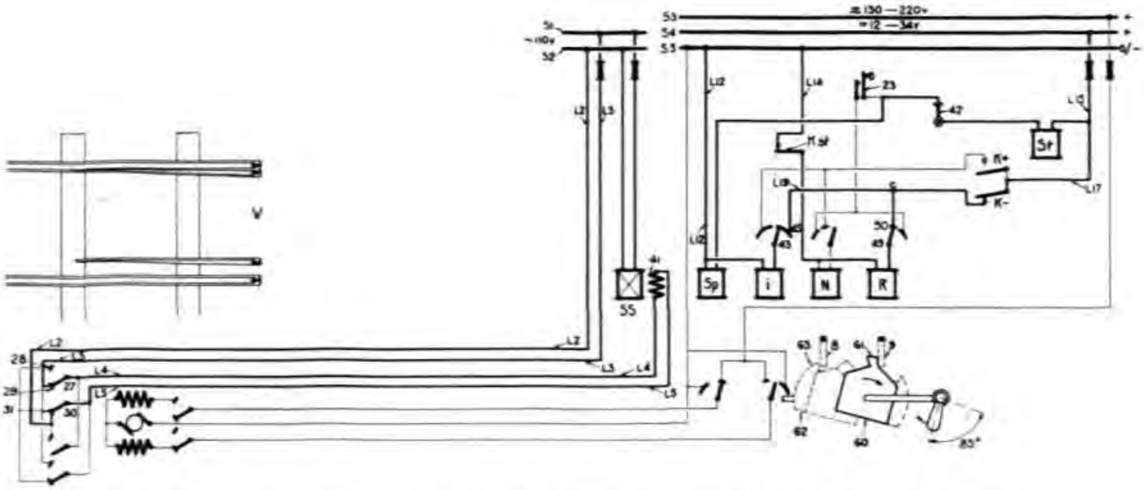
of the lever to reverse position would also be prevented, as locking bar 8 prevents catch 63 of locking plate 62 from passing when the normal magnet *N* is energized. This provides a check on the locking bar of the normal magnet having dropped into position ready for locking the return movement, i. e. to perform the same function will be prevented by locking bar 9 meeting catch 65 of locking plate 64. This position is called *reverse locking-control position*, and corresponds to a turn of 130° of the lever from normal position (fig. 8). This is a check on the reverse magnet *R* now being prepared to lock any reverse movement. If the reverse magnet is de-energized and its locking bar 9 has dropped into position for locking, the lever can now be fully turned to the end position, fig. 9. Contact 49/50 is now closed.

In turning from normal position and until the locking position illustrated in fig. 5 has been passed, the locking stud must be kept pressed in, but for the continued movement to the end position this stud is not to be pressed.

over which the current liberating the signal is led as described below for signal levers.

When a signal lever is moved and has locked the point lever, this is indicated by the hand 5 of the interlocking-control magnet *Sp*, fig. 1, appearing in the point lever window, the interlocking-control magnet being de-energized when contact 42 is broken.

Two points levers can be made interdependent



R 2036 Fig. 7. Point lever still in *reverse indicating position*; points completely laid over; indicator magnet I again energized; reverse magnet energized.

Return of points from reverse position.

The return of the points from reverse to normal position is perfectly analogous.

Locking the point levers.

Contact 42, shown in figs. 4—9, of a signal lever which depends on the position of the points for its movements, is closed in the normal signal lever position, and broken when the lever is moved 7° from normal position. If this contact is broken, e. g. when a train-route is laid and the signal is set to "clear", the point lever is thus locked and cannot be moved, as the circuits through the normal magnet *N* and the reverse magnet *R* are broken even though the locking stud may be pressed in and the latch contact 23 closed in trying to move the lever.

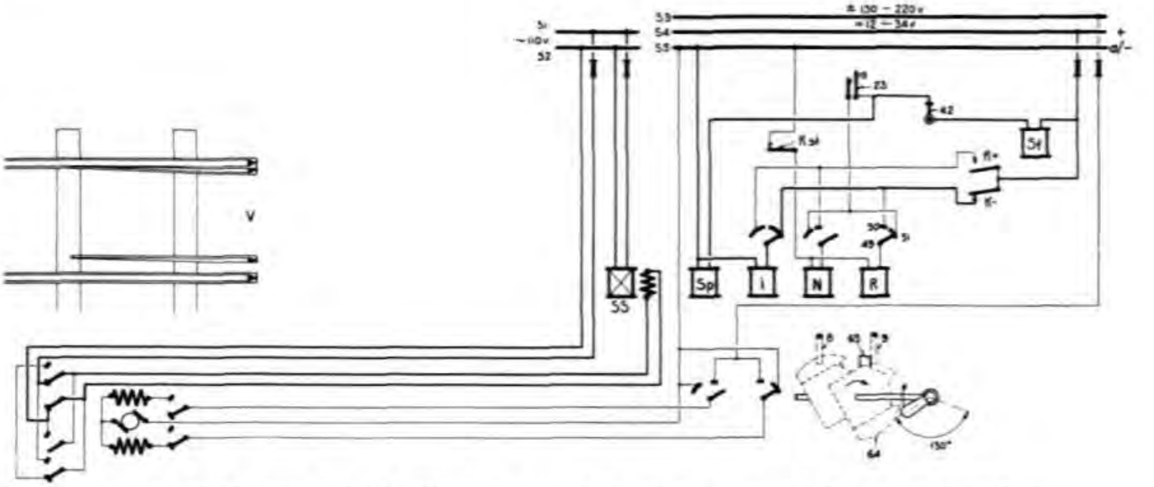
Whether the point lever is to be locked (i. e. the points interlocked) in normal or reverse position is determined by contacts on the point lever, in the same way as now described for a signal and a point lever.

If the points are connected by insulated rails to prevent them being moved while carriages are passing over them, a contact connected to the relay of the insulated rail is put in between *d* and *St*, fig. 4. This contact is closed when the relay is energized, i. e. when no carriages are passing the insulated rail. Both the normal and the reverse magnets can then be energized and the point lever moved.

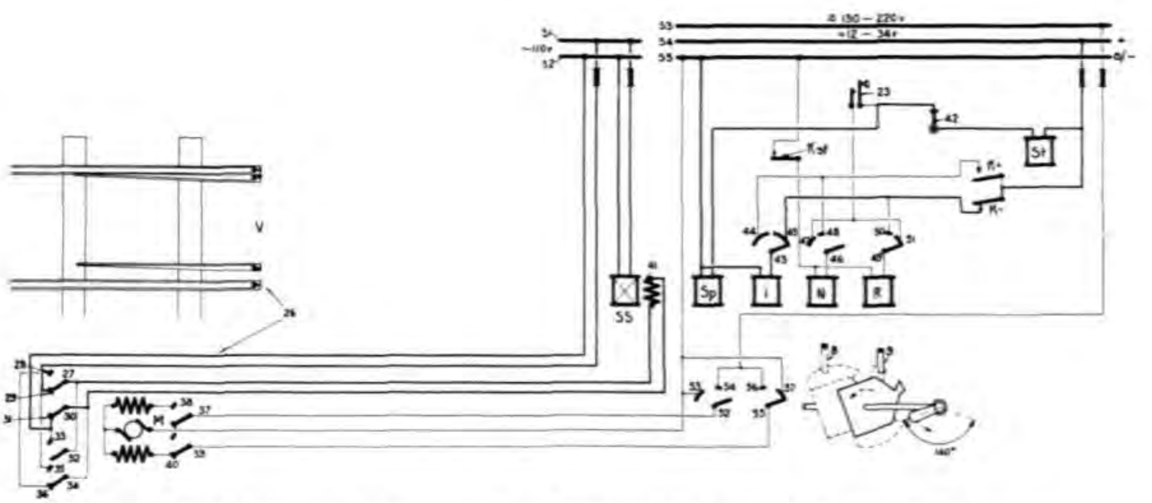
Forced points.

If points are forced, the connexion to the winding 41 of the *SS*-relay is broken by the motor contacts, and the relay takes up an intermediate position. Its contacts, *K*+ and *K*—, are then both broken, the indicator magnet *I* is de-energized, and a red disc in the lever window indicates that lever and points are not in corresponding positions. The signal for a train-route affected by these points cannot then be set to "clear", and if such signal has been set to "clear" before the points were forced, it will automatically be returned to "stop" (see description of signal levers below).

tions of movement. The circuits of the route-locking magnets are determined partly by the latch contact 23, which is closed when the locking stud 24 is pressed in, partly by contacts on the vertical shaft of the lever, and partly by



R 2035 Fig. 8. Point lever turned 130° from normal position — *reverse locking-control position;* indicator magnet I energized; reverse magnet again de-energized.



R 2034 Fig. 9. Point lever and points reversed; indicator magnet I energized; normal and reverse magnets N and R de-energized.

Signal levers.

In the normal position, signal lever handles (see figs. 1 and 3) are pointing straight upwards, and may be moved either 70° to the left or 70° to the right, and thus be used for two conflicting train-routes and signals or groups of such.

The signal lever is fitted with 2 route-locking magnets T_1 and T_2, one for each of these directions of movement.

contacts on other levers or devices on which the movement one way or the other of this particular signal lever depends. Each route-locking magnet can be energized only when all corresponding levers and devices are in a proper position to permit movement of the signal lever.

Fig. 10 shows a signal lever connected to a daylight signal A. The lever is indicated as follows:

handle, 2, and locking plates, 12, on the horizontal lever shaft,

route-locking magnet T_1, which by means of locking bar 11 controls the left hand movement of the signal lever,

latch contact 23, and

contacts 76, 77, 78, 79, on the vertical lever shaft.

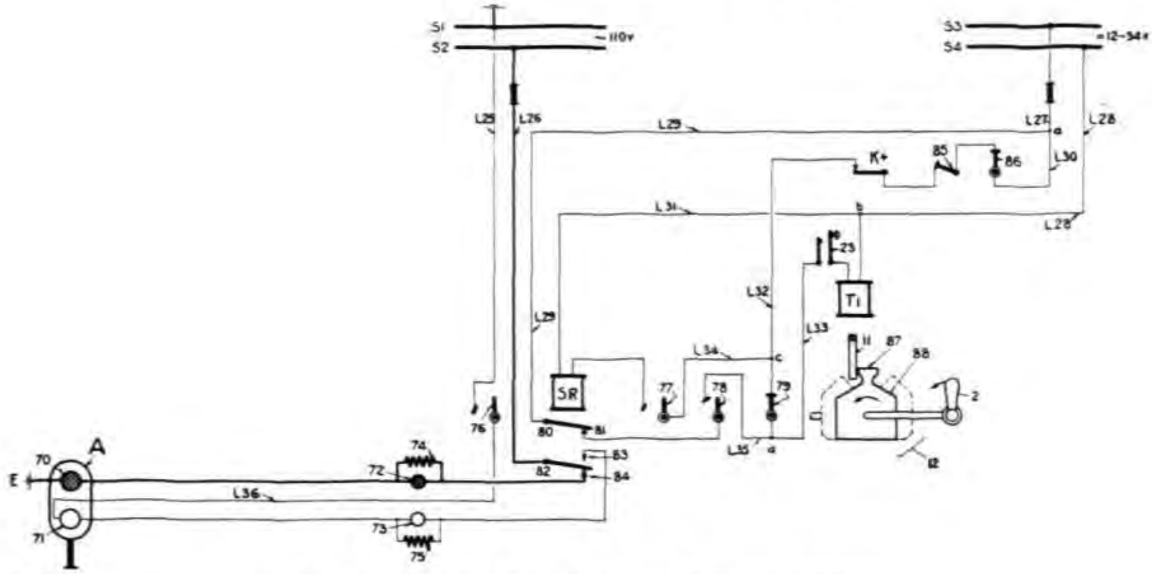
Signal A has two light-openings, 70 for red light (stop), and 71 for green light (clear). The signal lamps are connected to control lamps 72 and 73.

Signal relay *SR* is de-energized, and its contacts 80/81 and 82/84 are closed (fig. 10).

Lamp 70 of the light signal (red light) is lit (circuit S_2-L_{26}-82/84-72-70-*E*).

Setting the Signal to "clear".

The locking stud of the signal lever handle is pressed in, closing the latch contact 23 and energizing the route-locking magnet T_1 (circuit S_3-L_{27}-*a*-L_{30}-86-85-*K*+ -L_{32}-*c*-79-*d*-L_{33}-23-T_1-*b*-L_{28}-S_4). A white disc then appears in the left field



R 2033

Fig. 10. Signal lever in normal position. Signal at "stop".

of the window, indicating that the lever can be moved to the left. Contacts 85 and *K*+ in this circuit check that the points which must be interlocked before signal A can be set to "clear" are in the correct position, as they are closed only if the points and the corresponding lever are in the correct position. The "stop" position of the conflicting signal is also checked, as contact 86 on the lever for this signal is closed only in the normal position of that lever.

The signal is operated by relay *SR*, provided with contacts 80/81 and 82/83/84.

The signal lever is assumed to depend on a set of points which is supposed to be interlocked in normal position when signal A is set to "clear", as well as on another signal in conflict with A. In fig. 10, contact 85 on the point lever, contact *K*+ on the *SS*-relay of the points, and contact 86 on the lever of the conflicting signal, are consequently provided.

Normal Position.

Signal A shows "stop".

The route-locking magnet T_1 of the signal lever is de-energized and locks the lever, as locking bar 11 lies in front of catch 87 of locking plate 88. A blue disc is visible in the left field of the lever window 3, fig. 1.

When the signal lever is turned 7° from normal, contact 79 is broken, which again de-energizes the route-locking magnet T_1, but its armature is mechanically prevented from dropping, and the white disc therefore still shows in the lever window. Simultaneously the signal lever contacts forming part of the *N*- and *R*-magnet circuits are broken, which interlocks the points. 42 in figs. 4—9 is such a contact.

For continued movement of the signal lever the latch contact 23 need not be kept closed, and the locking stud should therefore now be released.

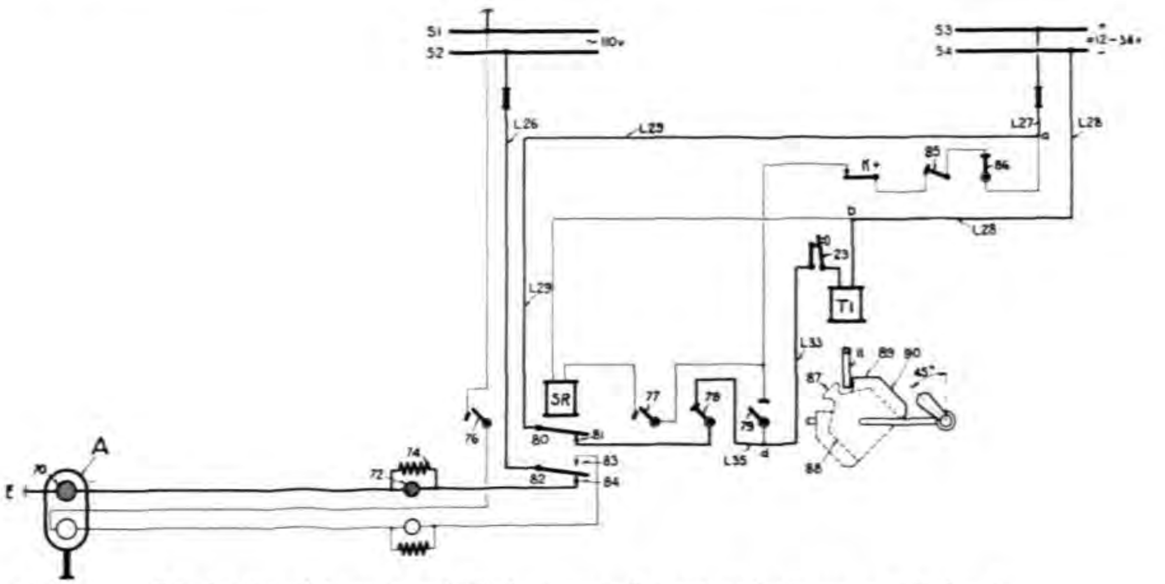
When the signal lever is turned 35° from normal position, contact 78 is closed. If the latch contact 23 is still closed, the route-locking magnet T_1 will again be energized (circuit S_3-L_{27}-a-L_{29}-80/81-78-L_{35}-d-L_{33}-23-T_1-b-L_{28}-S_4).

When the lever is turned to 45° from normal, signal and lights the green lamp (circuit S_2-L_{26}-82/83-73-71-L_{36}-76-L_{25}-S_1).

Returning the Signal to "stop".

The locking stud on the handle is pressed in, closing latch contact 23.

When the lever is turned 7° from its reverse position contact 77 is broken, which de-energizes signal relay *SR*. This closes contact 80/81 and switches contact 82/83 to 82/84, which turns out



B 2032 Fig. 11. Signal lever turned 45° from normal position; latch contact 23 closed; route-locking magnet T_1 energized.

locking bar 11 of the route-locking magnet comes on the other side of catch 87 of locking plate 88, provided that the latch contact 23 is now broken. If this is not the case, the lever cannot be turned further, as catch 89 of locking plate 90 blocks locking bar 11 of the energized route-locking magnet T_1 (see fig. 11). Latch contact 23 must therefore be broken to set the route-locking magnet T_1 for blocking any reverse movement.

When the lever is moved to 55° from normal position, contact 78 is again broken.

Continued turning of the lever to the end position, fig. 12, will close contact 77 which, controlled by the above-mentioned contacts 85, 86, and *K*+, on lever and *SS*-relay respectively, energizes signal relay *SR* (circuit S_3-a-L_{30}-86-85-K+-c-L_{34}-77-SR-L_{31}-b-L_{28}-S_4). This breaks contact 80/81 and makes contact 76, while contact 82/84 is switched to 82/83 on the signal relay *SR*, which in its turn switches off the red lamp 70 of the the green light of the signal and lights the red lamp 70.

When the lever is turned 15° from reverse position contact 78 is closed and route-locking magnet T_1 is energized (circuit S_3-L_{27}-a-L_{29}-80/81-78-L_{35}-d-L_{33}-23-T_1-b-L_{28}-S_4). In this position of the lever, locking bar 11 is in the opening between catch 87 and catch 89 (see fig. 11). As the magnet T_1 is energized, locking bar 11 will then be pushed to one side, so that catch 87 can pass it when the lever is turned towards the normal position. Latch contact 23 must therefore be kept closed until the lever is turned about half way to normal position.

Because contact 80/81 on the signal relay *SR*, which is closed when the signal is de-energized, is connected in the route-locking magnet circuit, the signal lever cannot be returned to normal position until the signal is returned to "stop".

When the lever has been turned 35° from the reverse position, contact 78 is again broken, which again de-energizes the route-locking magnet T_1 and so locks the lever when normal position is reached.

Signal set to "stop" if the points are forced.

If points are forced while any signal to it is set to "clear", the *SS*-relay of the points will take up an intermediate position and break its contacts ($K+$ and $K-$). The signal relay will then be de-energized, which sets the signal to "stop".

Blocking a signal lever in normal position.

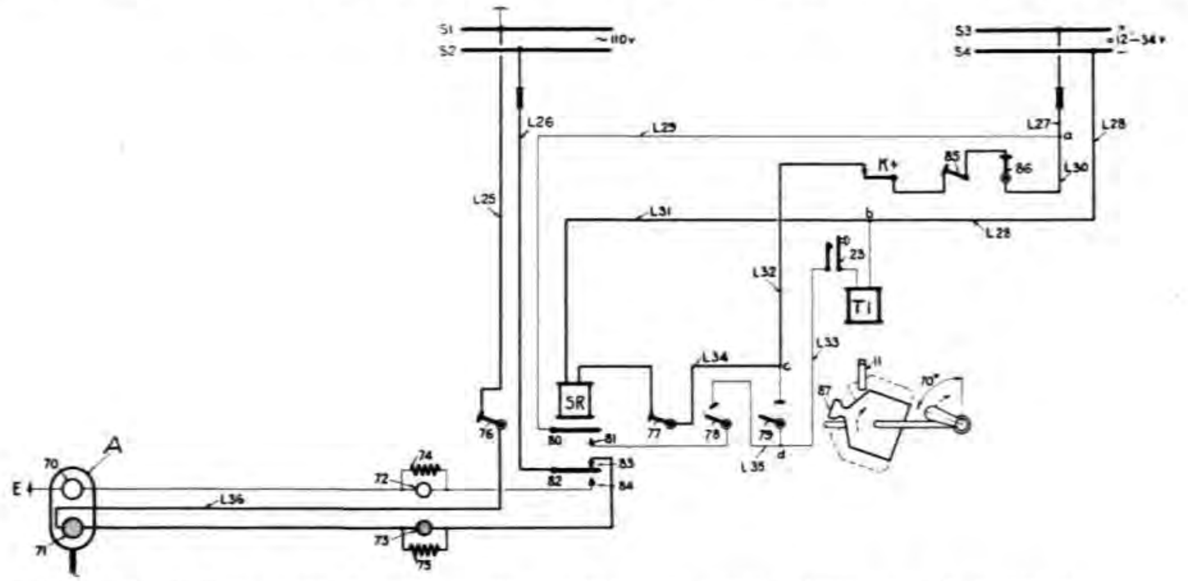
If it is desired that a signal lever should not be moved from the normal position without the consent of the train dispatcher or of some other signal cabin, the circuit a-L_{30}-L_{32}-c (see fig. 10) is provided with a contact in some convenient position (e. g. in one of the relays), which is closed when due permission is received from the station or the other cabin, and allows the route-locking magnet to be energized by closing the latch contact 23.

Interlocking of train-routes.

By connecting a contact (e. g. in a relay) in the line L_{29} which forms part of the route-locking magnet circuit for restoring the signal lever to normal position (see fig. 12), and by keeping this contact open normally, the return of the signal lever from half way over to normal position can be prevented, and the train-route thus kept interlocked until the route has been released in the usual manner.

Control of Signal Lamps.

The lamps of the signal are connected in series with lamps 72 and 73, which is a check on the lamp in the signal being lit. Lamps 72 and 73 are mounted in the signal cabin and provided with shunt resistances 74 and 75 to prevent the signal lamp being extinguished by a control lamp breaking.



R 2043 Fig. 12. Signal lever in reverse position; signal set to "clear": signal relay SR energized; route-locking magnet T_1 again de-energized.

Motor-driven Signals.

Obviously, there is nothing to prevent motor driven signals being connected to signal levers of this type. Signal relay *SR* will then not be required, and instead the magnet couplings of the signal machine are connected in the circuit b-L_{31}-77. The current to the motor is led over contacts on the signal lever or over contacts on a relay operated by the signal lever, and contact 80/81 on the signal relay *SR* is replaced by a contact in the signal machine which is closed when the motor is in the "stop" position. Signal control may be arranged by for instance a special control magnet connected to a contact on the semaphore arm.

Plants on this system installed on the Swedish State Railyays.

	Number of		Number of connected				Completed in
	cabins	levers	Signals	Points	Scotch blocks	Crossing gates	
Hässleholm (see page 30)	1	57	60	52	12	—	1926
Lund C. „ „ 30)	1	64	58	48	4	1	1929
Stockholm S. „ below)	1	16	22	15	—	—	1929
Göteborg C. „ page 1)	1	67	101	58	1	—	1930
Abisko	1	19	15	15	4	—	1930
Kiruna	1	13	11	14	2	—	1930
Ordered for completion in 1931:							
Boden	1	27	35	25	11	4	—
Kävlinge	1	37	31	30	6	3	—
Jönköping	1	40	26	31	7	1	—
Stockholm C.	1	127	91	100	5	2	—

R 1868 Interlocking Frame, Stockholm S. station.

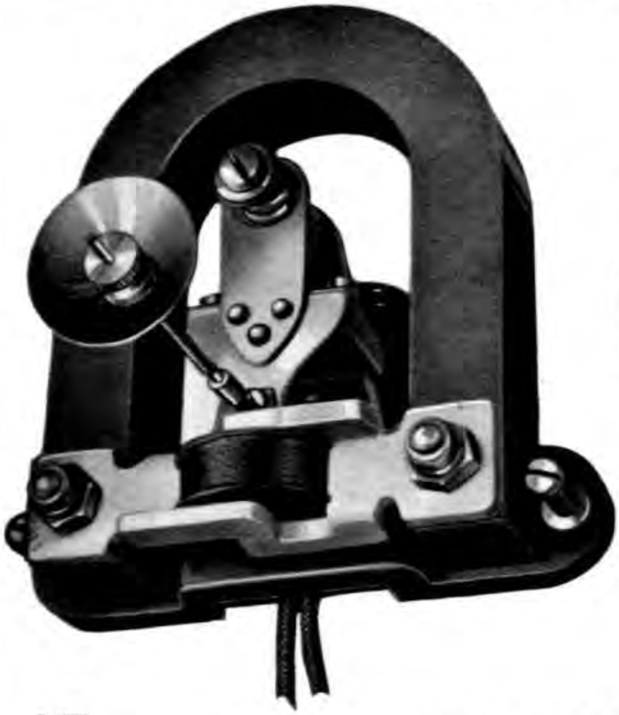
R 1676

The Lund Interlocking Frame.

R 594

The Hallsberg Interlocking Frame.

Four-Pole Loud Speaker Unit



R 1880

R 1879

With large permanent magnet, and adjusting device.
Great sensitivety.
Most up to date principles of design.
First class workmanship.
Natural and clear reproduction of speech, singing, and music.
Independent of polarity of connexions.
Resistance 1000 ohm, Weight 0.77 kilos (1 lb. 11 oz.)
Dimensions, including attachment for membrane: 100×100×94 mm.

TELEFONAKTIEBOLAGET L. M. ERICSSON
SHOWROOMS: KUNGSGATAN 33, STOCKHOLM

The Action of Temperature Variations on Insulated Cables and Appurtenant Fittings.

By *Bernhard Ell*, Chief Engineer with the Sievert Cable Works, Sundbyberg, Sweden.

"Necessity is the mother of invention", says an old proverb. This has been applied not least to the progress and development in installation technique. The inferior materials of the inflation period as a matter of fact brought about constant breakdowns and a multitude of fires and accidents, and conditions grew so serious that we were able to talk about actual necessity which called for, and necessitated, improvement in material.

The manufacture of cables for higher and higher voltages has, maybe, more than many other articles of manufacture contributed towards gaining an insight into the necessity of very carefully studying the qualities and nature of the material used.

For both installation material and cables variations in temperature with concomitant alternations in moisture and atmospheric pressure have proved to be of the utmost importance.

In the following pages the action of temperature variations upon installation material will therefore be dealt with, not only with regard to cables in course of manufacture but also in respect of cables in use, together with the influence exercised by variations in temperature upon installations of various kinds of material.

Cables for extra high voltage and appurtenant fittings.

The development in the sphere of high voltage cables has also in recent years progressed with giant strides, particulary so since the demand for cables for extra high voltages has become more and more actual. Throughout the world work is going on feverishly, both scientifically and practically, with a view to solve this problem.

Theories for cable designs and constructions have been propounded, theories for the insulating material forming part and parcel of the cable both in regard to penetration and passage of current, have determined its phycival and chemical characteristics, its dielectrical losses and ionisation voltage, and one should be able to construct a suitable cable on the basis of this information. But very serious difficulties are caused by variations in temperature, both such as occur within a cable and boxes and those that occur in the surroundings, and they both affect the manufacture of the cable and the cable itself after it has been put into operation.

The action of temperature variations on a cable in course of manufacture.

It if were possible to discover an insulating material that would be perfectly homogeneous and possessed the same coefficient of expansion as lead, the action of variations in temperature would be practically nil, but such is not the case now; on the contrary, the insulating materials used for high voltage cables (fig. 1), viz. paper and oil, are anything but ideal ones, for not only does oil posses a great coefficient of expansion in proportion to paper and lead but the insulating sheath also consists of a layer of oil-soaked paper and pure oil, and is, consequently, not homogeneous. To this must be added the risk of moisture remants and vacuum formations in the insulating layer, which cannot be altobether eliminated even with the very best drying and impregnating methods. The utimate result depends upon the quality of the paper and the characteristics of the oil even with the best manufacturing methods.

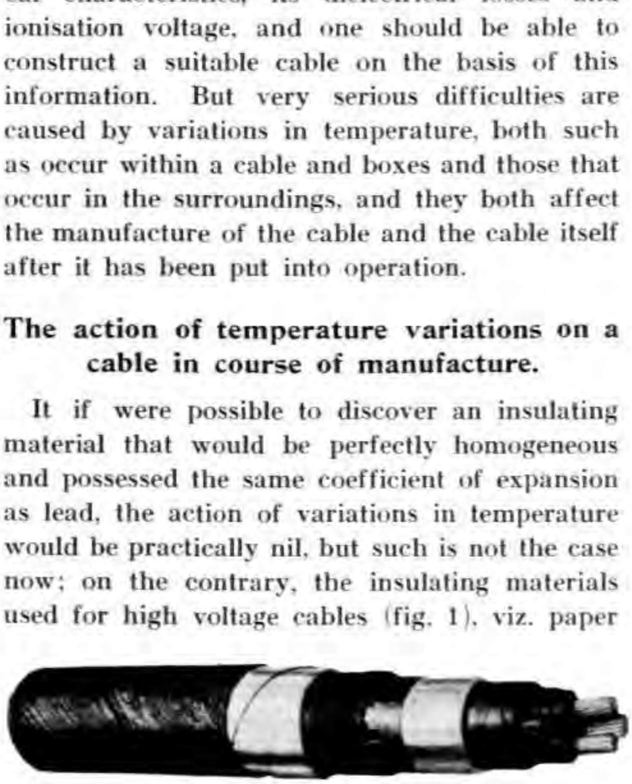


Fig. 1.

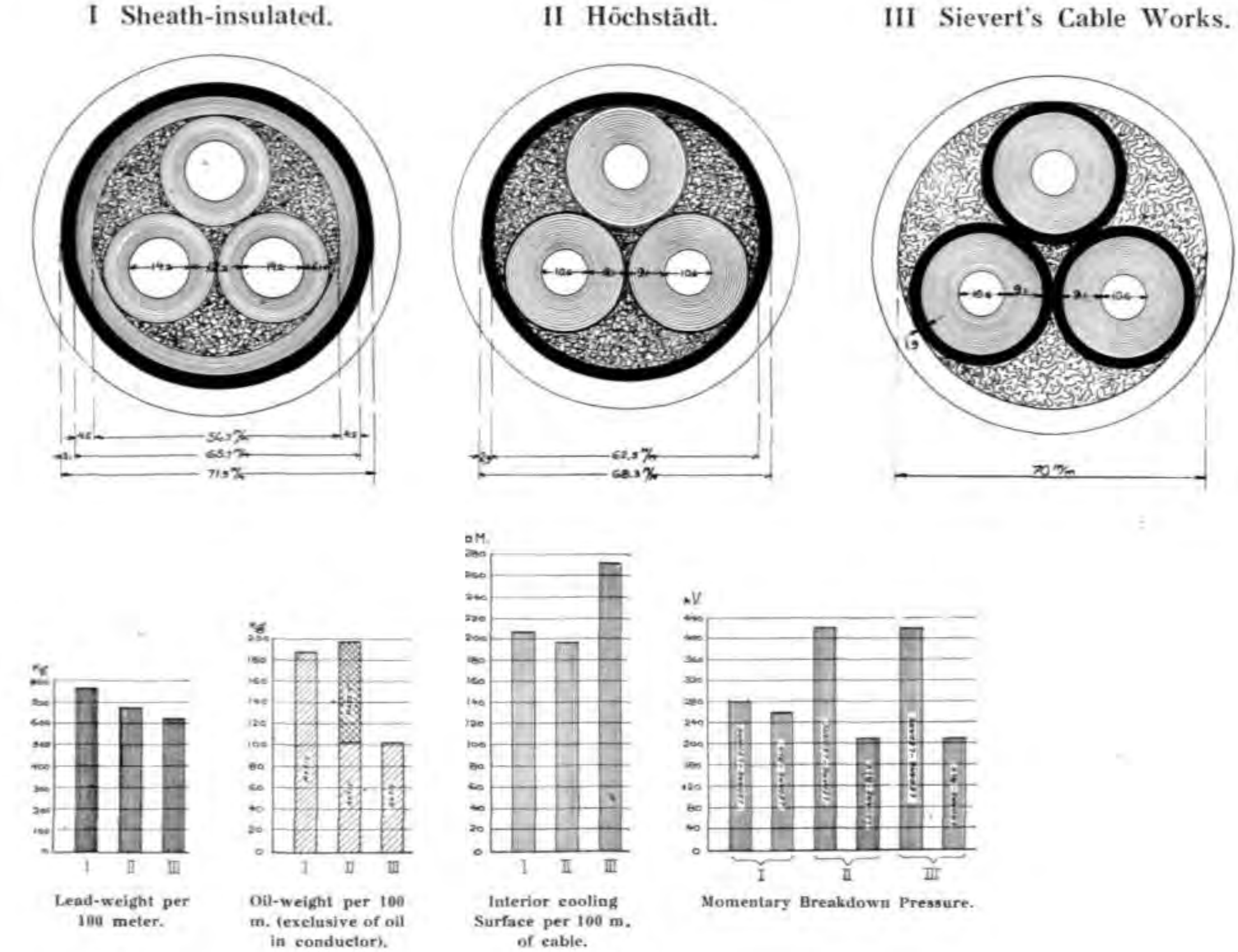


Fig. 2.

On account of the oil's large coefficient of expansion — 4 % expansion for 25° rise in temperature — the cable should be constructed in such a manner that the requisite quantity of oil in the same is restricted to the least possible (fig. 2). This can only be done partly by the conductor being made more massive, i. e. several flat wires (fig. 3) instead of round ones (fig. 4) or the conductor is provided with a lead sheath (fig. 5), partly by the paper being wound harder and more evenly. The lead sheath is then pressed tightly around the conductor. This method, however, will make drying and impregnation difficult, possibly also the laying of the cable. As a cable for high voltage has a larger volume and poorer cooling than one with the same cross section for lower voltage, the cable should not be ordered for a higher voltage than that for which it is to be used.

Provided a cable is constructed on the aforesaid

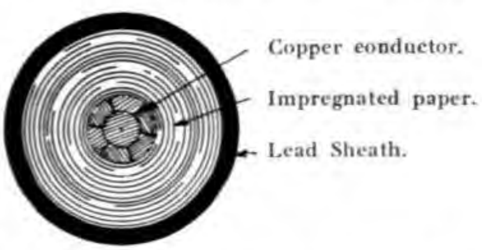


Fig. 3. High voltage cable with conductor of moulded wire around a round wire for reducing the oil space in the conductor.

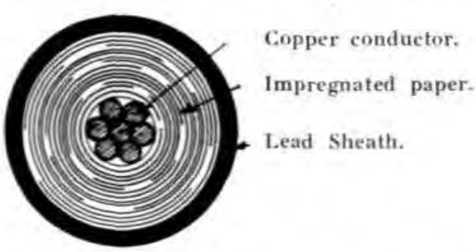


Fig. 4. High voltage cable with conductor of round copper wires, in which the oil space between the wires form 3 % of the conductor space.

lines, the choice of paper is the most important thing first of all. A paper must be procured, which, at a temperature not detrimental of the same, is capable of parting with its moisture, and which also possesses *small* dielectric losses after drying. Cellulose paper has here displayed the best qualities. Secondly we must find an oil with high disruptiv strength, high insulating resistance, small dielectric losses, low viscosity and a slight coefficient of expansion, together with the capacity of not being disintegrated at high electric voltages. Mineral oils are for the

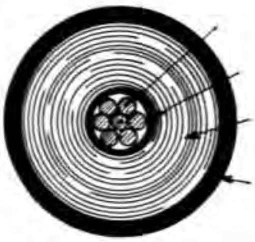


Fig. 5. High voltage cable with lead sheath over the conductor to prevent oil in conductor.

present the only practicable ones, and it is a question of finding the most suitable ones amongst them.

After the copper conductor has been wound with paper, the cable is dried under a vacuum at a suitable temperature. The drying process is preferably controlled by automatic recording of temperatures and by electric measurement direct on the insulating layer. After drying the cable is impregnated with oil under vacuum, which in its turn has been deprived of its water under vacuum, and has been heated to a suitable temperature. Even the impregnation is controlled electrically. At these high temperatures the oil is comparatively thin and liquid, and thoroughly penetrates and fills the insulating layer of the cable, particularly if the oil is under pressure. But the danger of vacuum formations does not make itself manifest until the cooling of the cable. At the same rate as the temperature drops the viscosity of the oil rises and makes it more difficult to penetrate into the insulating layer and fill the gaps that are due to the contraction of the oil being greater than that of the paper. Consequently these vacuum spaces occur sooner or later in the insulating layer at a certain temperature, which depends upon the rapidity of cooling. We call this temperature the vacuum-forming temperature. By a further increase in the pressure exerted on the oil for some considerable time it is possible to lower this vacuum-forming temperature slightly. In order to get a cable which at room temperature is thoroughly filled with oil, it is, therefore, necessary for the vacuum-forming temperature to be below that of the room temperature.

The viscosity of the oil should neverthless be selected in such a way that a vacuum-forming temperature below room temperature can be attained without excess pressure on the oil in the

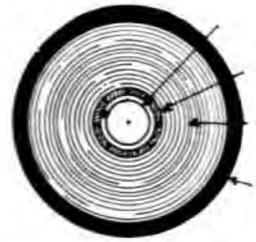


Fig. 6. High voltage cable with oil duct in conductor.

impregnation process, since otherwise vacuum formations may occur in the insulating layer in the further manufacturing process of the cable, and these may subsequently not be capable of elimination.

In the process of pressing on the lead sheath there arises a further risk of vacuum formations, for while stationary in the press the cable is heated in that part, which is in the press, the oil expanding and being partly pressed out of the insulating layer. In the subsequent cooling process vacuum voids are formed at these spots. This has been confirmed by measurements of dielectrical losses, carried out not only on pieces of cable that have been in the press for a few minutes, but also on pieces of cable that have been fed through the press at a normal working rate. If the cable then has a vacuum forming temperature which is below room temperature, without any excess pressure having been exterted, these vacuum formations can as a rule be filled with oil when the lead sheath contracts on cooling. The sheathing machines should be arranged in such a way that in a stationary condition the cable is not subjected to heating at certain spots, with ensuing risk of vacuum formation.

To obviate these stationary conditions or moments in the lead-press is, however, rather difficult. With existing presses it is impossible. The only solution is to design a press which runs continuously, e. g. by several minor pistons constantly pumping molten lead into the recipient.

On the other hand, it the method is employed of first pressing the lead on the insulated cable, and then dry and impregnate it, existing presses may certainly be employed, but in that case channels or ducts must be constructed in the cable (fig. 6) which not only enable efficient drying but also the introduction of the oil into the cable during the impregnation process. The oil required for this purpose must be very thin. Through the ducts having to be filled with oil the volume of the latter in the cable is considerably augmented, and the result of this is that the vacuum formations are greatly magnified. As the oil is thin it will run out unless the ends of the lead sheath are soldered up, and if these are soldered up the cable must also in the course of manufacturing have some expension vessels to prevent the lead-sheath being forced out by the interior oil pressure in the event of any increase in temperature. To draw off the oil and fill the ducts with an indifferent gas during the manufacturing and laying-down process, and replenish the oil after the latter, possesses also some drawbacks. This method is said to be employed abroad for cables for 132.000 volt.

It would undoubtedly be better to dry the cable and fill it with an indifferent gas, press on the lead sheath, and, if necessary, armour it, then lay it down in ground and, after laying-down, dry it again and impregnate it with oil. Drying and impregnation can then be carried out in such a way that a current is passed through the copper core or through an insulated resistance-wire for heating the cable, located in the core. The cable is dried under vacuum and then impregnated, even this under vacuum, with a thin oil. Cables of the future for extra high voltages will certainly be made in this way, for by this means the action of variations in temperature upon the quality of the cable during manufacturing and laying-down is obviated. Nor is the cable so sensitive on being handled.

A Swedish patent based upon placing elastic organs inside the lead sheath and in the longitudinal direction of the cable (fig. 7) for the

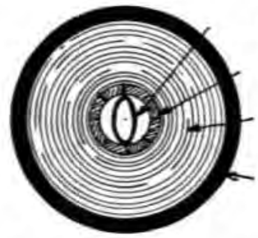


Fig. 7. High voltage cable with elastic organs incorporated in the conductor, which look after the expansion and contraction of the oil in case of any variations in temperature occurring in the table.

purpose of locking after the expansion and contraction of the oil and impart to it a radial direction of motion,, will certainly have bright future prospects.

Testing cables for extra high voltages and concomitant risks of the cable's durability.

To carry one's demands in testing a cable too far, may entail certain risks for the finished article. for from the preceding remarks it will be seen every variation in temperature exercises its effect upon vacuum formations in the cable, and, consequently, also upon its electrical qualities. If tests have to be carried out at different temperaturs, such should be done on a short piece of a cable in process of manufacture, and not on a whole cable-length, as is sometimes stipulated. It is quite certain that the cable after such a test at a high temperature has lost in quality, and it may happen to the cable as it did with the matches the boy was to buy for his mother and was strictly told by her to see that they could be used. He bought the matches and tried them one after the other, until they had all been tested. When he came home to his mother he said: I've bought some really nice matches this time, and I'm quite sure of it, because I have tried every one.

That variations in temperature in measuring or gauging dielectric losses and ionising play a very important part, is obvious from the preceding remarks, since their values largely are due to gas or vacuum formations in the insulating layer.

A too high test voltage for any length of time may also be sufficient for spoiling an otherwise perfect cable.

The action of changes in temperature on a cable in use.

After a cable has been put down it generally gets a temperature lower than that of the room in which it has been made. The result of this is bound to be that vacuum formations occur in the insulating layer. Tests with cables that have been laid down should, therefore, be carried out with a certain amount of circumspection. If a too high test voltage and a long period are used there is a risk of carbonization, caused by flashlight phenomena in the vacuum voids, without the cable manifesting any signs of penetration. In reality the cable is weakened and its life shortened.

If, therefore, there is any chance of heating the cable before the test, e. g. by passing a current through it, so that the temperature reaches room heat, the risk is diminshed.

From practical experience there are many examples to show how a cable has been operating faultlessly for years, but after having been put out of operation for some time, showed penetration on being put down afresh. This is undoubtedly due to vacuum formations on account of variations in temperature.

Carbonization in an insulating layer occurs as a rule in the centre of the layer and not, as one might think, nearest the conductor, where the electrical field is strongest. Whether this is due to the paper having been less thoroughly dried, or whether the electro-osmotic pressure on the oil has forced the oil partly to the lead sheath and partly to the conductor, has not been elucidated. A high voltage cable that has been in use for any length of time always proves to be somewhat deficient in oil in the centre of the insulating layer.

Fittings for cables for extra high voltages.

Even in the connection and end boxes for extra high voltages the variations in temperature play an important part. The expension and contraction (breathing) of the oil with changes in temperature are so great that they must be taken into consideration in the manufacture of the boxes. The old type of boxes filled with a compound (fig. 8) for high voltage is bad, because the oil, if a rise in temperature occurs, forces its way out. Cable and boxes must form an

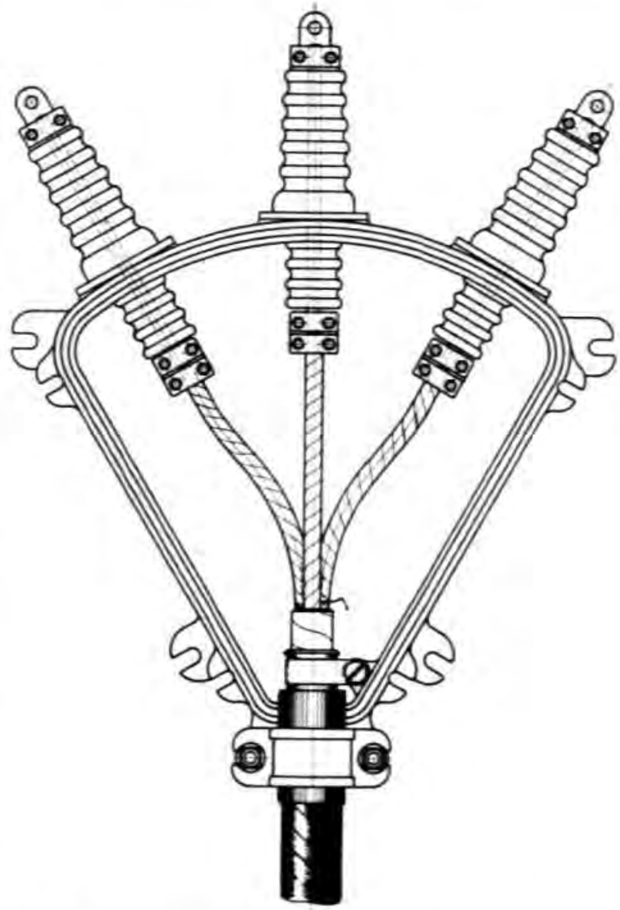


Fig. 8. Straight end box for cable with bolts passing through.

entirely hermetically closed system if the oil is not to run out, and the boxes must be provided with expansion vessels (fig. 9—11) in which the oil can breathe. Previously, it was been difficult to make these boxes fit tight, but the question was solved with the arrival of rubber-lead packing (fig. 12). In this packing the rubber is protected against the action of the oil by a lead covering. This packing is used not only for making a tight fit between the leadsheath and the box (fig. 13 and 17), as simultaneously a metal connection is attained between them, but also for holding together insulator and box, and at the same time making a tight fit between them (fig. 14). Although the lead covering metallically connects the cable's lead sheath with the box, an extra earth connection must nevertheless be added which takes charge of any possible short circuit currents. Other tightening is also effected by rubber-lead packings, the expansion vessel being tightened against the porcelain by means of such tightening

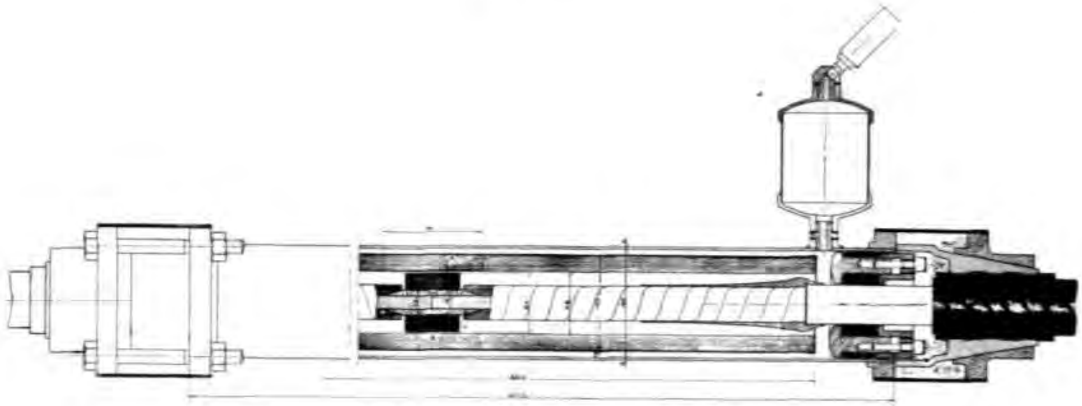


Fig. 9. Connection box for single phase cable.

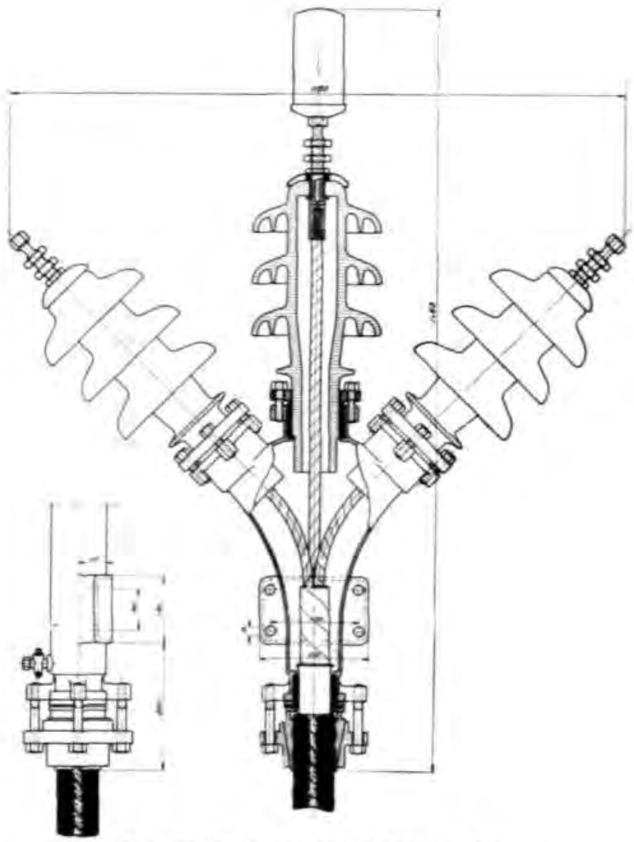


Fig. 10. End box for 3-phase cable.

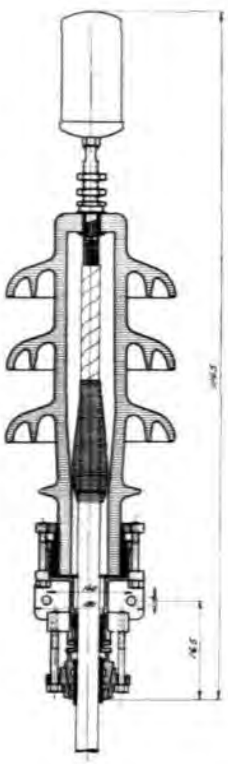


Fig. 11. End box for single phase cable.

(see fig. 15). The expansion vessels are also made of glass, so that the oil level can be observed, and, in case of need, provided with a manometer and vacuum meter for recording the variations in pressure (fig. 16).

If thin oils are used, it is necessary to divide the cable line into separate, hermetically sealed sections, particularly so if the entire cable line is not located on the same horizontal plane. This is feasible by every section being finished off with connection boxes (fig. 17), which are interconnected in a function-box. The latter can be placed overground in a kiosk, or underground in a hermetically sealed box. The tracing of faults is facilitated by this division into sections.

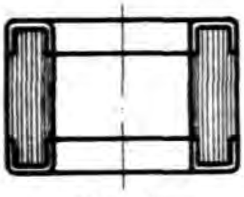


Fig. 12.

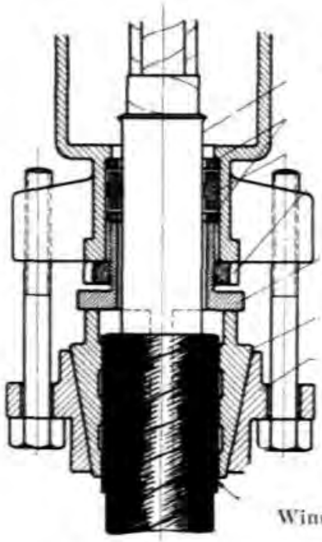


Fig. 13.

Installation material for damp premises and its fitting-up.

After thorough researches into the conditions prevailing in farm-yards, pig-sties, breweries, cellulose mills and other kinds of damp premises it has been found that the variations in temperature play an important part in the duration of the installations. This has previously not been sufficiently taken into account.

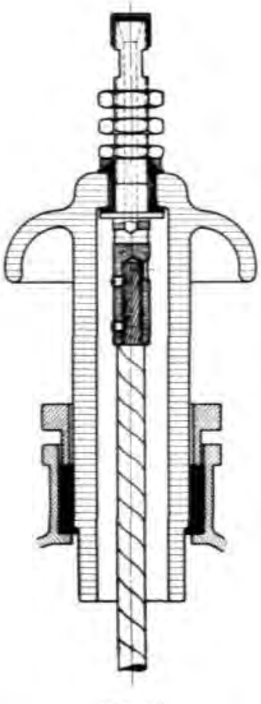


Fig. 14.

The air which exists in some part of an installation system assumes with an increase in temperature a higher pressure, with a lowered temperature, a lower one. Unless the entire system is air-tight, it breathes, as has previously been stated about the cables. With a falling tempera-

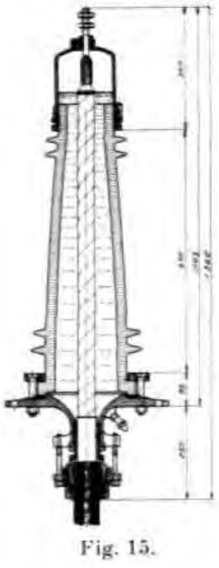


Fig. 15.

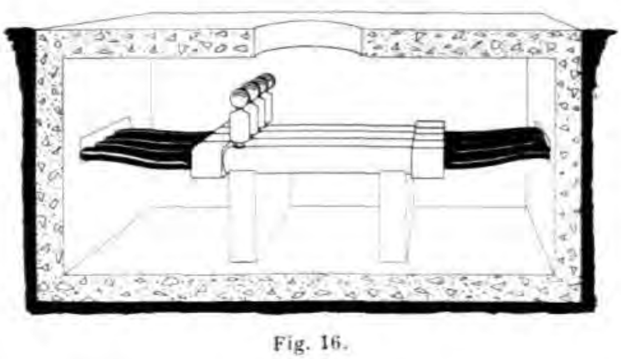


Fig. 16.

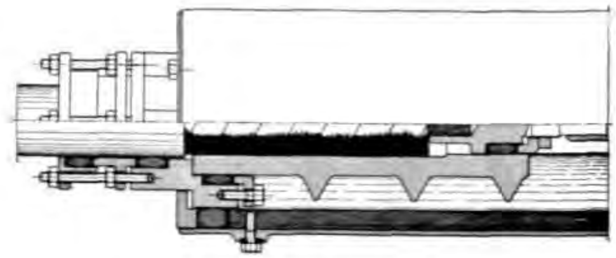


Fig. 17.

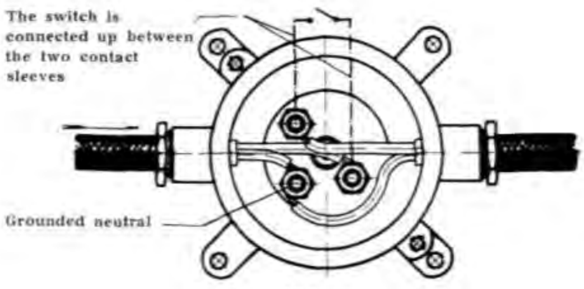


Fig. 19.

Fig. 18.

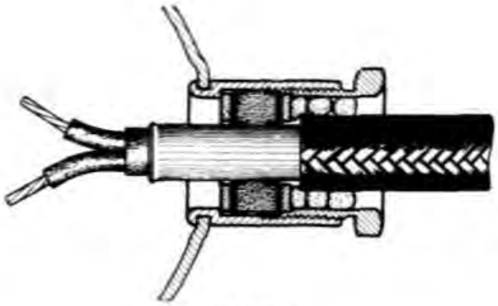


Fig. 20.

ture there is then a risk that some of the moisture in the air is precipitated inside the material, which depresses the resistance to insulation, and, consequently, causes a certain amount of deflection current. This current may in adverse instance cause dangerous heating, yet without the stipulated fuses switching off the current. The result of this may be a fire, and many are certainly the fires that are generally attributed to short circuiting, which have been caused by this very arc-ing over. Even danger to life and limb arises by the condensed moisture making apparently insulated parts of the installation live.

In designing a conductor (fig. 18) and fittings (fig. 19 and 20) the air spaces inside the system should be as minute as possible. It is of vast importance that the conductor itself is made massive and not with air ducts through which moisture may be disseminated from box to box, if one of the latter through negligent fitting-up or for some other reason should become defective.

If lamp-brackets are constructed together with

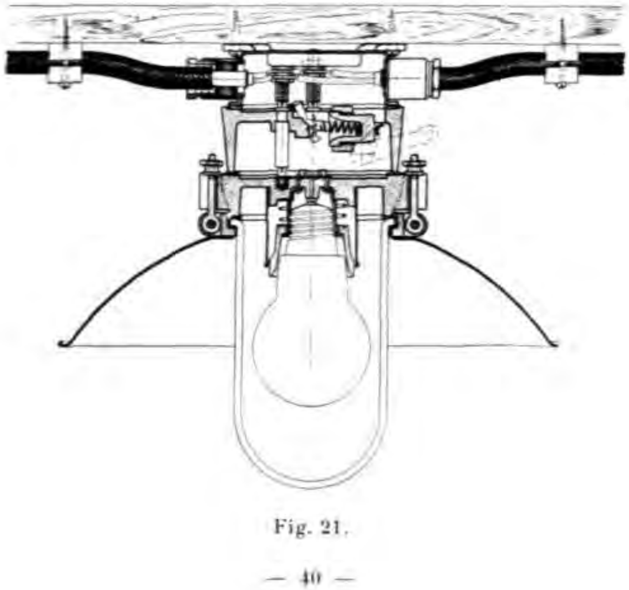


Fig. 21.

a tiebox, the bracket should be such that it fits the tiebox tightly, no matter whether and guard-glass be put on or not (fig. 21 and 22).

To fill the function-boxes with an insulating compound would be advantageous from a breathing point of view, but this method possesses from a fitting-up point of view so many drawbacks, that it is inadvisable.

As function-boxes naturally are vulnerable points in a system, their number should be restricted to the least possible. A cause of defect in an installation increases to a certain degree with its total length of conductor, and, therefore, the same should be curtailed to the utmost. Both these desiderata are gained by the use of apparatus that can be constructed into one unit, for by then attaching switches and lamp-brackets direct to a function-box we save separate functions-boxes for these apparatuses, and the switch conductors are altogether eliminated.

Summary.

From the preceding remarks it will be obvious that not sufficient regard can be taken to the action of variations in temperature, no matter whether it concerns the manufacture of installation material for damp premises or cables for extra high voltages and appurtenant fttings. Unfortunately this has not been taken into consideration until quite recently.

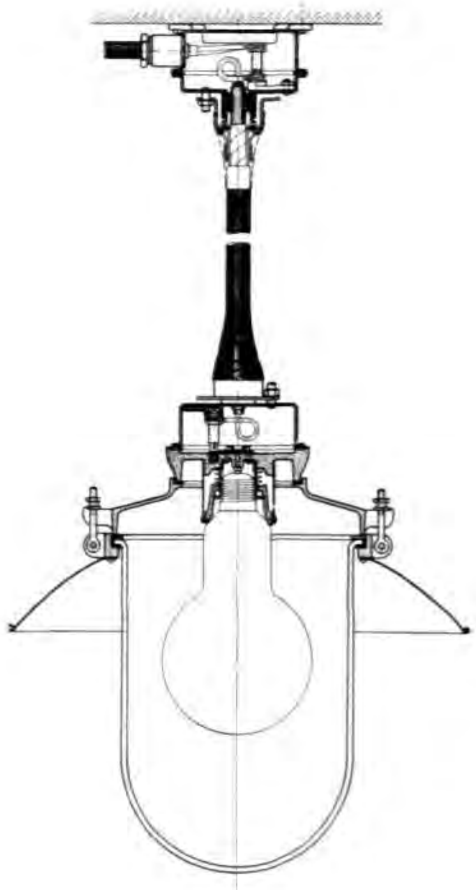


Fig. 22.

Totalisator for Fully Mechanised Racecourses.

Ericsson Telephones Ltd., London.

General Remarks.

The Totalisator, as a whole, has two main functions to perform for each bet made. One is to record on a ticket the particulars of the bet, the person making the bet receiving the ticket in return for the cash which represents the bet. The other is to record upon the totalising equipment the particulars of the bet, which should correspond with the ticket issued.

The first of these functions is taken care of by the Ticket Issuing Machine which is a mechanical arrangement of Keys, 40 in number, capable of issuing tickets stamped with numbers 1 to 40 (or 41 to 80) according to the key which is depressed. (A further variation may be made by a switch which causes all tickets issued to be stamped "Win" when operated in one direction and "Place" when operated in the opposite direction.)

The second is carried out by the Totalising equipment which, as made by Ericsson Telephones Ltd., Beeston, England, and approved by the Racecourse Betting Control Board, consists primarily of standard relays and Rotary Line Switches such as are used on the standard equipment for Post Office Automatic Telephone Exchanges in the Country.

For the working of a totalisator scheme of betting on racecourses, it is required that all bets made on each horse in a race should be registered and totalled, also that the public should be advised continuously how betting on each horse is proceeding from the time betting begins right up to the start of the race when betting closes.

The Totalisator is designed to do this work, automatically registering all bets, and simultaneously giving the increasing total on each horse running as the bets are accepted, without any manual work being performed beyond the action of the pressing of a key on the Ticket Issuing Machine when the bet is made. This action is also sufficient to print and issue to the party making the bet the ticket which serves as a receipt for the money accepted and also as a voucher on which payment of any winnings accruing will be made at the end of the race. In order to ensure accuracy, arrangements are made so that the ticket cannot be issued until the bet has been recorded on the totalising equipment.

The explanatory description which follows has been split into the various sections which comprise the Totalisator equipment, and details of each section are given under the relative heading.

A Schematic Trunking Diagram is attached which shows the linking up of the various sections. It will be seen that the bets are put out from the Ticket Issuing Machine to the Decoding Relay Group which in turn puts the bets out to the Collecting Switch.

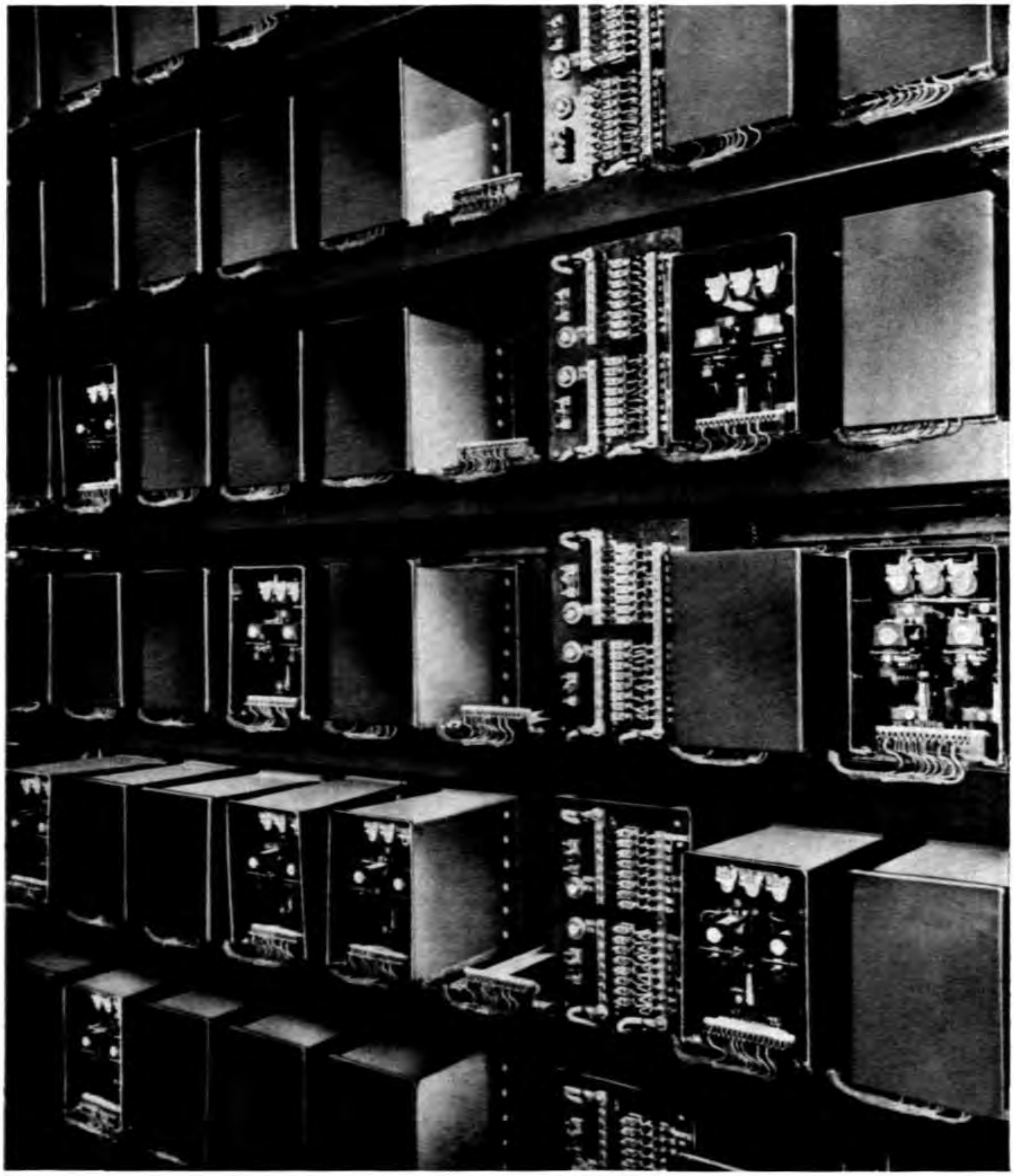
The Collecting Switch rotates to pick up the bets which take the form of earths on its bank contacts. These earths are passed forward to the Adding Machine when the wipers of the Collecting Switch reach the bank contacts which are earthed.

The leads from the Collecting Switches are connected to the Adding Machine via the Plugging Down Rack, the Collecting Switch side terminating on jacks and the Adding Machine side terminating on plugs. By this arrangement Adding Machines may be fewer than Collecting Switches, only those representing horses which are actually running in the race being plugged through

In the Adding Machine switches are provided to control the displays on the Public and Miniature Indicators, these switches are stepped forward by the incoming bets and continuously record on the indicators the total of bets received.

The Manual Control Rack is provided to control the set up for Horse Numbers which have to be displayed to the public in addition to the total of bets appearing for each horse. Each digit of the Public Indicator is a separate unit controlled by the controlling leads from the Adding Ma-

R1734 Public Indicator. (Demonstration Totalisator.)



R 1742 Back of Public Indicator. (Showing indicator boxes.)

chine; these leads may be connected through the Manual Control Rack as shown on the diagram, so that the digits for Horse Total may be controlled manually in a manner similar to that for the Horse Numbers.

In the Control Switchboard are vested the controls for the whole Totalisator and safeguarding arrangements are provided so that the controls may only be operated by a responsible official who has a special key which can electrically lock in the controls and either start or stop betting.

After a race has been run a dividend is declared and shown as £. s. d. to be paid for every 2/— unit placed on the winners, both Win and Place. The figures representing £. s. d. are set up from

B 1735 Manual Control Rack.

the Manual Control Rack in exactly the same way as the Horse Number is set up.

The Ticket Issuing Machine.

The function of this machine is to print a ticket for issue to the public when a bet is made. It also starts the train of operations through the automatic equipment which registers the bet, with safeguarding arrangements which prevent the issue of a ticket until the bet has been registered.

The machines are provided with keys bearing numbers which correspond with the numbers of the horses entered for the race as shown on the race card. Forty keys are fitted per machine and are generally sufficient to cover all the requirements for any one race, but arrangements can be made for eighty horses, if necessary, by using two machines together. Win and Place bets are controlled from a switch known as the "Win and Place Switch".

The pressing of a key representing the number of the horse on which a member of the public desires to place a bet, together with the operating of the "Win and Place Switch" in the Win or Place direction, starts the operations necessary to register the bet. When the bet is registered on the Totalisator equipment the ticket is issued and bears on its face the following information:—

1. The name of the Race Course.
2. The value of the bet.
3. The date on which the race is run.
4. The number of the horse on which the bet has been placed.
5. The number of the race.
6. Whether the bet is for a "Win" or a "Place".

In addition to the foregoing there is also printed on the ticket for the information of the Control Board operating the Totalisator:—

1. The number of the machine from which the ticket has been issued.
2. A secret code which is changed each day to prevent fraud.

From each machine tickets of one value only are issued, but a bet on any horse either "Win" or "Place" can be taken by any machine. The different values are 2/—, 10/—, £1, £10 and £100.

If any member of the public wishes to place a bet of 4/— on a horse, he gets two tickets of a value of 2/— each; and so on throughout the various values to the total desired.

Since the Ticket Machines may be situated some distance from the Totalisator equipment, a "Coding" and "Decoding" scheme is used for the connections between the machines and the Totalisator equipment.

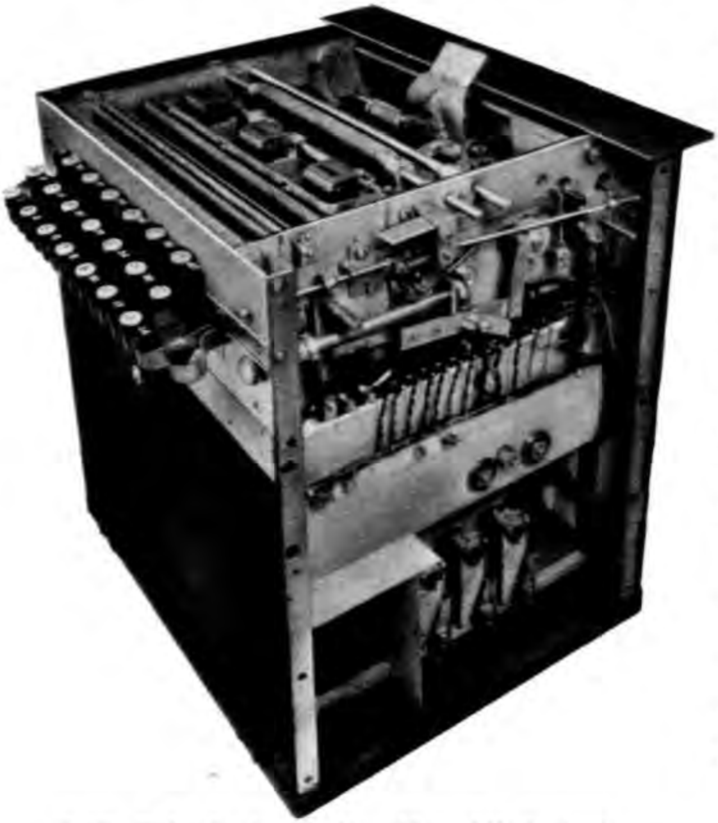
It is required that when any one of the 40 keys on a Ticket Issuing Machine is operated, a bet shall be registered on to any one of 40 horses. In other words, any one of 40 different conditions are required from the machine for the operation of any one of 40 keys, the Win and Place Switch not being condsidered for the moment.

This is easily arranged if 40 leads are brought out from the machine and connected to the totalising equipment, but the number of connecting leads required would then be excessive and a "Coding" arrangement is provided on each machine to reduce the 40 different conditions required to the compass of 6 springs, and so, of 6 junction leads.

Six spring sets are provided per machine, operated by cams which are in turn operated by the operation of the various keys. The attached table illustrates how the 40 combinations are obtained from the 6 contacts.

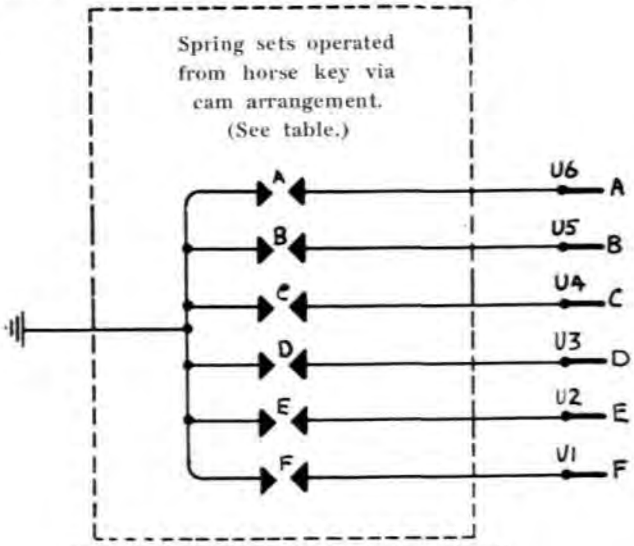
The machines may be locked against or unlocked for the issue of tickets, this arrangement

B 1736 Ticket Issuing Machine.



R 1377 Ticket Issuing Machine (View of Mechanism).

being provided by a solenoid plunger fitted in each machine. These solenoids are controlled from a distant point and betting may be stopped at any moment, arrangements being made on the controlling switches to prevent accidental or malicious misoperation.



R1745 Ticket Issuing Mach. Coding circuit.

The *"race number"* which the machine prints on the tickets is changed by the persons operating the Ticket Machines when betting is closed down on a race. This change can only be effected when the machines are locked by the above-mentioned solenoid plunger and it is only possible to change the *"race number"* to the next higher digit. This arrangement is provided to prevent the fraudulent issue of tickets on a race which has been run.

Decoding Relay Group.

This is a group of relays associated with a Ticket Issuing Machine and its function is to "decode" the coding combination set up on the 6 spring sets of the Ticket Issuing Machine when a bet key is operated. Two relay groups are required per Ticket Issuing Machine, one for "Win" bets and one for "Place" bets.

The description of the ticket issuing machine has shown that the operation of any one of the 40 keys results in the operation of cam springs such that any one of 40 combinations may be made on 6 springs and over 6 junction leads, as per the attached table.

Horse number	Spring sets operated
1	A
2	B
3	C
4	D
5	E
6	F
7	A & B
8	A & C
9	A & D
10	A & E
11	A & F
12	B & C
13	B & D
14	B & E
15	B & F
16	C & D
17	C & E
18	C & F
19	D & E
20	D & F
21	E & F
22	A, B & C
23	A, B & D
24	A, B & E
25	A, B & F
26	A, C & D
27	A, C & E
28	A, C & F
29	A, D & E
30	A, D & F
31	A, E & F
32	B, C & D
33	B, C & E
34	B, C & F
35	B, D & E
36	B, D & F
37	B, E & F
38	C, D & E
39	C, D & F
40	C, E & F

When a bet is made the Decoding relays set themselves in accordance with the above combination and reproduce the bet conditions on any one of 40 horse circuits exactly as though each key on the Ticket Issuing Machine operated separate spring sets, each spring set closing the bet circuit for an individual horse over one of 40 junction leads when the key is depressed.

The movement of the "Win" and "Place" switch automatically changes over the six junction leads from the "Win" decoding group to the "Place" decoding group which deals with the "Place" bets.

The Ticket Issuing Machines are segregated into denominations, one group of machines operating for 2/— bets only, another group operating for 10/— bets only, and so on through the denominations which are catered for by the Totalisator. Since each Ticket Issuing Machine has a "Win" and a "Place" Decoding Relay Group associated with it, it follows that these relay groups are also segregated in denominations, one group serving 2/— bets, another group serving 10/— bets, and so on.

A connection is provided from *each* Decoding Relay Group to 40 different betting circuits representing 40 different horses, and the operation of a key in a Ticket Issuing Machine results in the relative betting circuit having earth potential applied to it from the Decoding Relay Group. This earth potential is passed forward to the "Collecting Switch".

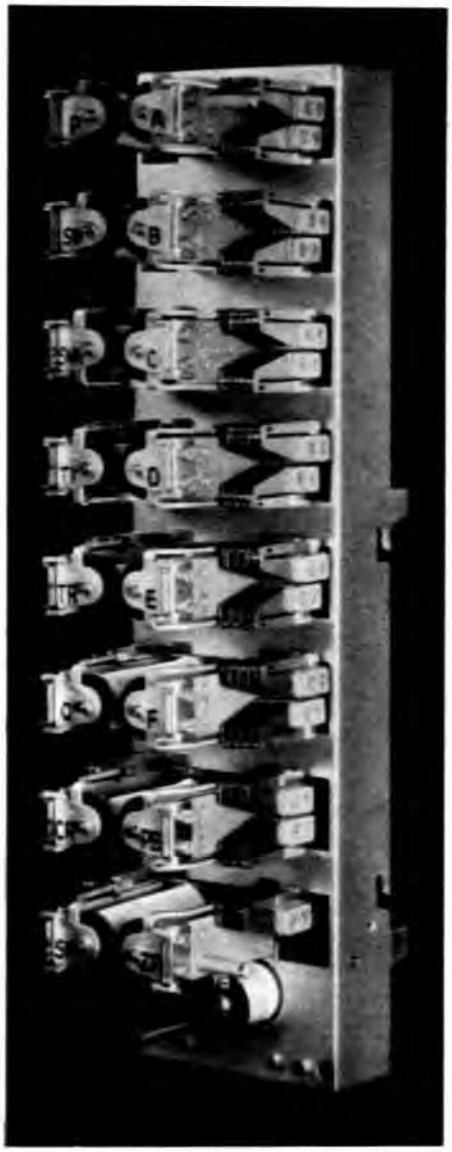
The Collecting Switch.

This is a Rotary Line Switch and, as its name implies, serves to collect bets which have been put forward by the Decoding Relay Groups controlled by the depression of keys on the Ticket Issuing Machines.

The wipers of these switches are connected to Adding Machines and the bank contacts to Decoding Relay Groups. When a wiper reaches a bank contact upon which earth potential has been applied, this earth is transmitted to the Adding Machine concerned.

Two switches are provided for each horse, one for "Win" bets and one for "Place" bets and each has five levels or sets of levels which pick up bets for each of the five denominations, 2/—, 10/—, £1, £10 and £100. One switch, therefore, picks up all the "Win" bets or all the "Place" bets for each horse whatever their denomination may be.

For example, Horse No. 1 has a collecting Switch for "Win" bets: the bank contacts of the 2/— sets of levels are wired to Horse No. 1 con-



R1738 Decoding Relay Group.

nection on each 2/— Decoding Relay Group (each contact being connected to a separate group) and the wipers associated with this set of levels are connected to the 2/— Adding Switch in the Adding Machine. The bank contacts of the 10/— set of levels are similarly connected to the 10/— Decoding Relay Groups, and the wipers to the 10/— adding circuit in the Adding

Machine. This arrangement is repeated for the other denominations.

The Adding Machine.

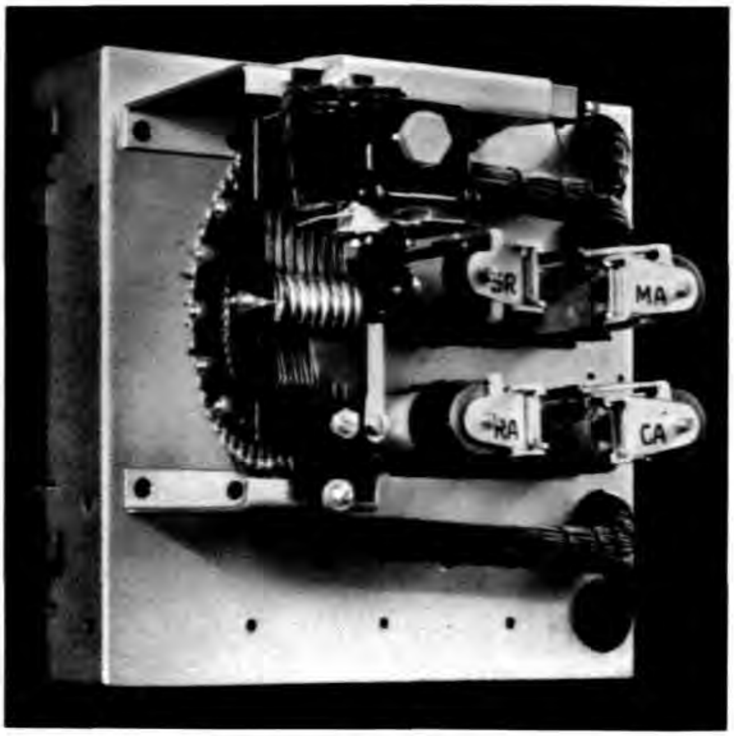
The Adding Machines are provided two per horse, one dealing with "Win" bets and one dealing with "Place" bets. Each comprises a set of Rotary Line Switches and controlling relays into which all the Win bets for a horse, or alternatively, all the Place bets are directed.

A separate Rotary Line Switch is provided per Adding Machine for each denomination, and each incoming bet serves to step the relative switch, in the relative Adding Machine, one step. The number of switches provided for the bets is five, one for each of the denominations, viz:— 2/—; 10/—; £1; £10; £100. The bets are passed into the Adding Machine switches one at a time by the Collecting Switches as they collect the earth potentials put forward by the Decoding Relay Groups.

Rotary Line Switches are also provided to cater for denominations higher than the group of denominations for which bets may be made, two additional switches being provided to cater for £1,000 and £10,000.

The first five switches in each Adding Machine are stepped by bet impulses received direct from the Collecting Switches. Other impulsing circuits are closed, however, under the following conditions; every 5th step of the 2/— switch gives one impulse to the 10/— switch, every 2nd step of the 10/— switch gives one impulse to the £1 switch, every 10th step of each of the other denominations except the last, gives one impulse to the switch controlling the next higher digit. These impulses are called transfers, and circuit arrangements are made to prevent overlapping between transfer and bet impulses which may occur simultaneously on those switches being controlled directly by bets.

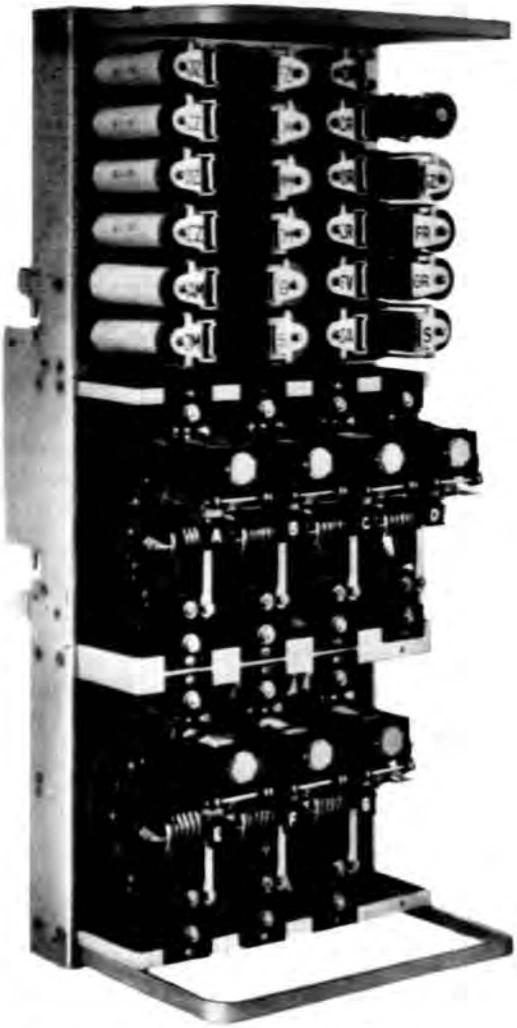
The Adding Machine switches control the display of the bets made on each horse. This display constitutes a number which represents the number of 2/— bets made on that horse; for instance, a 2/— bet increases the display by one, a 10/— bet by 5, a £1 bet by 10, a £10 bet by 100 and so on. The display is therefore arranged on a decimal basis and instead of regarding the displays as 2/—, £1, £10, etc. they may be regarded as Units, Tens, Hundreds, etc., the unit being 2/—. The seven switches in each Adding Machine serve to control six digits per horse on the display, Win or Place: (the 10/— switch has



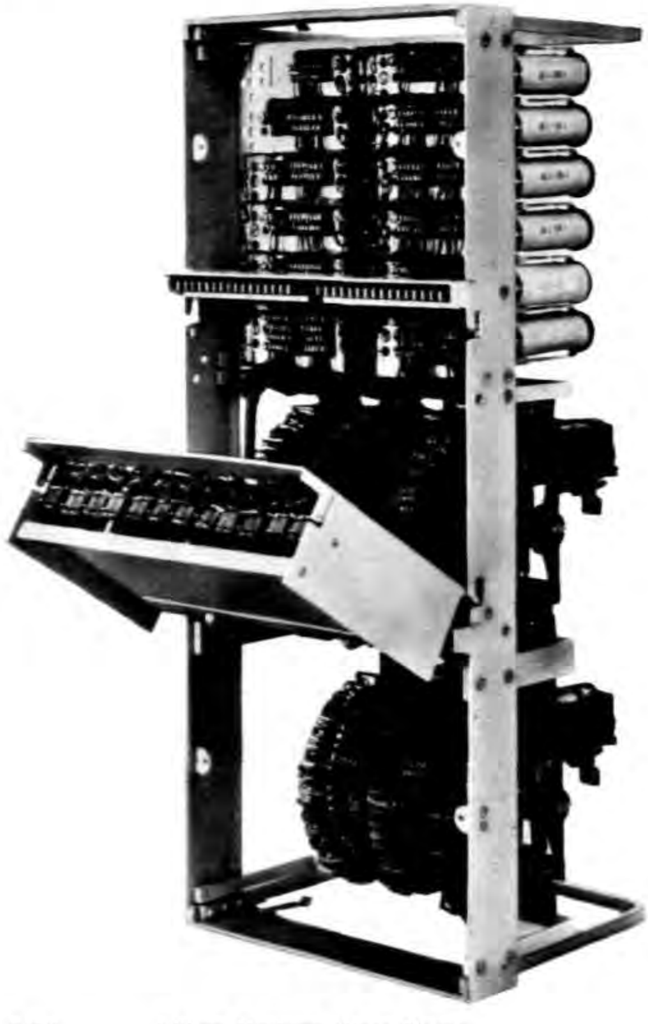
R1739 Collecting Switch.

no separate display, one step of this switch controlling the display from the 2/— switch by adding'5').

In addition to the Adding Machines provided to total up the number of 2/— units laid on each horse Win or Place, two more Adding Machines are provided, (one Win and one Place) for the 'Totals' or 'Aggregates'. These machines total up all the bets laid on all the horses Win, or on all the horses Place, and control a display in the same way as the Horse Adding Machines.



B1740 Adding Machine (Front View).



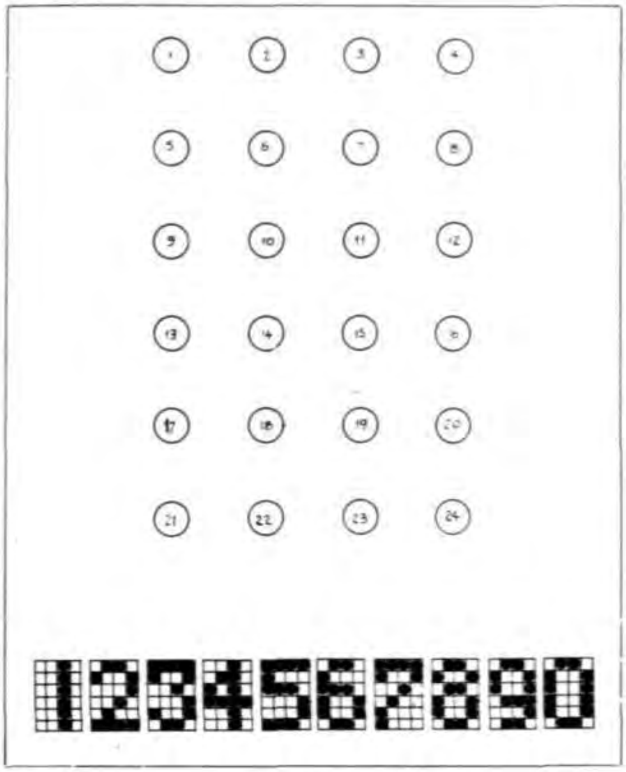
B1741 Adding Machine (Rear View).

Indicator Boards.

There is associated with the Adding Machines an Indicator board on which are displayed for the information of the public the amounts of the bets laid on each horse as the betting proceeds. To accomplish this a nest of 24 lamps is provided for each digit. By lighting a group of these lamps, which are arranged in six rows of 4 lamps each as shown, an illuminated figure is displayed. For example, to show the figure '2' lamps Nos. 5, 2, 3, 8, 12, 15, 18, 21, 22, 23 and 24 are lit.

The figures for each digit are formed by the setting of two rotary line switches operated by controlling relays which are in turn controlled by the Adding Machines, the setting of the switches in each Adding Machine determining the setting of the switches for each digit on the display for the particular Adding Machine concerned. These digit switches, which are provided two per digit, follow the Adding Machine switches as they are stepped under the control of the incoming bets.

In addition to the public display described above, a Miniature Indicator is provided inside



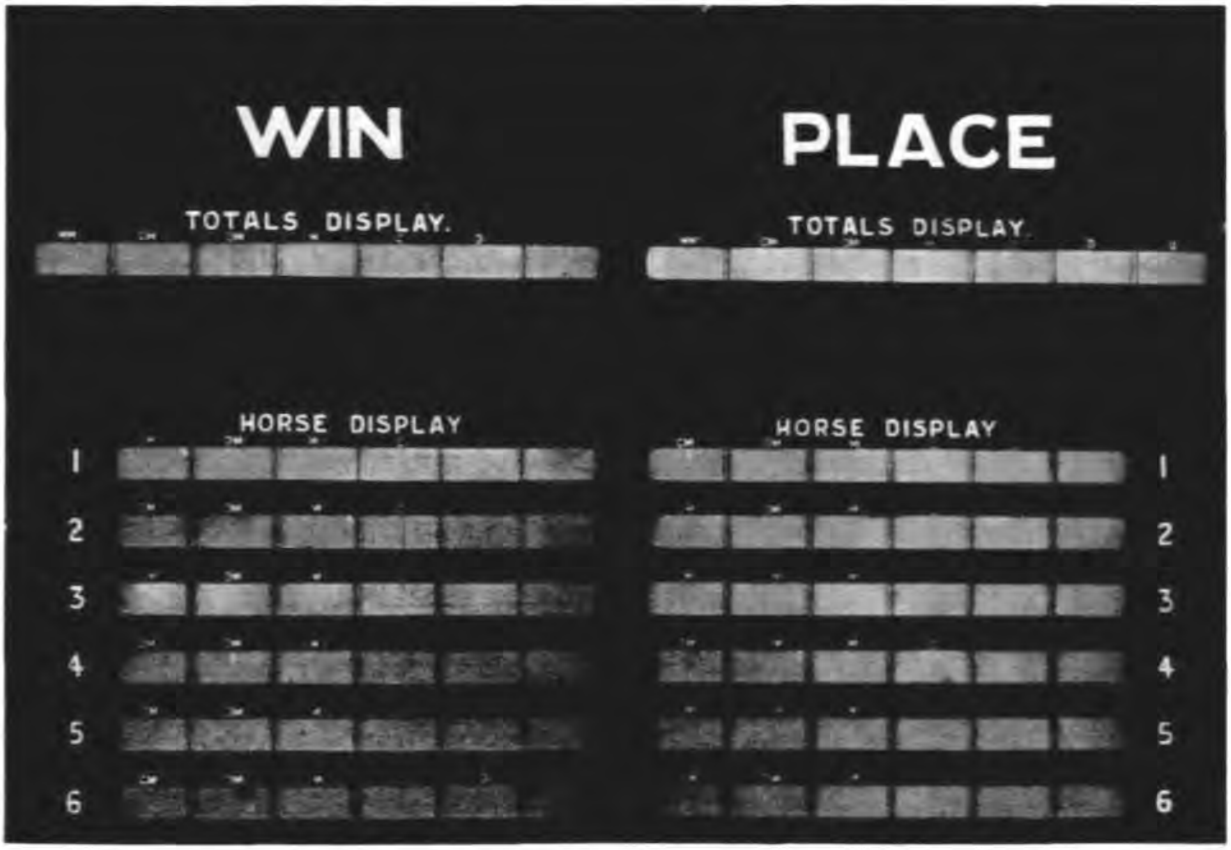
B 1746 Lamp numerial indicator.

the building which duplicates the reading shown to the public. In this case, as the figures do not require to be visible from a distance, only one small lamp is lighted per digit, the light appearing behind a stencil in which the figure is cut. The lamps are lighted by the switches in the Adding Machine which control the Public Indicator display.

Each display, in addition to showing the number of 2/— units laid on each horse, also shows the Race Card Number of the horse. The digit switches and relays which provide the display of the horse numbers (the lighting of the digit lamps) are identical with those providing the displays for the number of bet units. The Horse Numbers are set manually before the start of betting on each race, and are controlled from the Manual Control Rack.

Collecting Relay Groups.

The number of bank contacts on any Collecting Switch which may be connected to one wiper circuit and to one bet lead is limited to 50. All

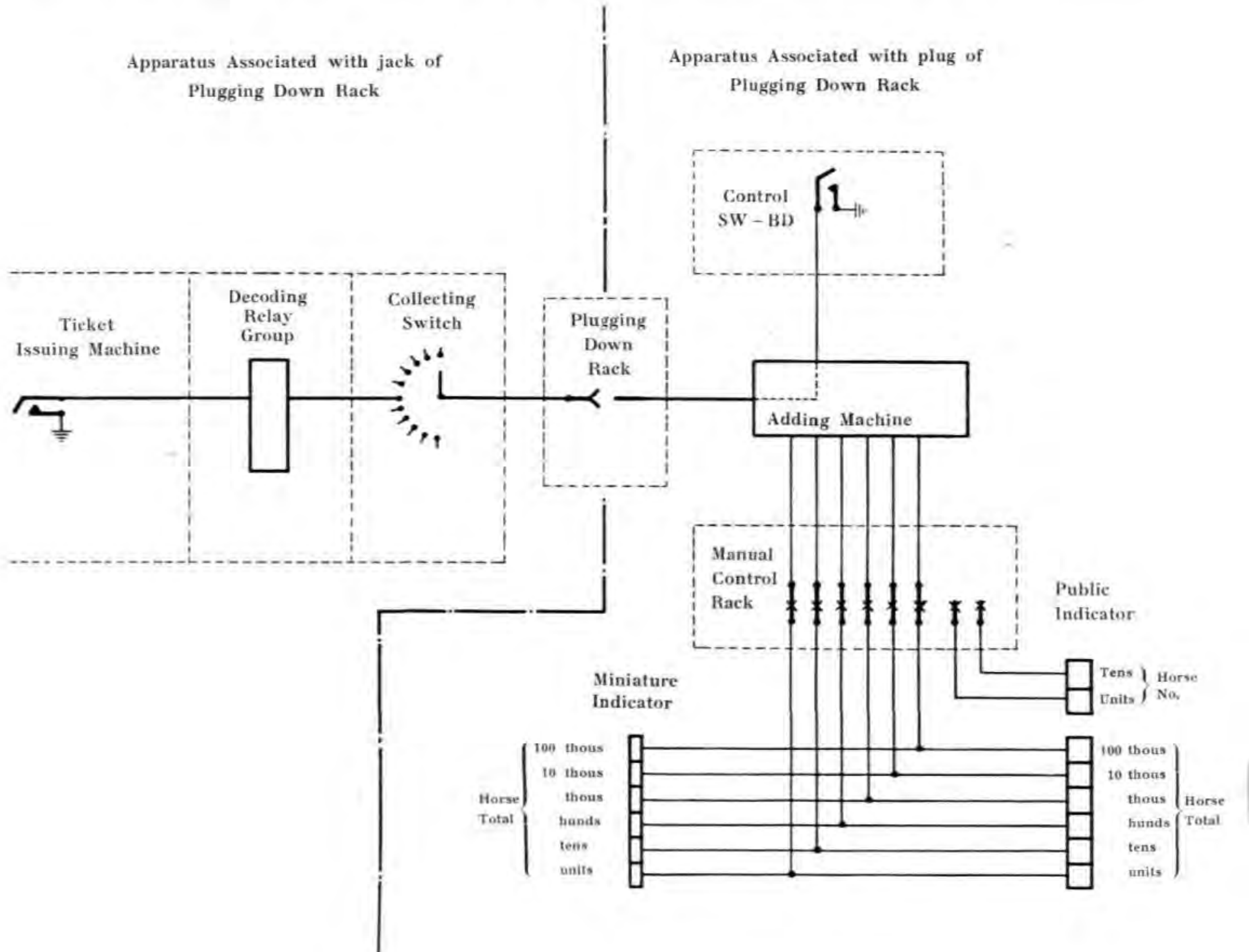


B 2743 Miniature Indicator. Demonstration Totalisator.

bets of any one denomination for any one horse must be routed to one counting switch in the Adding Machine, and it follows that the direct impulsing scheme already described, where the bet impulses are picked up by the Collecting Switches and routed direct to counting switches in the Adding Machines, must be limited by the number of bank contacts to which any one wiper circuit can make connection. This number is 50 and the direct impulsing scheme is limited to 50 Ticket Issuing Machines of any one denomination.

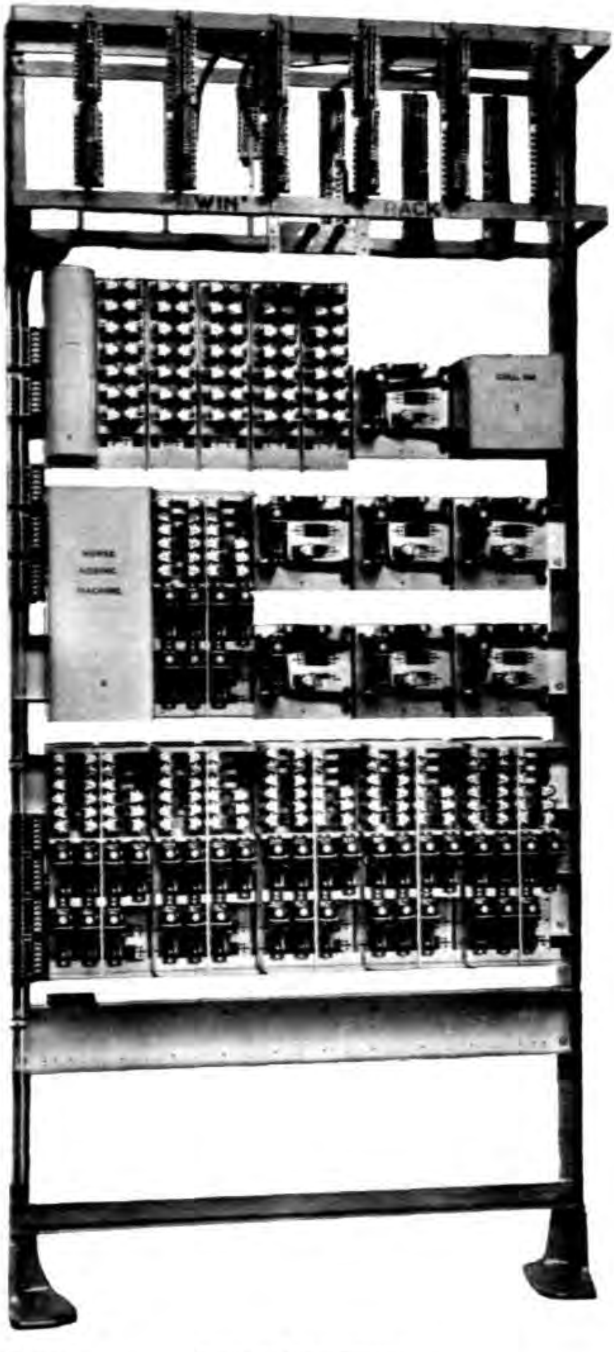
When this number is exceeded the additional machines work to additional Decoding Relay Groups which work to additional levels of the Collecting Switches. This results in two main bet leads being used over which bets are to be routed to one counting switch. Since bets may be on both leads simultaneously, arrangements must be made to collect from each bet lead separately. Each lead is connected accordingly to a separate relay group which collects the bets from each until sufficient have been collected to make up one digit of the next higher denomination, when a transfer of 'one' is effected.

By means of this arrangement the number of Ticket Machines which can be dealt with is not limited by the size of the bank of the Collecting Switch, and the largest racecourses may be successfully equipped with totalisator apparatus.



R 1747

Schematic Trunking Diagram.



B1744 Rack of Equipment.

Collecting Relay Groups are not shown on the Schematic Trunking Diagram but they are inserted between the Plugging Down Rack and the Adding Machines.

The Plugging Down Arrangements.

The Race Card issued for any race includes all Horses entered for that race, each horse being numbered. The actual number of runners, however, rarely exceeds half the number of entries and, therefore, in the majority of cases, adding equipment is only required for half the number of horses entered on the race card. On a Race Card of 40 horses the actual runners may bear any number up to 40 and the ticket machines must, therefore, be capable of issuing bets on any one of 40 horses. The Decoding Relay Groups and Collecting Switches must also be capable of dealing with any one of 40 horses, but economy in adding equipment may be effected by the following arrangement.

The wipers of the Collecting Switches which constitute the actual bet leads to the Adding Machines may be terminated on jacks, while the Adding Machine bet leads may be connected to plugs so that any Adding Machine may be plugged into the bet leads of any Collecting Switch. The arrangement embodying this feature is known as the Plugging Down Rack an explanatory sketch of which is attached.

The Adding Machines can then be provided on the basis of the probably number of runners and not upon the number of entries on the Race Card, the Adding Machines being plugged into those Collecting Switches which represent actual runners only.

In practice where 40 horses are shown on the Race Card, adding equipment for 26 horses is provided, while adding equipment for 45 horses is provided where 80 horses are shown on the Race Card.

A Private Automatic Branch Exchange Equipped With L. M. Ericsson 500-line Selectors.

"Ericsson" Oesterreichische Elektrizitäts-A.-G., Vienna.

At the commencement of 1930 a new private automatic branch exchange was delivered to the Oesterr. Credit-Anstalt für Handel & Gewerbe in Vienna.

In this exchange the internal and the outgoing traffic is dealt with by a full automatic exchange equipped with Ericsson 500-line selectors, the incoming traffic being handled over a manuel exchange.

The manuel exchange and parts of the automatic equipment as well as the erection of the whole plant were made by the Vienna factory of the Ericsson concern. All other parts of the automatic equipment were made at the Stockholm factory of the Ericsson concern.

The following is a description of the construction and performance of the exchange.

The automatic exchange is calculated for an ultimate capacity of 1500 lines of which 1070 are already installed. These 1070 lines are divided as follows into:

1) 400 charged local subscriber lines, of which
   a) 60 are preference lines and
   b) 340 are ordinary lines.
2) 300 free of charge local subscriber lines, of which
   a) 6 are local junction lines from the manual exchange.
   b) 294 are subscriber lines of which 20 lines are to receivers installed outside the bank premises.
3) 340 local double call lines (Rück-frage).
4) 20 outgoing lines to the city exchange.
5) 10 outgoing local junction lines to the local manual exchange.

The above mentioned 400 charged lines can communicate with the city exchange over any of the 20 outgoing lines. The 294 free lines and the 6 incoming junction lines cannot communicate with the city exchange.

The manual part of the plant consists of a multiple board with 5 operator positions, at present equipped with the following lines.

1) 400 charged local subscriber lines, of which
   a) 60 are preference lines and
   b) 340 are ordinary lines.
2) 26 free local lines of which
   a) 6 are outgoing junction lines to the local automatic exchange.
   b) 20 are outgoing subscriber lines to receivers installed outside the bank premises.
3) 400 local double call lines.
4) 30 outgoing lines to the city exchange.
5) 10 incoming local junction lines from the automatic exchange.
6) 20 incoming lines from the city exchange.
7) 2 inter-urban lines.

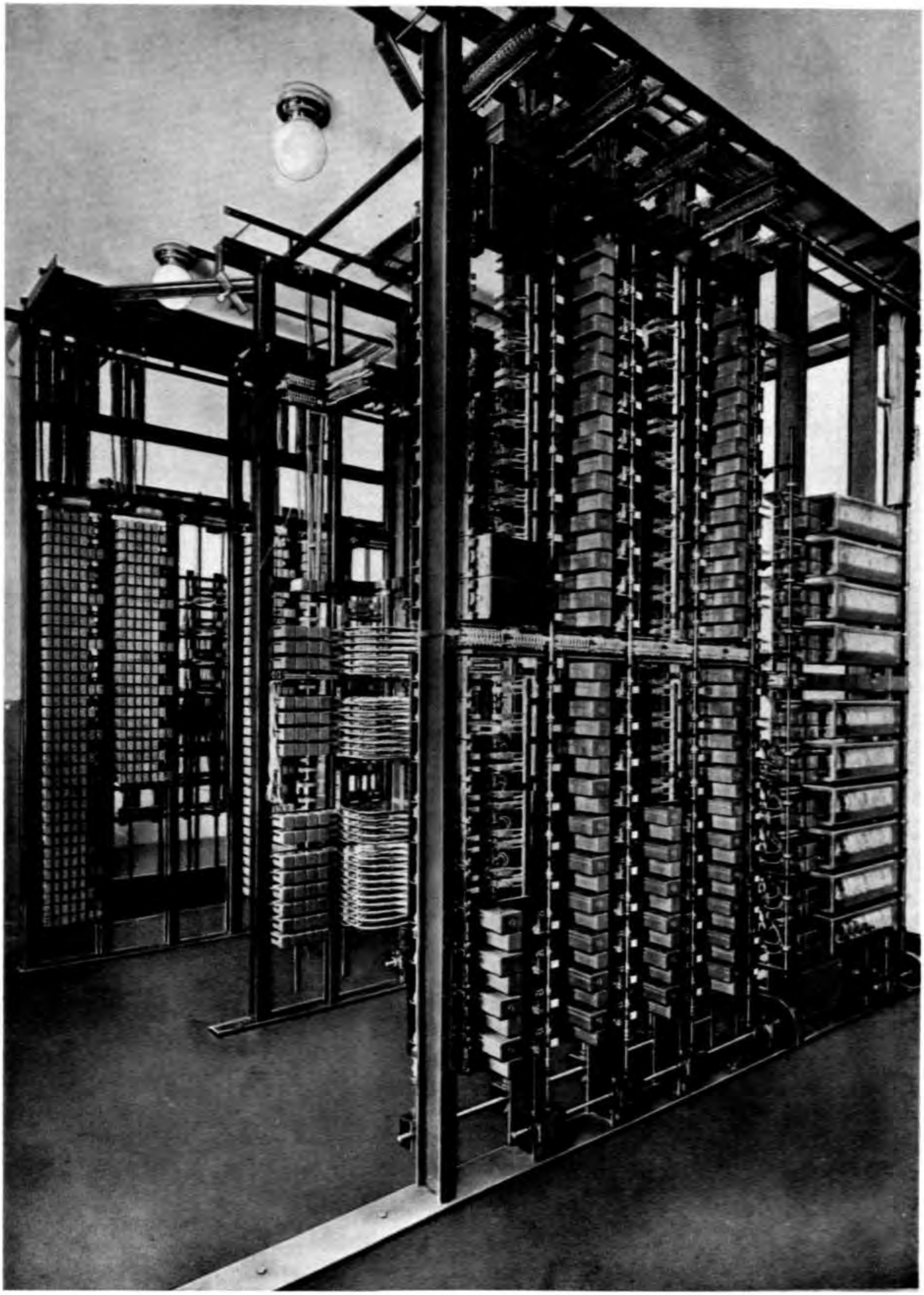
Together 888 lines.

Fig. 3 shows in a schematic form the distribution of the above mentioned lines on the automatic and manual exchanges.

Fig. 3 shows that the preference lines have 3 lines to the local exchange (one to the automatic exchange and two to the manual exchange). These 3 lines are connected so that the 3rd line can be used as an information or double call line when the 1st or 2nd are engaged in the automatic or manual exchanges.

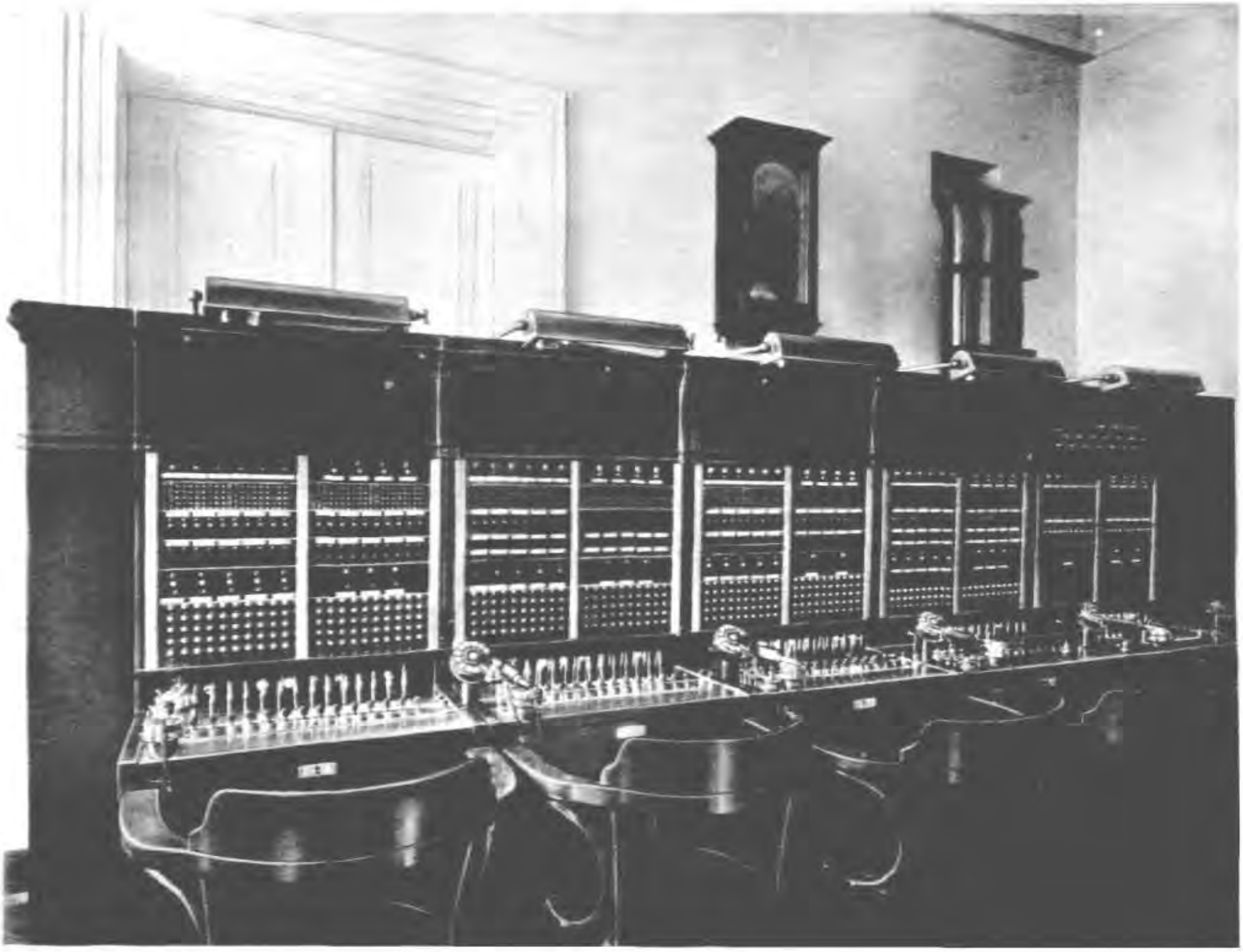
The 340 ordinary local telephones have 2 lines, both of which are connected to the automatic exchange over a series jack in the multiple board. One of these lines (the double call line) has a calling lamp, connected over a key and mounted on a separate key panel. This key is only pressed when the line connected to the automatic exchange is faulty.

The 6 junctions from the multiple board terminating in the rack for free subscriber lines in



R 1752

Fig. 1. The Automatic Exchange.



B 1753

Fig. 2. The Manual Multiple Board.

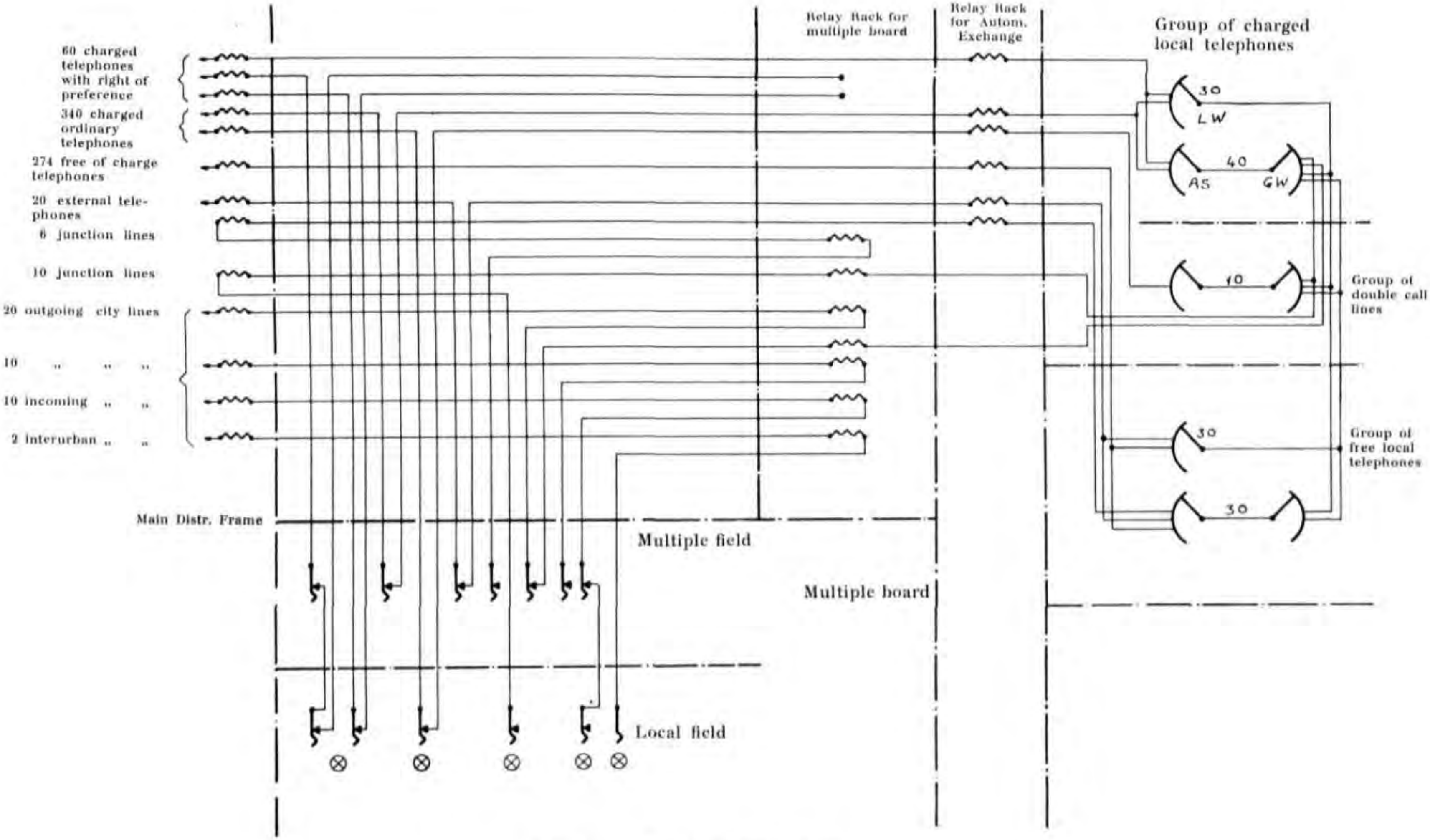
the automatic exchange are used for manual connection between telephones with right of preference and those that are free of charge.

The 10 incoming junctions to the multiple board are used for calls from the local subscribers to the operator and for manual connections to subscribers outside the bank premises. These lines as well as the 20 outgoing lines to the city exchange have group numbers.

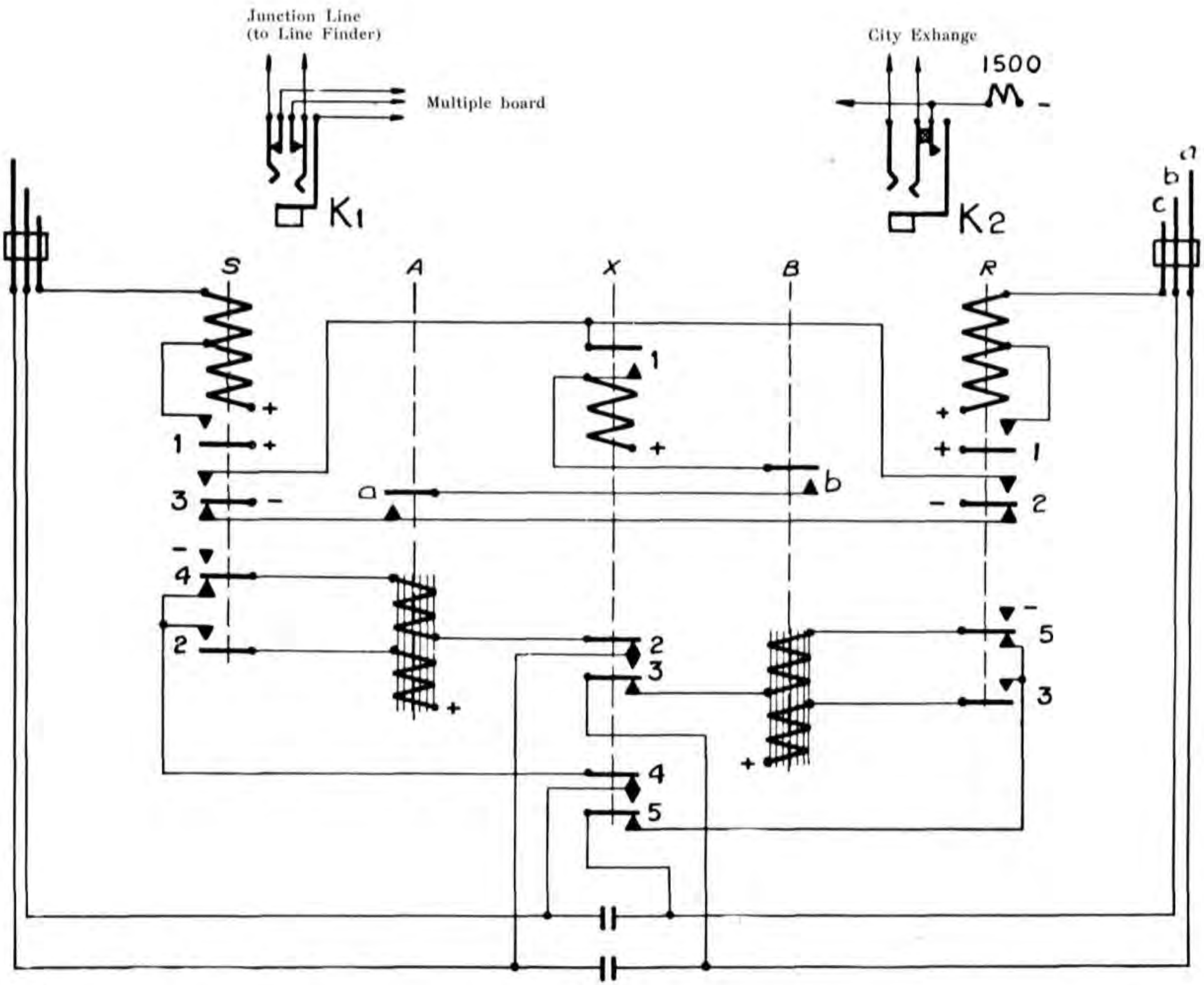
Figs. 4 and 4a show how calls from free lines are blocked from outgoing lines to the city exchange. Should the operator try to effect such a call over one of the 6 outgoing junctions from the multiple board, the following circuits operate.

When a plug is inserted into the jack *K*2 of an outgoing line to the city exchange, relay *R* will not pull up over the 1500 ohm resistance connected to the *c*-wire. After the insertion of the plug the operator presses the earthing key thus energizing relay *B* over the city exchange. Contact *b* on relay *B* is then closed. When the operator thereupon inserts the other plug into the jack of the junction line, relay *S* on the *c*-wire of the plug pulls up over the cut-off relay on the *c*-wire of the line finder. Then contact S_4 is changed over, relay *A* is connected to the negative pole, contact S_2 closes and S_3 changes over. The feeding coil RS_2 in the line finder pulls up over *A* and the corresponding choke so that relay *A* also pulls up and closes its contact *a*.

Relay *X* then pulls up over contacts R_2a and *b* and retains over X_1. When relay *X* has pulled up relays *A* and *B* are cut off from the *a* and *b* wires of the cord and the condensers short-circuited, so that the city line is connected to the

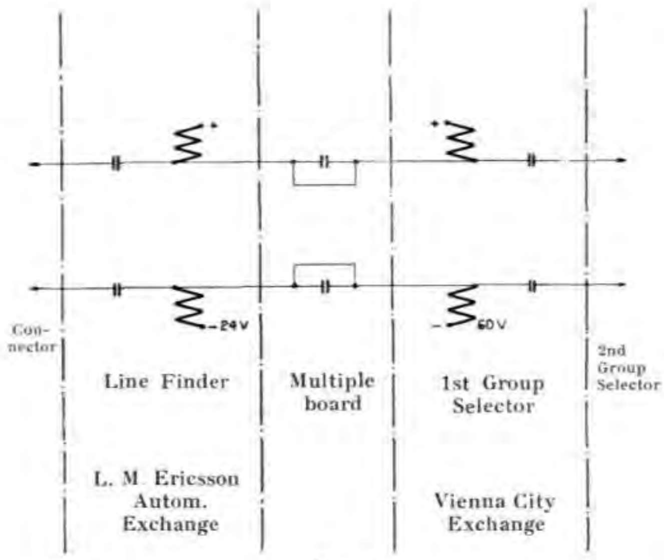


R 1872 Fig. 3. Skeleton Diagram.


Junction Line
(to Line Finder)
Multiple board
K1
City Exhange
1500
K2
S
A
X
B
R
a
b
c

R 1869

Fig. 4.



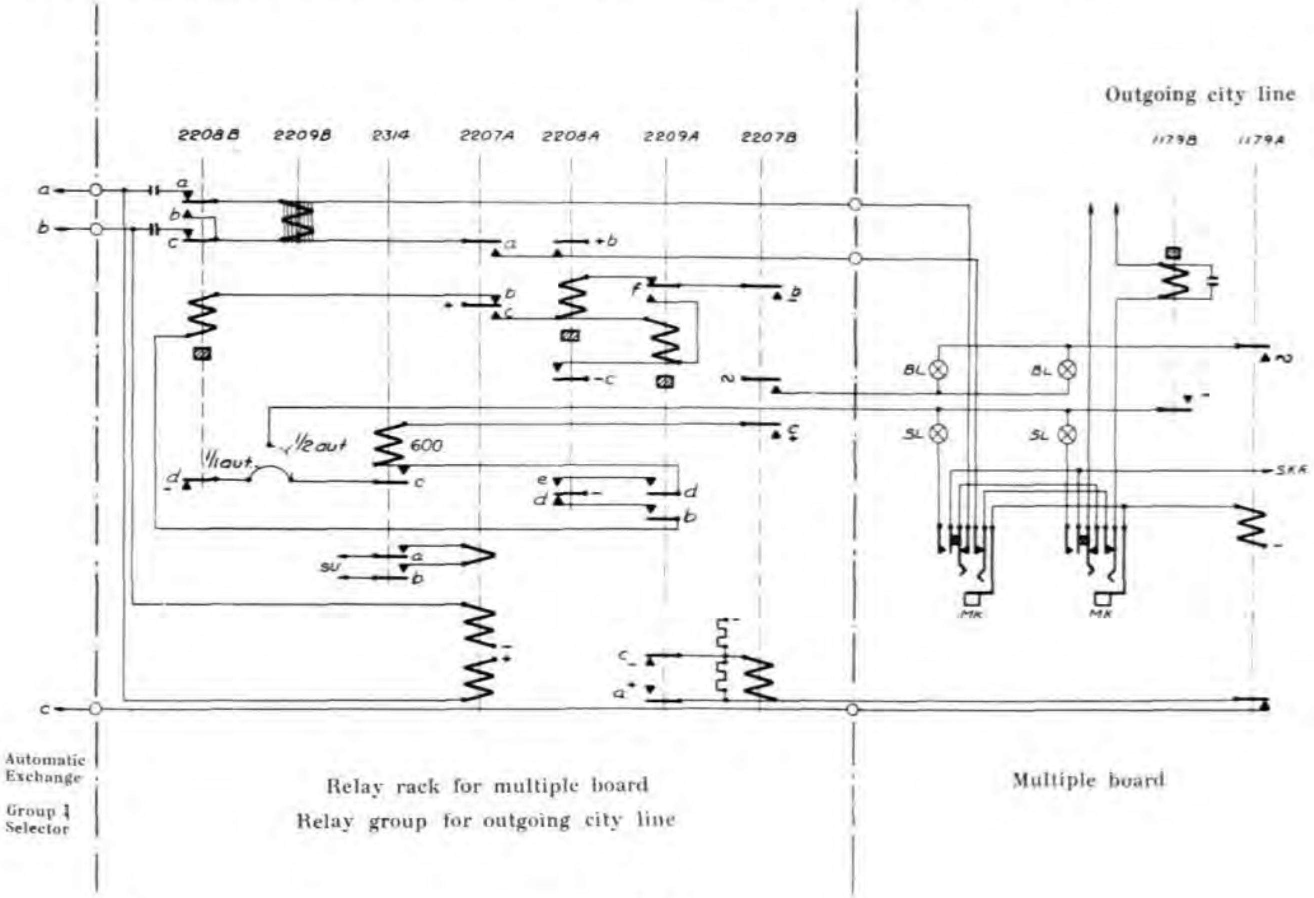
R 1873 Fig. 4 a.

line finder. This causes relay *A* and also the feeding coils of the line finder to be deenergized. The latter find no circuit over the cord to the condenser in the 1st group selector of the city exchange and thus a connection cannot be made.

Fig. 5 shows the connection of the outgoing line to the city exchange.

The outgoing city line is dialled by a single number. When the contact arm of the group selector has found an idle exchange number the test relay of the group selector pulls up in series with relay 2207 *B*. The group selector's test relay pulls up relay RG_4, thus connecting the subscriber line to the feeding coil 2207 *A*. At the same time as relay 2207 *A* pulls up relay 2208 *A* energizes connecting *earth* to the *b*-wire over its contact *b*. Contact *c* closes a circuit for relay 2209 *A* which pulls up and retains over its contact *f*, contact *b* on 2207 *B* and contact *c* on 2207 *A*. The circuit through 2208 *A* is then broken, so that this relay cannot pull up during the call.

At the same time as the *earth* impulse is connected to the city line, i. e. when relay 2208 *A* pulls up causing relay 2209 *A* also to pull up, relay 2314 energizes over the following circuit: *earth* at *c* on 2207 *B*, 600 ohms on 2314, *d* on 2209 *A*, *e* on 2208 *A* to *negative*.



R 1874 Fig. 5

Relay 2314 holds over its contact *c* and contact *d* on 2208 *B* until the first impulse is given and connects a tone *SU*, to the coil on relay 2207 *A* notifying that the subscriber may commence to dial a number in the city exchange.

When contact *b* on relay 2207 *A* closes during the break period of the first impulse, relay 2208 *B* energizes over the following circuit: (after relay 2208 *A* in the meanwhile releases, relay 2209 *A* on the other hand being sluggish remains actuated during the whole train of impulses): *earth* at *b* on 2207 *A*, relay 2208 *B*, *b* on 2209 *A*, *d* on 2208 *A* to *negative*, and remains actuated during the whole train of impulses. The holding circuit at *d* on 2208 *B* is broken so that relay 2314 releases thus disconnecting the tone signal from the feeding and impulse relay 2207 *A*. Relay 2314 can no longer pull up as its circuit is broken at *e* on 2208 *A*.

When the subscriber at the end of a call replaces the receiver, the feeding coil 2207 *A* releases and opens the circuit for relay 2209 *A* at its contact *c*. Relay 2207 *B* must also release, as its holding circuit is broken at contact *a* on relay 2209 *A*. The test relay of the group selector in series with 2207 *B* must also release, so that the connection is broken successively backwards to the subscriber.

Should the line be engaged on the manual exchange, relay 1179 *A* is actuated and its break contact open. The circuit through the test relay on the *c*-wire of the group selector is broken so that the contact arm of the selector cannot remain on the engaged line.

Fig. 6 shows the average load per hour during one day.

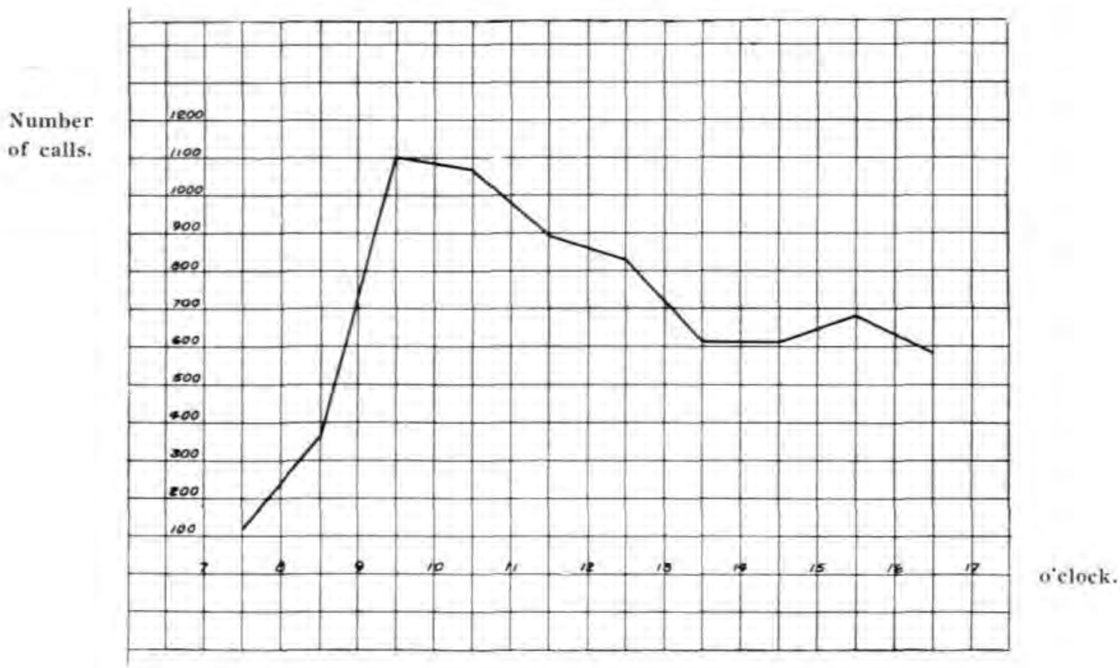
The curve is drawn to the average value of 6 different accurate readings taken about $2^1/_2$ months after the opening of the exchange.

For this load the following switches were available: for the charged lines 32 line finders and 26 connectors, for the free lines 22 line finders and 24 connectors, for the double call lines 6 line finders and altogether 15 registers. The total number of lines connected to the exchange was 996. At the present time the curve is somewhat higher, but its character is about the same.

At the present equipment of in all 1070 lines the average number of calls per day with 80 line finders, 60 connectors and 20 registers is 8922. This average value is obtained from readings during 140 days.

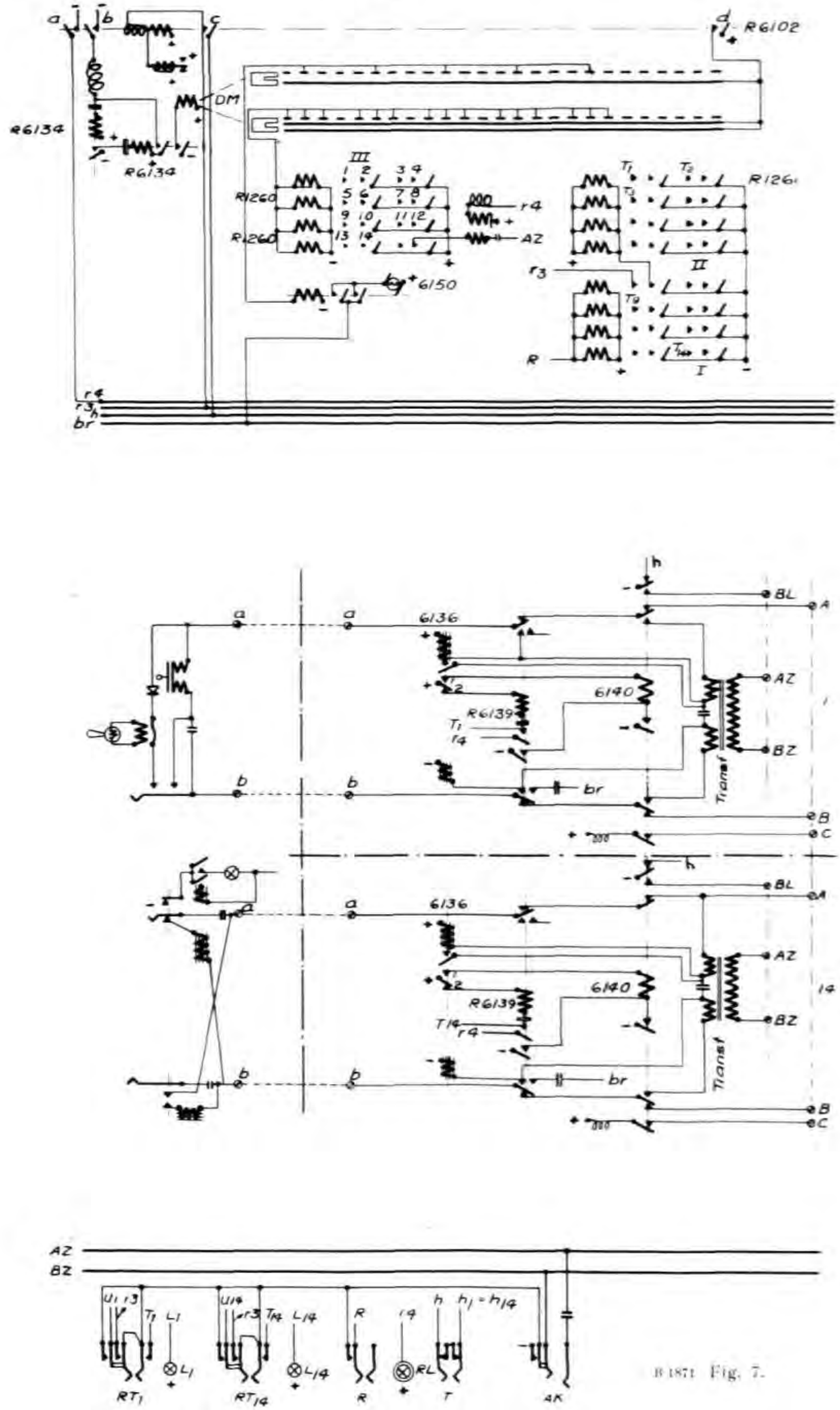
The average duration of local calls was 75 seconds, obtained from 122 readings. For city

Number of calls per hour during one day.



R 1870

Fig. 6.



a
b
c
d
R6102
R6134
R6134
DM
III
R1260
R1260
r4
AZ
6150
T1
T2
R126
II
r3
T9
T140
R
I
r4
r3
h
br
a
a
6136
b
b
6140
R6139
T1
r4
br
BL
A
AZ
BZ
Transf
B
C
h
a
6136
6140
R6139
T14
r4
b
b
br
BL
A
AZ
BZ
14
Transf
B
C
AZ
BZ
U1 r3
T1
L1
U14
r3
T14
L14
R
r4
h
h1 - h14
L1
L14
RL
RT1
RT14
R
T
AK

B 1871 Fig. 7.

exchange calls the average duration was 117 seconds, obtained from 81 readings.

With duration of a call is meant the time counted from the start of the line finder until its contact arm has again returned to rest.

In this exchange it has proved to be of great value that line finders and connectors may be alternated at will according to the requirements of the traffic, either allowing a reduction or making an increase necessary of the number of switches. It was for instance necessary to increase the 6 cord circuits in the double call group as these were unsufficient. Four selectors were therefore taken from the free group and added to the double call group. No difficulties were encountered after this alteration.

A special arrangement in this exchange worth closer description is the Information Despatching Arrangement. It is used for despatching information, such as exchange notifications, from one central telephone to 14 others.

The arrangement is operated from the 5th position of the multiple board. Each of the 14 telephones has a calling key (RT_1—RT_{14}) with corresponding lamp (L_1—L_{14}). Fig. 7. In addition the arrangement is equipped with a common calling key *R* with control lamp *RL*, a cut-off key *T*, a common speaking jack *AK*, corresponding line relays, transformers, a common relay group and selectors.

When information is to be sent to all 14 members the operator in the 5th position plugs up the telephone from which information is to be sent with a pair of cords into the jack *AK* and presses the calling key *R*. The relay groups I and II in relay 1260 will hereby actuate. Relay 6102 also energizes from *negative* at I on *R* 1260 over wire r_3. When contact *b* closes, relay group *R* 6134 energizes and governs the selectors driving magnet by opening and closing its contacts. Relay 6150 energizes over contact *d* on *R* 6102 and the upper contact bank and ringing current is connected to the despatching arrangement. The relay group III of 1260 actuates over the lower contact bank.

At the closing of relay groups I and II of 1260 current is connected over contacts T_1—T_{14} to the individual relays *R* 6139 of all telephones not engaged on the automatic exchange. These relays pull up if the line is idle and connect ringing current to the line over: *earth*, ringing machine, contacts on 6150, wire *br*, condenser, make contacts on 6139, *b*-wire, condenser and bell in the telephone, *a*-wire, make contacts on relay 6139 to contact *1* on relay group III on 1260 and back to *earth*. Relay 6139 retains over its own contact, wire r_4 back to contact *a* and *negative* on relay 6102. When the microtelephone is removed relay 6136 pulls up and connects *earth* to relay 6140 over its contact *1*, so that this relay also pulls up over a contact on relay 6139 and retains over its own contact, disconnecting the telephone from the automatic line and connecting it to the secondary coils of the transformer.

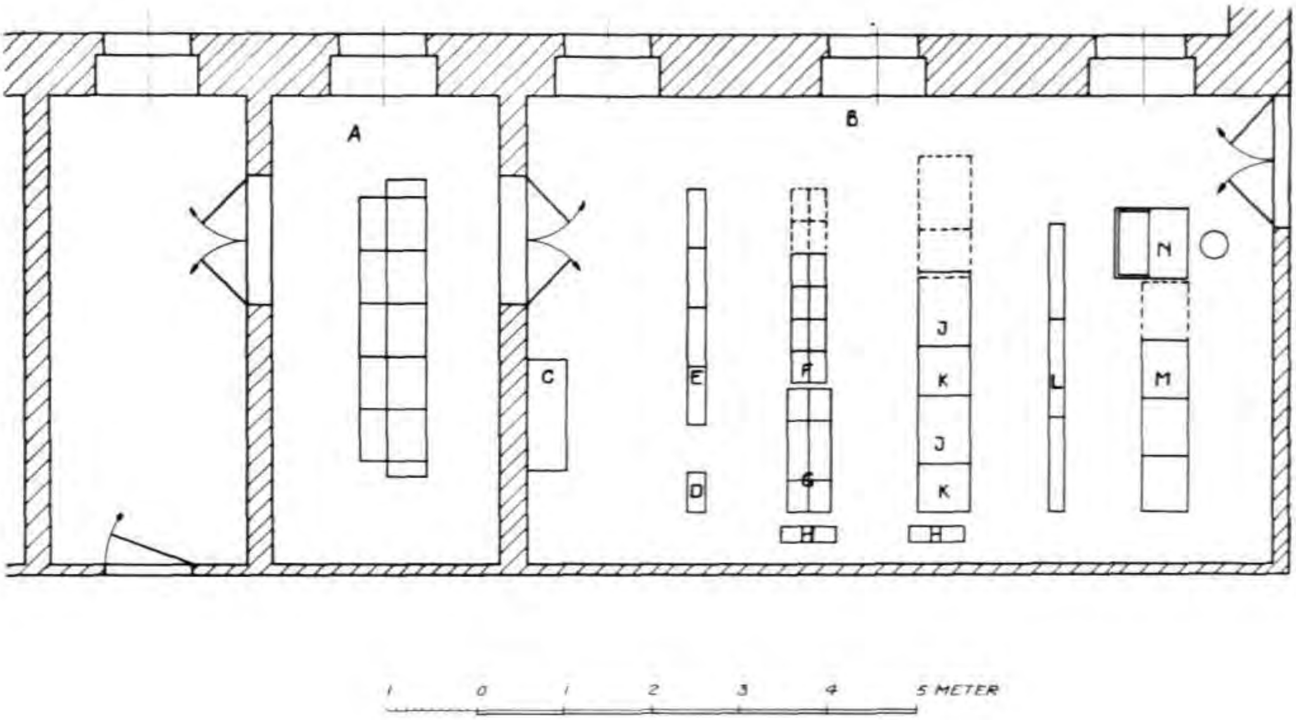
When relay 6140 pulls up, the busy lamp L_1 beside the calling key RT_1 lights showing the operator that this telephone is ready to receive information.

Each time a micro-telephone is lifted one of the wires h_1—h_{14} is disconnected from *negative*. When all 14 micro-telephones are removed, all *h*-wires and thereby also relay *R* 6102 are disconnected from *negative*, and therefore also the holding circuit of this relay broken. Relay *R* 6102 falls and stops the driving magnets of the selector. As long as all numbers have not removed their micro-telephones those that have done so will hear a tone in their receivers. The operator can supervise the connecting up of the numbers, as for all connected lines the corresponding lamps L_1—L_{14} glow together with lamp *RL* which glows until all lines are connected up to the despatching arrangement. After a certain predetermined time the driving mechanism of the selector is disconnected by means of the thermal relay in connection with relay 6102, so that the selector indirectly stops.

If only some of the 14 lines are to receive information then the operator presses the corresponding calling keys RT_1—RT_{14} and notifies the members.

When the information is concluded all members replace their telephones, so that the feeding coil 6136 falls and cuts off relay 6140 over contact *1*. This relay falls and reconnects the member to the automatic line.

This arrangement belonged to the previous manual exchange of the Credit-Anstalt and worked then as well as now in the automatic exchange quite satisfactorily. The following fig. 8 shows a lay-out plan of the manual and automatic exchanges.



B 1875

Fig. 8.

LAY OUT PLAN.

A = Manual Exchange.
B = Automatic „
C = Power Board.
D = Interm. Distr. Frame.
E = Relays for Man. Exchange.
F = Sequence Switches.
G = Registers.
H = Rack Motors.
J = Group Selectors.
K = Line Finders and Connectors.
L = Line Relays.
M = Main Distr. Frame.
N = Control Desk.

B 572 D

The Swedish Voice Frequency Signalling System.

By *Torbern Laurent*, Engineer with the Svenska Radioaktiebolaget, Stockholm.

1. Introduction.

Until amplifying methods were introduced in telephony, 16- and 25-cycle signal currents were exclusively used for signals on long distance telephone lines. The signal current sent out must be considerably (c. 10000 times) larger than the speaking currents in order that they might be able to actuate the signal receiving units employed. The reason why any occurring false signals on an occupied line do not disturb the auditory organs of the subscribers at either end, or that calls disturbed by cross-talk are comparatively rare in spite of the large signal current, is the insensibility of the human ear to frequencies as low as 16 or 25 cycles per second. The use of strong signal currents therefore met with no difficulties until telephone amplifiers began to be used. A telephone repeater strengthening the telephone currents by means of amplifying valves can only give a maximum power which is very slightly larger than that of the maximum speaking current required, and can therefore not be used for amplifying ordinary signal currents. It is consequently necessary to introduce a special signal repeater, working with electromagnetic relays, which will necessarily make for some mechanical slowness of action in signal transmission. When several telephone repeaters became necessary on one and the same line, each telephone repeater was bound to have a signal repeater, which made the resultant slowness of the signal transmission—increasing in proportion to the number of signal repeaters—troublesome to the traffic. The obvious solution was then to try to use signal currents which could be amplified by the ordinary telephone repeaters. According to the above, such signal current must then be of the same magnitude as the speaking currents. Further, the signal current frequency must be within the normal audio-frequency range to avoid the increased cost of the telephone repeaters which would be a consequence of an increase of their range of frequencies, which is suited to the amplification of speaking currents. But the use of such so-called tone signal currents brought in its train some new problems, particularly regarding the signal receiver. This must obviously be considerably more sensitive than its predecessors, but by the use of amplifying valves this problem could be immediately solved.

On the other hand, it was considerably more difficult to prevent false signals occurring through the influence of the speaking current on the signal receiver, which is connected to both wires of the telephone line in question and therefore will be exposed not only to signal currents but also to speaking currents, as the abovementioned change of the signal currents will cause these to approach the nature of the speaking currents, and the capacity of the signal receivers to distinguish between speaking- and signal currents cannot be obtained without special steps being taken, which have proved extremely hard to carry into effect. In the Swedish system of tone signalling, however, which is founded on an entirely new principle, the difficulties have been completely overcome.

Tone signals will probably prove the only form of signalling possible on international lines, and the "Comité Consultatif International des Communications Téléphoniques à grande distance", the "C. C. I." for short, has therefore discussed this problem and have established certain standards for tone signals on international telephone lines.

In the following, the C. C. I. standards will be indicated, the difficulties of the tone signal problem explained, and the Swedish system of tone signalling described.

The Swedish voice frequency signalling system, which has been in use for several years and been found very satisfactory in practice, is protected by patents in most countries. The Ericsson Concern has the sole manufacturing rights in all countries with the exception of Sweden, where the Swedish Board of Telegraphs is entitled to manufacture what is required for its own plant.

2. C. C. I. Standards.

According to the "Green Book" 1928, the C. C. I. makes the following recommendations regarding tone signalling:

"1:o. Que, pour les circuits assurant des relations internationales et à titre provisoire, il soit fait choix d'un courant de signalisation sinusoidal à la fréquence de 500 p. p. s. ± 2% interrompu suivant une fréquence comprise entre 20 et 25 p. p. s. et à une puissance effective du courant non interrompu fixée provisoirement entre 3 et 6 milliwatts pour un niveau de transmission égal à zéro.

2:o. Qu'il est désirable d'adopter, quand cela est possible, la fréquence d'interruption de 20 p. p. s."

Cross talk between two lines, as well as the sensitivity of the ear to disturbances, diminishing with the frequency of the disturbing currents, the C. C. I. has chosen as low a signalling frequency as possible, to avoid as far as may be any disturbance of the calls, 500 cycles being the lowest frequency advisable while retaining normal amplification in the telephone repeaters. Sinusoidal current is also recommended on account of the disturbing effect, as the second and third harmonic of the signal current, 1000 and 1500 cycles respectively, lie within that frequency range to which the human ear is most sensitive.

The original idea of using a 20—25 cycle interruption of the audio-frequency was to obtain increased selectivity of the signal receiver. When the signal currents have arrived in the receiver, they have to go through a filter which passes a band of frequencies round the 500 cycles, and the signal currents are then demodulated so that currents of 20—25 cycles are obtained. These currents must then energize a resonance relay or the like tuned to 20—25 cycles. In this way two conditions must be fulfilled to enable the currents arriving in the signal receiver to give a signal, viz. both that the frequencies of the current is about 500 cycles, and that these are modulated with frequencies round 20—25 cycles. In the following, however, we shall find that the speaking currents have no difficulty in simultaneously fulfilling these two conditions also, and complete protection against false signals is therefore unobtainable by these means alone.

3. Experimental comparison between signal receivers for receiving modulated and unmodulated signal currents of audio-frequency.

The experimental work of designing a suitable tone signal receiver, showed great difficulties in the attempt to make this absolutely unaffected by speaking currents and proved that no advantage was obtained by the modulation.

Two tone signal receivers were built, one for reception of unmodulated signal currents, and the other for reception of 500 cycle signal currents modulated by 20—25 cycles.

In the first receiver, which we will designate "Signal receiver 0", the signal currents were first admitted through a band filter passing frequencies between 490 and 510 cycles, and were then rectified to energize a D. C. relay. In the second receiver, designated "Signal receiver 20", the signal currents were first admitted through a band filter which passed frequencies between 465—535 cycles, and then demodulated so as to actuate by means of the 20—25 cycle current a resonance relay tuned to 20—25 cycles. Both receivers were adjusted so that the same respectively unmodulated and modulated voltages at the input terminals of the signal receivers gave current actuating the relays. In other respects the receivers were made as nearly equivalent as possible with regard to safety margins etc. Each signal receiver relay was connected to a call meter, which thus recorded every time the relay was energized, and the input sides of the two receivers were connected in parallel to a telephone instrument, which thus exposed both the signal receivers to the same speaking voltages.

Speech in the microphone consisting in loudly pronounced single words, reading some text, etc., gave as a result that the receiver 20 relay was energized 394 times and the receiver 0 relay 85 times. The proportion between the relay energizings in receivers 20 and 0 was thus

4.63.

The following observations were also made:

1) The relay of signal receiver 20 was always attracted for a short time only. A protracted attraction during say a drawn out vowel sound could only be obtained in signal receiver 0.
2) Certain monosyllables with long vowel sound caused the relay of receiver 20 to be energized twice and certain polysyllables still more times.
3) The signal receivers were only sensitive to such words as contain the vowel sounds of *e* in *end*, and *a* in *ball*.

In consequence of observation 2), experiments were undertaken which demonstrated that the relay of signal receiver 20 will always be energized when an unmodulated voltage applied to the receiver, of a frequency within the frequency band of the filter and an amplitude which is greater than that of the minimum current required to energize the relay, is turned on or off.

4. Theory of the occurrence of false signals.

If a vowel sound is divided into its components, a fundamental tone and a number of harmonics are obtained (cf. a paper by K. W. Wagner "Der Frequenzbereich von Sprache und Musik" in E. T. Z. 1924). The sound volume is confined to one or two near harmonics, the so called characteristic frequencies, which by their position in the scale of frequencies characterize the vowel sound in question. The frequency of the fundamental tone varies considerably with the timbre of the voice, but the characteristic frequencies are only moved sufficiently in the scale of frequencies to keep their place as harmonics of the fundamental tone.

The following table gives the characteristic frequencies of the different vowel sounds:

Vowel sound.	*Chief characteristic frequ.*
a, pronounced as in *sofa*	1050 cycles
a, „ „ „ *arm*	910 „
a, „ „ „ *ball*	732 „
o, „ „ „ *fore*	461 „
long o, „ „ „ *fool*	325 „
a, „ „ „ *ate*	950 and 1240 „
a, „ „ „ *care*	800 and 1840 „
e, „ „ „ *end*	691 and 1935 „
long e, but „ „ „ *den*	488 and 2461 „
e, „ „ „ *eve*	308 and 3100 „

We note that the later vowel sounds have two characteristic frequencies, but the higher one has only a fraction of the oscillating energy of the lower characteristic frequency.

The consonant sounds are richer in harmonics than the vowel sounds, and their oscillating energy is not concentrated in the same way as in the vowels. But the consonants also have characteristic frequencies. The main portion of their oscillating energy, however, lies beyond 1000 cycles.

If we regard the table of characteristic vowel frequencies, we find that a vowel sound between b*a*ll and f*o*re has a characteristic frequency round about 500 cycles, as has also the sound of a long e pronounced as in d*e*n. This is consequently the explanation why signal receivers are particularly sensitive to these sounds. When these vowels are abruptly pronounced, as they are pronounced in words, the characteristic frequency will be modulated in a way which generally consists in a series of different modulating frequencies, one of which is the 20—25 cycle modulating frequency, and with that the speaking currents have imitated the 500-cycle signal current modulated by 20—25 cycles.

Let us now make a mental experiment.

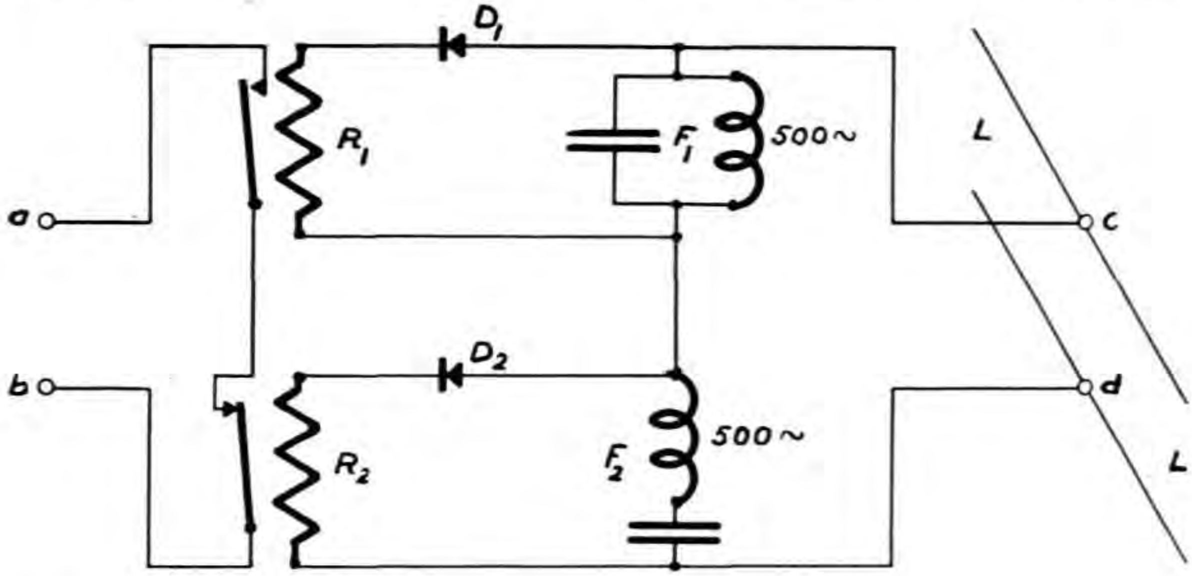
Suppose the relay of Signal Receiver 20 to be energized (cf. previous chapter) by every audio-frequency arriving in the 70-cycles wide frequency band, in such a manner that audio-frequencies of very short duration will energize the relay once and other frequencies twice (once at the beginning of the audio-frequency and once at the end), while in Receiver 0 the relay will only be energized once by each audio-frequency arriving in the 20-cycles wide frequency band. The proportion between the number of times the relays have been energized in Signal Receiver 20 and in Receiver 0 would then in all probability be something between $1 \cdot \frac{70}{20}$ and $2 \cdot \frac{70}{20}$, i. e., between 3.5 and 7, which agrees with the experimental result 4.63.

5. The Principle of the Swedish System of Receiving Tone Signals.

As appears from the above, a tone signal current consisting of a 500-cycle current interrupted by 20—25 cycles cannot be properly distinguished from speaking currents. The question will then be, does any sound exist, the character of which can be distinguished from all sounds of speech? Certainly, there is at least one sound—the pure tone, free of harmonics. A spech sound must always contain several frequencies, otherwise flute-like sounds would be produced in speech. Consequently, if a signal current consisting in only a single pure frequency were used, and a signal receiver designed which will only be actuated by this particular frequency when it is unmixed with other frequencies, the problem should be solved.

but the resonance shunt F_2 will then act as a large resistance. The currents will therefore pass the rectifier D_2, which rectifies them so that the relay R_2 is energized. This leaves the local signal circuit a—b broken even if relay R_1 be energized, and signals are prevented.

Such is the very simple principle on which the Swedish system of tone signalling works. The blocking of the signals caused by any other than 500-cycle frequencies is exclusively electric in the actual design of the receiver described below.



R 1860 Fig. 1. The principle of the Swedish system of Tone signalling.

Fig. 1 gives a diagram indicating how such a signal receiver can be made. At points c and d the receiver is connected to a telephone line L, and this receiver is composed of a resonance shunt F_1 containing a parallel resonance circuit tuned to 500 cycles, a resonance shunt F_2 containing a series resonance circuit tuned to 500 cycles, two rectifiers D_1 and D_2, and two relays R_1 and R_2. A current coming from the line, of 500-cycle frequency alone, will be short circuited by the resonance shunt F_2, and so denied access to relay R_2. The resonance shunt F_1, on the other hand, acts as a large resistance to this frequency, and the current will therefore pass the rectifier D_1, which rectifies the current so that relay R_1 will be energized. The local signal circuit a—b is closed, causing a signal to be given.

If, simultaneously, currents of other than 500-cycle frequencies also arrive in the receiver, these are short circuited by the resonance shunt F_1,

A modulated audio-frequency differs from a pure unmodulated frequency in that it contains a narrow band of adjacent frequencies instead of one frequency alone, but the same principle for reception of tone signals can be applied to a modulated audio-frequency if the resonance shunt F_2 will short circuit and the resonance shunt F_1 will pass any and every frequency within that particular frequency band. It is consequently not difficult to make a signal receiver on this principle, designed to receive a 500-cycle signal current interrupted 20—25 times per second, but the interruptions will obviously only be a superfluous addition, with the additional drawback that the selectivity of the receiver will be reduced, as the increased width of the band of signal frequencies has the effect of exposing the signal receiver to a larger number of voice frequencies.

In this connexion we will further elucidate the working of the resonance shunts F_1 and F_2.

When a pure signal frequency wave front enters the receiver, the resonance shunt F_1 will, in the first instant, act as a short circuit and the resonance shunt F_2 as a large resistance. A blocking effect is consequently obtained during the first moment, even though the wave sequence is of pure signalling frequency. An increasing transient oscillation of both F_1 and F_2 then begins, which results in a change-over of the parts played, as this transient oscillation will cause the resonance shunt F_2 to act as a short circuit. The emission of signals will therefore obviously be delayed on account of the time required for the transient oscillation to increase. Blocking caused by frequencies outside the signal frequency range, however, will not cause such delay. The blocking of the signal receiver will consequently always be quicker than the emission of

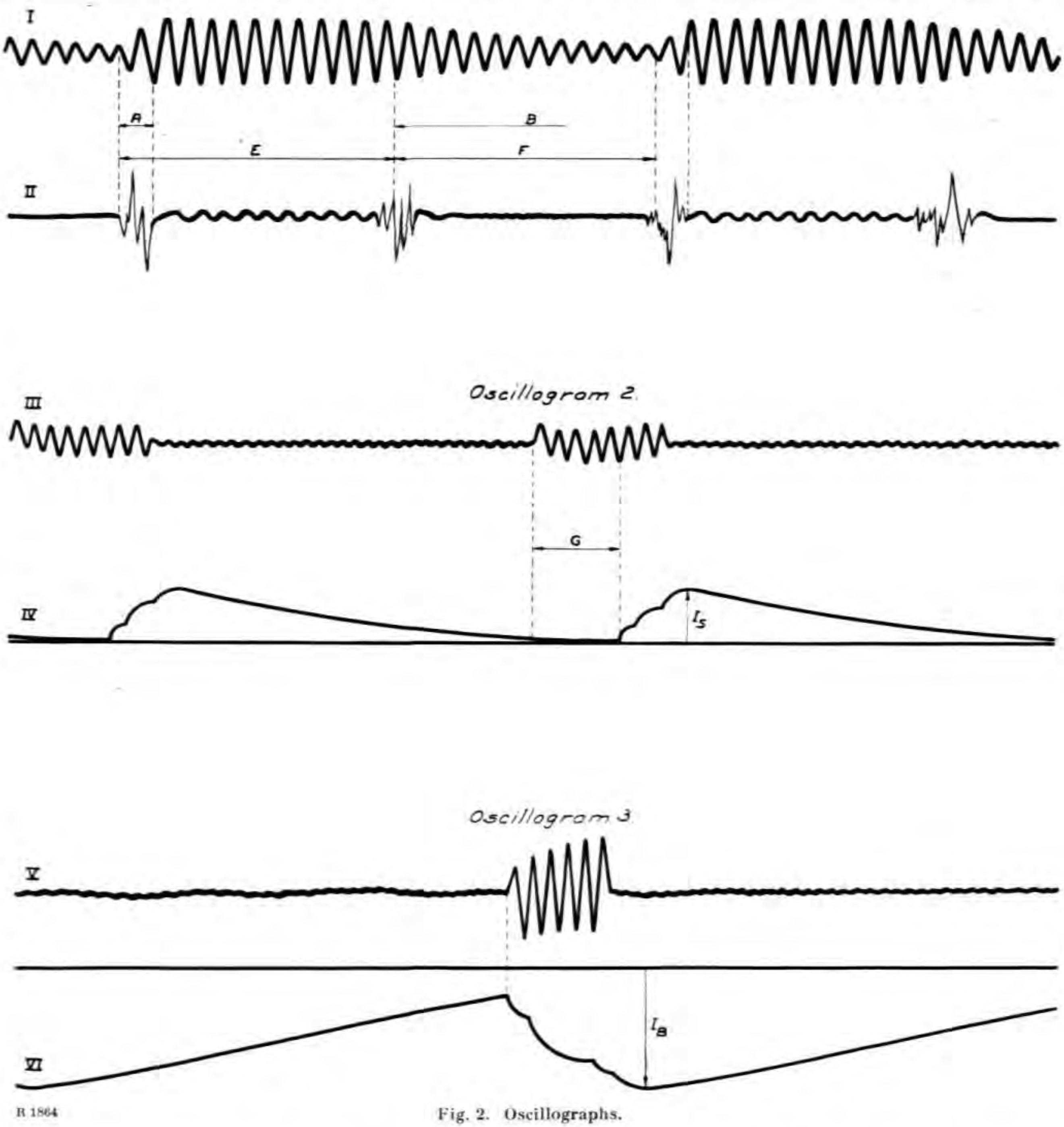


Fig. 2. Oscillographs.

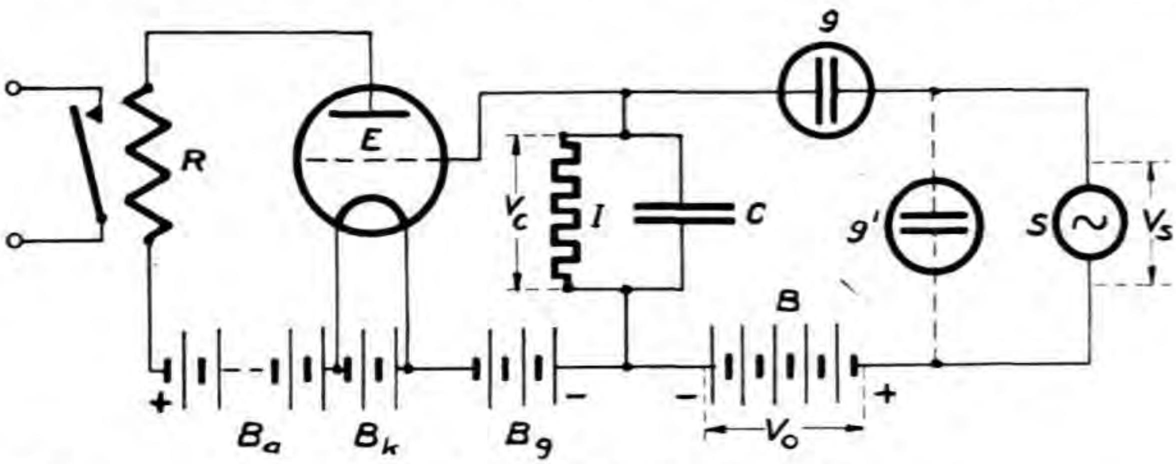
signals, and therefore no risk of false signals caused by delayed blocking effect exists. Further, the relay R_2 should be fairly slow in releasing, so that voice currents representing a connected sequence of words cause a persistent energizing of relay R_2, which provides further security against false signals. The progress of the transient oscillations is illustrated by the oscillographs 1, 2, and 3 of Fig. 2, obtained during the experiments. Curve I in oscillograph No. 1 represents the voltage over the parallel resonance circuit, and II the voltage over the series resonance circuit, when these are simultaneously affected by an interrupted 500-cycle current. The wave sequences arriving are of a duration E, and the time interval between them is F (the time increases from left to right). During the time A the transient oscillation of the tuned circuit is increasing, and during the time B it is decreasing. We note that voltage arises over the series resonance circuit during both periods of transient oscillations, and the voltage over the parallel resonance circuit is continuously respectively increasing or diminishing during these periods. This obviously will cause the blocking effect mentioned above when the wave sequences enter the tuned circuits.

Curve III of oscillograph No. 2 represents the 500-cycle wave sequence arriving in the parallel resonance circuit. By devices which will be described in detail in subsequent chapters, the voltage over the parallel resonance circuit will cause a current I_s through the signal relay, which current is represented by curve IV. This oscillograph shows that the relay current is delayed for the time G on account of the increasing transient oscillation of the parallel resonance circuit. Oscillograph 3 shows that this will not be the case when a wave sequence of a frequency outside the signal frequency range enters the series resonance circuit. Curve V represents such wave sequences, and curve VI a current I_b which is increased (in the negative direction) by voltages over the series resonance circuit.

6. Theory of Condenser Charging by means of a Neon Lamp.

In practice, the actual signal receiver in the Swedish system contains a device consisting of a condenser which is charged to a specified voltage by means of neon lamps. This device, the properties of which must be understood in order to comprehend the functioning of the signal receiver, and which further offers certain points of specific interest, will be described below, and is diagrammatically shown in Fig. 3. S is an A.C. supply of an effective A.C. voltage V_s, B a battery with a D.C. voltage V_o, g and g' two neon lamps with the lighting voltages V_t, c a condenser which can be charged by the neon lamps to a voltage V_c, I a grid leak, and E a three-electrode valve, the anode voltage, filament voltage, and grid bias of which are obtained from the batteries B_a, B_k, and B_g respectively. The object of the three-electrode valve is assumed to be to control the electromagnetic relay R in its anode circuit. To begin with we will suppose the neon lamp g' to be removed.

The characteristic of a neon lamp is that when the voltage between its electrodes has risen to a



B 1859

Fig. 3. Neon lamp device for condenser charging.

certain value, the so called lighting voltage, V_l, the lamp will be lit. Until this happens, the lamp acts as a break in the circuit, but the circuit is closed when the lamp is lit. The lighting of the lamp will cause the lamp voltage to drop somewhat to what might be called its incandescence voltage. The difference between lighting and incandescence voltages is of no particular influence in this special case, and in the following we will therefore assume the lighting voltage V_t to be equal to the incandescence voltage.

The incandescence voltage is practically constant, i. e. independent of the current passing through the lamp, and this in its turn means that currents caused by EMF:s superimposed on the incandescense voltage will be short circuited over the neon lamp.

The current supply is assumed to generate a sinusoidal voltage V_s, superimposed on the voltage V_o of the neon lamp battery B. With the polarity selected for the neon lamp battery, the aggregate voltage may momentarily amount to

$$V_o + \sqrt{2}\, V_s$$

with the positive pole on the right hand of the neon lamp g. If $V_o + \sqrt{2}\, V_s \geq V_l$, the lamp will light up. As the lamp cannot absorb a larger voltage drop than V_l, the surplus

$$V_o + \sqrt{2}\, V_s - V_l$$

must be applied to the condenser c, which is done by a positive charge of the upper condenser plate. We therefore get a momentary condenser voltage

$$V_{c1} = V_o + \sqrt{2}\, V_s - V_l.$$

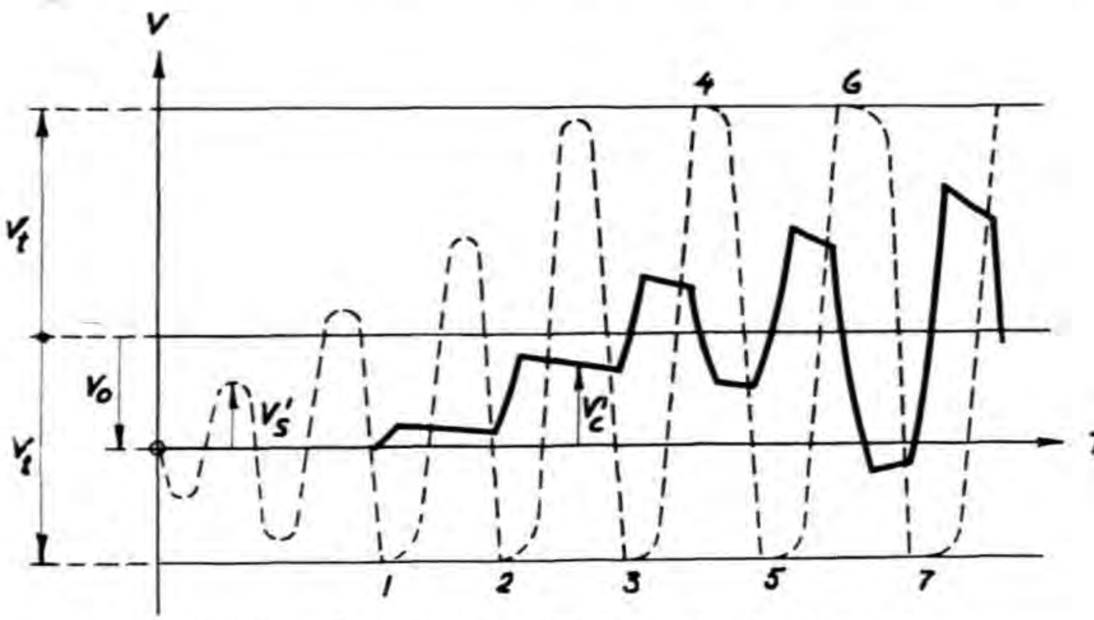
The next instant the A. C. voltage will drop, the incandescence voltage V_t cannot then be maintained, which results in the lamp going out. During the interval T_o before the next charge the condenser voltage will drop to the value

$$V_{c2} = V_{c1} \cdot e^{-\frac{T_o}{CI}}$$

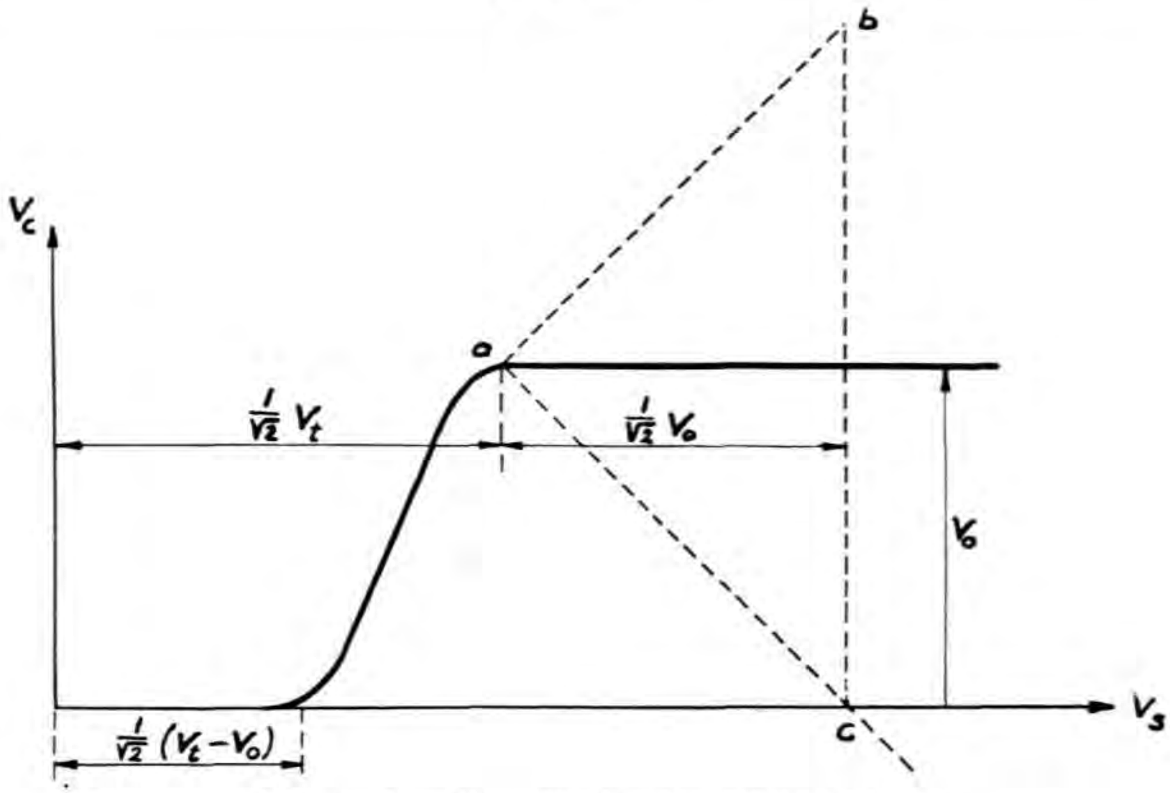
where I represents the resistance of the grid leak, after which the condenser is again chargd to the value V_{c1}.

If $\frac{T_o}{CI}$ be made small by selecting large values for C and I, and the A.C. voltage V_s remain constant, the condenser voltage will be practically constant with respect to time.

If the A.C. voltage, the momentary value of which we will call V_s', increase with respect to the time T, the momentary condenser voltage V_c' shown by Fig. 4 is obtained. As long as V_c' is so small that the lamp cannot light, the condenser voltage will remain zero. For the light flashes 1, 2, and 3, the condenser voltage will increase step by step, but will subsequently oscillate near the voltage V_o, on account of the light flashes 4 and 6. These oscillations may grow



B 1859 Fig. 4. Momentary condenser voltage V_c' at increasing A.C. voltage.



R 1861 Fig. 5. Condenser D.C. voltage V_c as a function of A.C. voltage V_s.

to such an extent that the condenser may be momentarily charged to a voltage of opposite sign to the former one, as for instance happens after light flash 6.

Fig. 5 gives the condenser voltage V_o as a function of the effective A.C. voltage V_s. The dotted lines a–b and a–c denote the limits between which the condenser voltage will oscillate. The effective condenser D.C. voltage, however, will be constant and equal to V_o when $V_s \geq \frac{1}{\sqrt{2}} V_t$. If we want to get rid of these condenser voltage oscillations, the A.C. supply should be shunted by a neon lamp g' (see Fig. 3), which limits the A.C. amplitudes to the value V_t.

In Fig. 3 the grid bias from the battery B_g is assumed to be of a size to make the anode current, i. e. the current through the relay R, zero when $V_c = 0$. An A.C. voltage V_c will consequently cause a change of the grid bias in a positive direction, with consequent anode current and energizing of the relay. An advantage of this arrangement over the direct rectification of the A.C. voltage V_s by the valve E is that a relay current about three times as strong is obtained with the same valve, for if the whole of the valve grid voltage space is utilized, a stronger anode D. C. is obtained for a constant grid voltage change than with a grid voltage working with sinusoidal half-periods. The battery B may be taken away in actual practice, and the lower pole of the A. C. supply be connected to the cathode of the valve E.

The neon lamps being comparatively cheap and very durable, and not needing to be fed by auxiliary currents like the thermionic valves (filament- and anode currents), the introduction of neon lamps in a design is from the point of view of economy equivalent to the introduction of resistance and condensers, and the devices in Fig. 3 will therefore hardly be more expensive than direct rectifying by a thermionic valve. The introduction of this neon lamp device in the tone signal receiver also made one valve superfluous, which was another practical and economic advantage.

Fig. 6 shows the types of neon lamps (to the right) and thermionic valves used in the Ericsson tone signal receiver, and gives an idea of the more convenient size of the neon lamp compared

R 1855 Fig. 6. Amplifier valve and neon lamp for tone signal receiver.

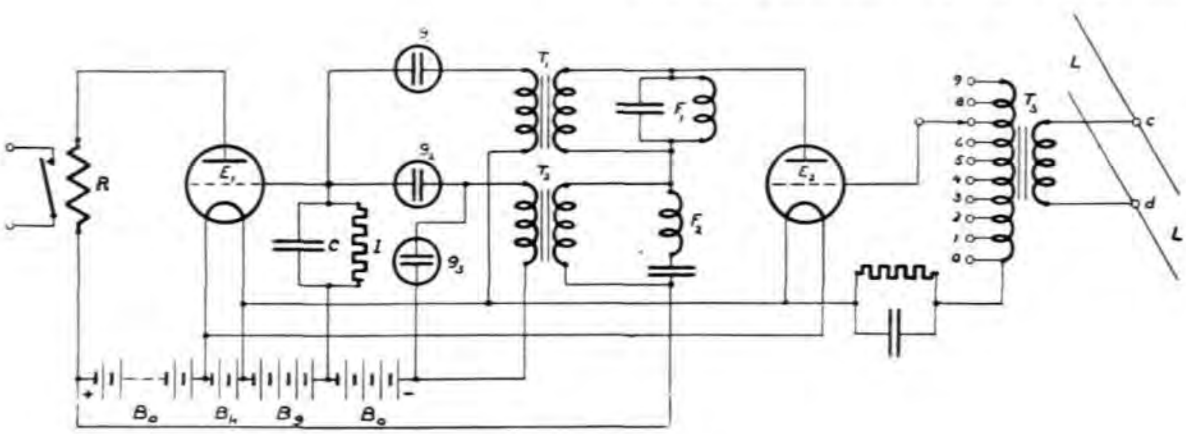
to the thermionic valve from a practical point of view. The peculiar way in which the neon lamp functions frequently enables the solvation of problems which might otherwise be insoluble.

7. The Swedish System Tone Signal Receiver in actual practice.

Fig. 7 is a diagram of the Swedish system tone signal receiver. The signalling currents arrive in the transformer T_3, the secondary winding of which is provided with several taps (0—9), so that the grid voltage of the valve E may be adjusted to a suitable value by connexion to one or another of these secondary taps. The resonance shunts F_1 and F_2 of the anode circuit of the valve E_2 are tuned to the 500-cycle frequency, and their object is to shunt any A. C. voltage having a frequency outside or inside the signal frequency range respectively, arriving over the input sides of the transformers T_1 and T_2 (cf. chapter 5).

If the output side of the transformer T_1 is regarded as an A. C. source, this, together with the neon lamp g_1, the condenser C, the grid leak I, and the battery Bg will form a neon lamp device like that described in the previous chapter. A. C. voltages over the transformer T_1 will change the grid bias of the valve E_2 in a positive direction. The battery B_g, which determines the grid bias of the valve E_1 when the receiver is inactive, is selected of such size that when the receiver is not in use the anode current of the valve is practically zero and the relay R is not energized. The grid voltage change referred to will thus energize relay R, which will close a local signal circuit.

The transformer T_2, the neon lamps g_2 and g_3, the condenser C, the grid leak I, and the battery B_o also form a neon lamp device as described in the last chapter, but A. C. voltages over the transformer T_2 will change the grid



R 1862 Fig. 7. Diagram of the tone signal receiver.

R 1936 Fig. 8. Front view of the tone signal receiver panel.

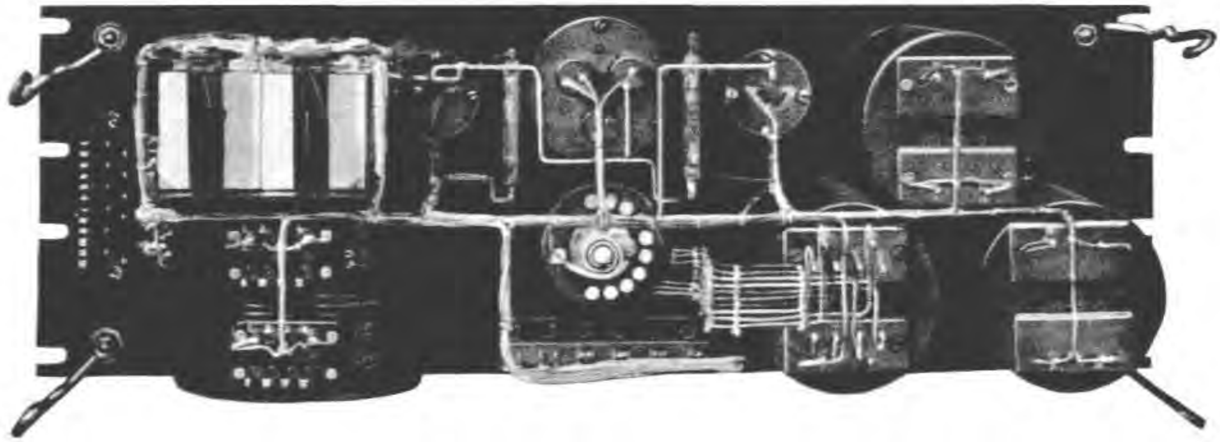
voltage of the valve E_1 in a negative direction. For voice currents, the frequencies of which are chiefly outside the signal frequency range, arriving in the signal receiver, the negative charges transferred by the neon lamp g_2 to the upper plate of the condenser C will more than neutralize any positive charges possibly transferred over the neon lamp g_1. This makes for a better blocking effect. The amplitudes of the blocking voltages are limited by means of the neon lamp g_3, which according to the above will improve the working of the blocking device.

The Ericsson tone signal receiver, of which Fig. 8 is a front and Fig. 9 a back view, is manufactured by the Svenska Radioaktiebolaget and built for an anode voltage of 120—130 volt and 6- or 24-volt filament voltage. When 24-volt filament voltage is used, all the filament circuits of two signal receiver panels are connected in series. Such an insignificant amount of energy is expended by the neon lamp batteries B_g and B_o—each of about 40 volt—that dry cell batteries may be used for the purpose. Storage batteries are, however, prefered. Like anode, filament, and grid batteries, the neon lamp batteries may be centralized.

If we regard the front of the panel (Fig. 8), we see in the centre the three neon lamps placed between the two valves. Below the neon lamps the dial for adjusting the sensitivity of the tone signal receiver is placed. With this dial, the tone signal receiver may be adjusted to nine different degrees of sensitivity, marked 1—9, which is done by connexions to the secondary taps of the grid transformer of the first valve as mentioned above (see Fig. 7). Below this dial we see the test jacks for plugging in instruments for measuring the anode currents and grid voltages of the two valves. If we now pass to the back of the panel (Fig. 9), we see the terminal tags furthest to the left, and close to them the condensers a little higher up, and the two induction coils of the resonance circuits a little lower down. To the right we see the three transformers, in the top centre the sockets for the amplifying valves, the neon lamps, and the grid leaks, and below these the contact device for the adjustment of sensitivity and the soldering tags of the test jacks.

When the sensitivity adjustment dial is set in a certain position, the tone signal receiver will only be actuated by tone-signal voltages within a limited range of amplitudes. By moving the dial, this range of amplitudes, which naturally must be wide enough to embrace any variations of tone signal voltages occurring, is deflected to a range of sensitivity corresponding to the value of the tone signal voltages at that particular point of the telephone lines where the tone signal receiver is connected. By adjusting the sensitivity of the tone signal receiver in this manner to the amplitudes of the incoming signal voltages, the signal devices are protected from any disturbing currents in the telephone lines, as these currents are usually considerably weaker than the signal currents, and can consequently only affect the tone signal receiver if this is supersensitively adjusted.

According to the C. C. I. tone signal standards (cf Chapter 2), the power of the uninterrupted tone signal current shall be 3 to 6 milliwatt at those points of the telephone lines where the speech transmission level is zero. If we fix this



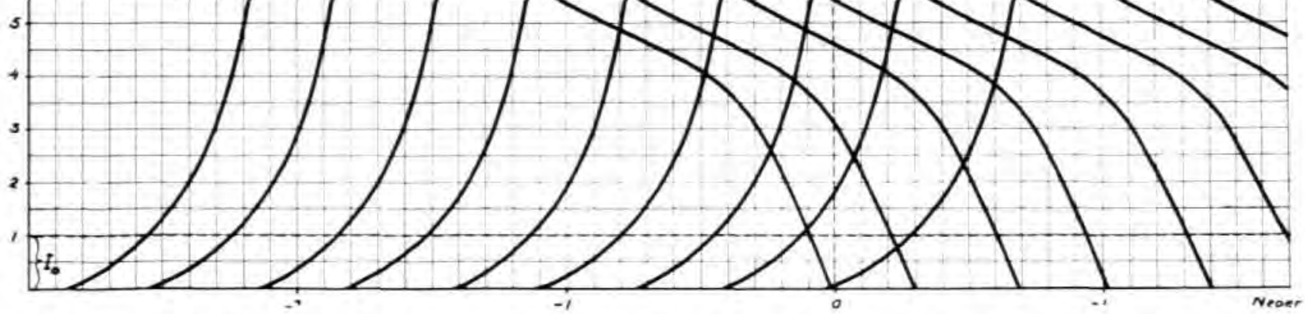
R 1852 Fig. 9. Back view of the tone signal receiver panel.

power at 4.5 m.watt, the tone signal voltage V in a line with a 600-ohm characteristic will correspond to a signal voltage level of

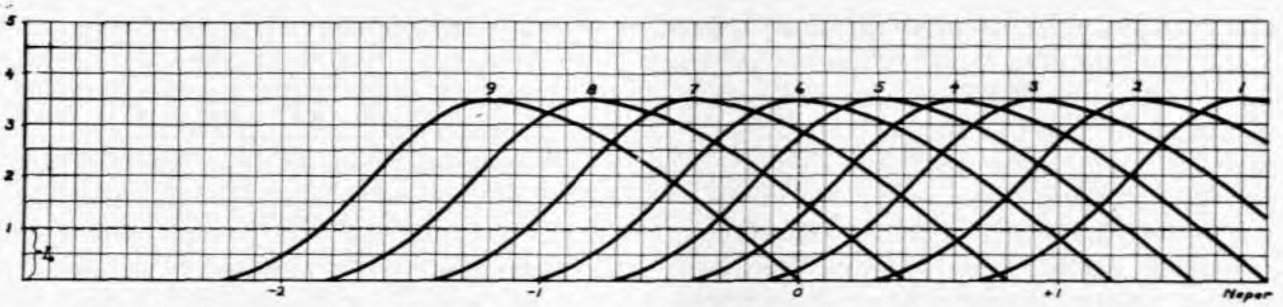
$$b = ln \frac{V}{\sqrt{600 \times 4 \cdot 5 \times 10^{-3}}} = ln \frac{V}{1.64} \text{ neper.}$$

Fig. 10 gives the current through the relay of the tone signal receiver as a function of the signal voltage level of the incoming pure 500-cycle tone signal current at different adjustments of sensitivity. Fig. 11 is the same, but the signal current is here interrupted 20 times a second. I_o is the energizing current of the signal relay when this relay is adjusted to greatest sensitivity. A circumstance immediately apparent from these curves is that the less of other frequencies are mixed with the 500-cycle frequency, the larger will be the maximum value of the relay current. By reducing the sensitivity of the relay, it is thus possible to increase the selectivity of the tone signal receiver, as the only way to obtain the relay current required for energizing is to increase the purity of the signal frequency. If, for instance, the sensitivity of the relay is reduced to make the energizing current 3.6 mA. instead of 1 mA., the tone signal receiver can obviously, with ample safety margins, work with pure 500-cycle signal frequency, while the 500-cycle tone with 20-cycle interruptions cannot under any conditions cause the relay to be actuated.

Fig. 12 gives the relay current as a function of the frequency for both pure (curves I and



R 1866 Fig. 10. Relay current as a function of the transmission level of incoming uninterrupted signal current.



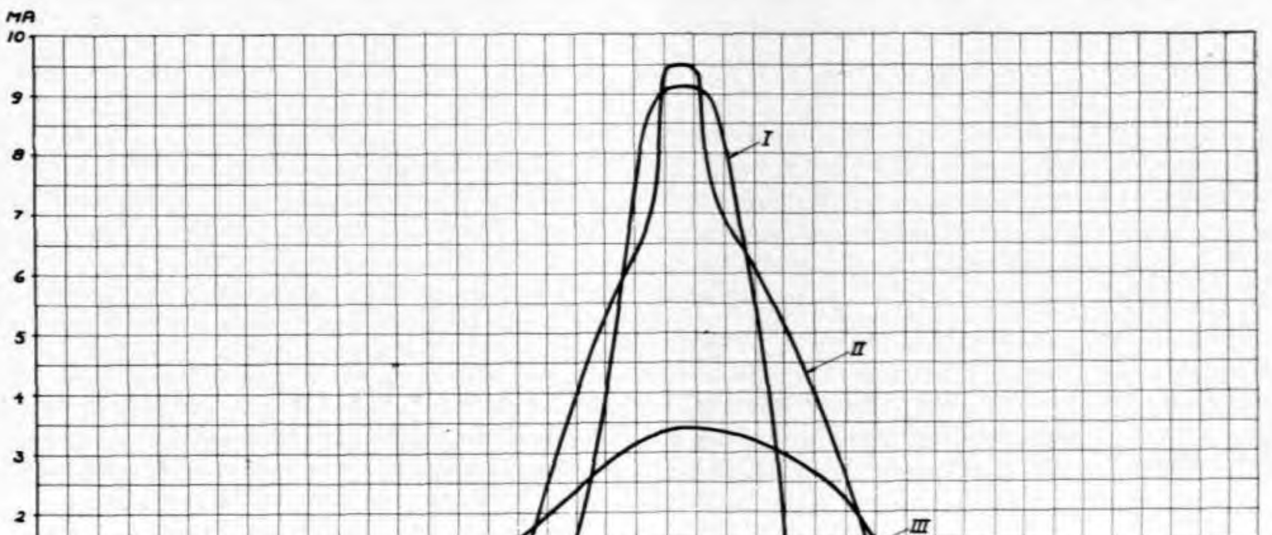
R 1865 Fig. 11. Relay current as a function of the transmission level of incoming tone signal current interrupted 20 times per sec.

II) and 20-cycle interrupted (curve III) signal current. These curves give some idea of the sensitivity of the tone signal receiver to variations in the signal frequency. Curves I and II are plotted for different signal voltage levels, and prove that the shape of the curve depends on this level.

8. The Svenska Radioaktiebolaget Ring Signal Repeater.

The question of replacing the 20-cycle signal current by audio-frequency current only arises in telephone lines with amplifiers or lines using the low frequency range for telegraphy or the like, which would be disturbed by 20-cycle signal currents. In all other cases the 20-cycle signal current will retain its position and, as far as the telephone is concerned, it is therefore preferable to retain the uniform 20-cycle signalling system in the switchboards. But this desideratum can ostensibly be attained by introducing signal repeaters at the terminal points of any lines requiring tone signals. 20-cycle signals sent out from the exchange to the signal repeaters will energize relays which will cause audio-frequency signals to be sent out on the long distance lines, and tone signals arriving from the long distance lines to the repeaters will act on tone signal receivers which in their turn will cause 20-cycle signals to be emitted to the exchange.

Fig. 13 is a diagram showing the principle of the Svenska Radioaktiebolaget ring signal repeater, which functions in the above manner. The long distance line is connected to the termi-



R 1867 Fig. 12. Relay current as a function of the signal current frequency.

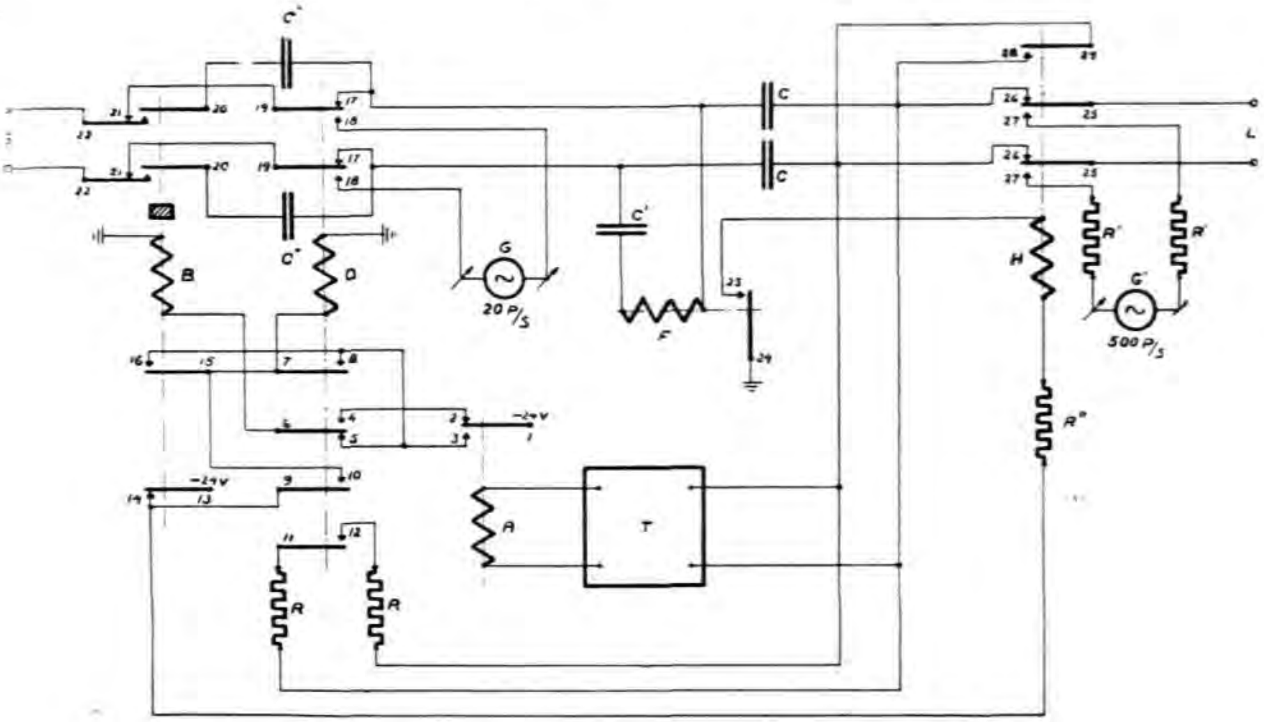
nals L, and the exchange to the terminals S. Telephone currents between the exchange S and the line L will obviously pass the repeater over the springs of the relays B, D, and H, and the condensers C, in the order (S, 22, 21, 19, 17, C, 26, 25, L). With present relay designs, the reliability of the telephone service is not considered to be appreciably reduced by this comparatively large number of relay contacts in the telephone circuit.

The inductance of the A. C. relay F, and the condensers C, form between them a half-section of a high pass filter with so low a cut-off frequency that all voice frequencies will freely pass the filter, while the 20-cycle signal currents cannot do so. The condenser C', which with the relay E forms a series resonance circuit tuned to 20 cycles, has little influence on this high pass filter in the voice frequency range, and by designing $\sqrt{\frac{2L}{c}}$ to equal the caracteristic impedance of the line, the telephone currents will pass the filter device without any reflexion.

A 20-cycle signal current arriving from the exchange to the terminals S will energize the A. C. relay F, which in its turn will close the circuit (earth, 24, 23, H, R", 14, 13, -24V), with consequent energizing of relay H. This causes the tone signal generator G', which is provided with separate protective resistances R' for each signal repeater, to send out a tone signal current on the long distance line over the contacts (27, 25). These protective resistances for the generator have two objects. One is to prevent other repeaters being put out of action if a junction line between the generator and one signal repeater be short circuited. In the absence of such protective resistances the generator would be directly short circuited, and rendered incapable of supplying the voltage required for tone signalling. The second object is that the protective resistances should form an internal resistance in the generator G' equal to the characteristic impedance of the line, so that the transmission of ring signal current will not disturb the balance of any amplifiers in the long distance line. While the 500-cycle signal is being sent out, the tone signal receiver is short circuited by contacts (28, 29) of the relay H, in order to protect the tone signal receiver from the 20-cycle currents, which would shorten the life of the first valve by overloading.

In transforming 500-cycle signal currents into 20-cycle signal currents, two considerations must be given due attention. First, the repeater should, in accordance with the C. C. I. standards, be able to function with 500-cycle signal currents interrupted 20 times per second. The sensitivity curves of the tone signal receiver (Figs. 10, 11 and 12) show that the tone signal receiver relay (A) must be adjusted to a comparatively high degree of sensitivity, which in its turn will cause an appreciable diminution of the selectivity of the tone signal receiver. Practical tests by the Swedish Board of Telegraphs have indicated that this diminished selectivity should be compensated by making the relays (A, B, D) transmitting the 20-cycle signal to the exchange slow-acting. Secondly, we must prevent any emitted 20-cycle signal current from energizing the relay set FH so that relay H will send out 500-cycle signal current on the long distance line, causing false signals. The connexion between the terminals S and the relay F will be restored the moment after a 20-cycle signal current has been sent out towards the exchange, but simultaneously charging currents will arrive in the repeater (at s), originating from line capacities charged by the 20-cycle signal current, and these charging currents may be powerful enough to energize the relay F. Later we will show how these so called back-charges may be neutralized by means of slow action.

The procedure of transforming 500-cycle signal current into 20-cycle is as follows: a tone signal current arriving at the terminals L is admitted to the tone signal receiver T over the relay springs (25, 26). Relay A is energized and closes the circuit (-24 V, 1, 3, 5, 6, B, earth). Relay B, which is slow-acting in breaking, is energized. This closes the circuit (-24 V, 3, 16, 15, 7, D, earth), and the speaking circuit (L, 25, 26, C, 17, 19, 21, 22, S) is changed to (L, 25, 26, C, C", 20, 22, S). When this circuit is closed, the relay D is attracted, and the contacts 21 which are insulated from the relay springs 22, receive 20-cycle signal voltage from the generator G over the relay springs (19, 18), and the circuit (-24 V, 1, 3, 5, 6, B, earth) is broken. The speaking circuit obviously remains the same, but relay B breaks with slow action. Relay D is then locked over the relay springs (1, 3, 8, 7) and remains energized, while the



R 1863

Fig. 13. Diagram of the Svenska Radioaktiebolaget ring signal repeater.

speaking circuit is opened at the relay springs (22, 20) and 20-cycle signal current is sent out from the generator G over (18, 19, 21, 22, S) to the exchange. Before the 20-cycle signal current is transmitted, the relays A, B, and D must thus each in their turn be energized, and B must finally break with slow action. If relay A is de-energized before these operations have had time to be carried out, 20-cycle signal current will not be sent out, nor will the speaking circuit be broken. The slow action mentioned above, necessary to compensate the diminished selectivity of the tone signal receiver, has thus been obtained.

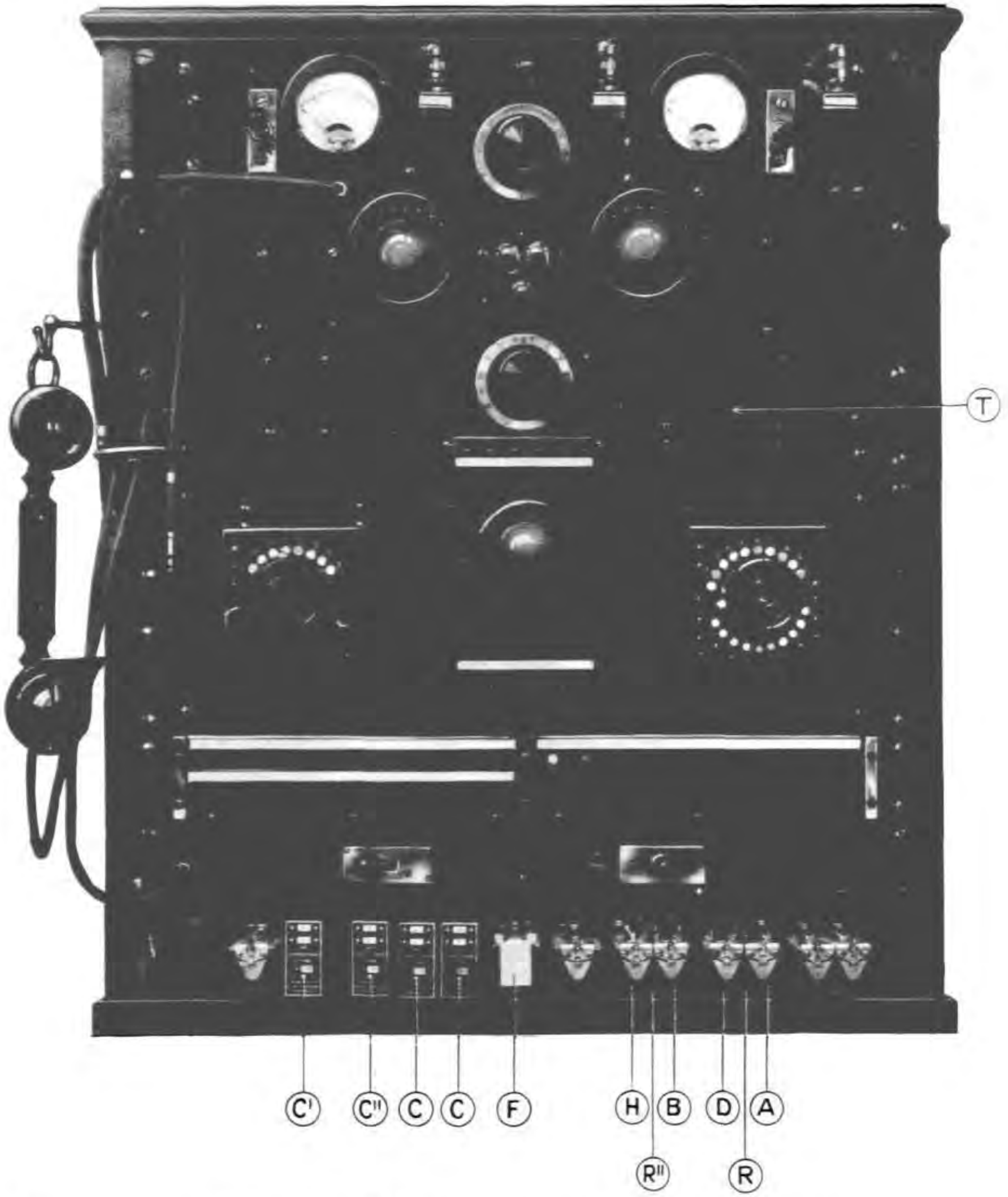
When the tone signal ceases, relay A will be de-energized, and the (-24 V, 1, 2, 4, 6, B, earth), circuit is closed. Although relay D will no longer be held by the circuit (-24 V, 1, 3, 8, 7), it will still be held by the circuit (-24 V, 13, 14, 9, 10, 7). The only result will thus be that relay B is energized. This stops the sending out of 20-cycle signal current, and the speaking circuit (S, 22, 20, C, C'', 26, 25, L) is closed. The back-charges from the exchange side mentioned above are partly checked by the condensers C'', but are still sufficient to energize relay F. The circuit (earth, 24, 23, H, R'', 14, 13, -24 V), however, is broken between the relay springs (13, 14), and relay H thus remains de-energized. But relay B has broken the locking of relay D (-24 V, 13, 14, 10, 7), and relay D is therefore de-energized. Relay D in its turn breaks the circuit (-24 V, 1, 2, 4, 6, S, earth), when the slow acting relay is de-energized. The speaking circuit is restored to its original state (S, 22, 21, 19, 17, C, 26, 25, L), and the relay set FH is again able to transform 20-cycle into 500-cycle signal currents.

The object of resistance R'' is to impart to relay H a certain amount of slow action in making when it is energized, and the object of resistances R is to balance the line connected to the terminals L when the speaking circuit is broken by relays B and D, in order to lessen the disturbance of the balance of any trunk line amplifiers.

Fig. 14 shows a ring signal repeater fitted in the same box as a four-wire amplifier. The letter symbols refer to Fig. 13.

9. Tone Frequency Dialling.

In recent years we have watched the automatic systems steadily replace purely manual service. This applies not only to local traffic in the large cities, but also to rural and even to long distance traffic. When automatic impulses have to be transmitted over long telephone lines fitted with amplifiers, the automatic impulses must, for the same reasons that have necessitated tone signals, be transmitted by currents of audio-frequency interrupted in time with the impulses. Although we have to do without any slow-action the problem can be solved in a perfectly satisfactory manner by tone signal receivers of the Swedish system. A very narrow band of frequencies may be used for transmitting the dial impulses, and by filtering the impulses in a suitable manner on the sender side, the relay current in the anode relay of the tone signal recei-



B 1857

Fig. 14. Joint fitting of a ring signal repeater and a four-wire amplifier.

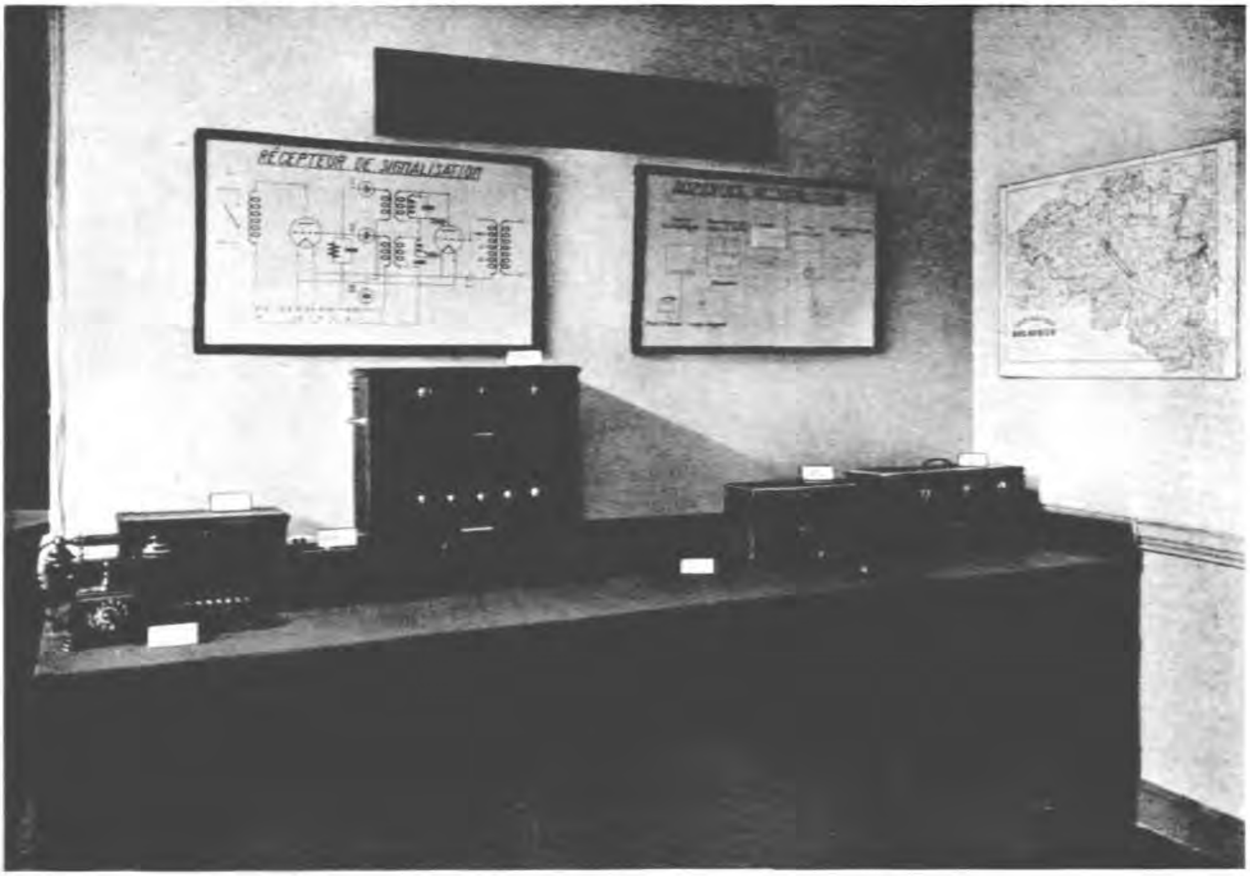
ver may, therefore, be considerably increased relatively to the relay current in ordinary tone signalling when interrupted tone frequency is used (cf. the sensitivity curves Figs. 10, 11, 12). This relay can therefore be made less sensitive which, according to the above, will make the tone signal receiver more selective. We then find that the selectivity can be increased sufficiently to dispense with the slow action. The automatic impulses will naturally be more or less deformed in transit, but this may be corrected by special devices on the receiver side.

A detailed description of the devices used in the Ericsson audio-frequency dialling system is not within the scope of this paper. We will show a few photographs, however, from trial plants exhibited at Düsseldorf and Brussels (Figs. 15 and 16 respectively). The 3rd sub-committee of the C. C. I., dealing with transmission questions, met in Düsseldorf March 24—31 1930, and an exhibition was arranged in connexion with that meeting by various makers of long distance telephone appliances. Fig. 15 illustrates the tone impulse apparatus exhibited by L. M. Ericsson. A similar exhibition was arranged in Brussels in connexion with the plenary meetings of the C. C. I. on June 16—23 1930, when the Ericsson Concern among other things also exhibited the tone impulse apparatus shown in Fig. 16. This illustration shows to the right a map of the loaded telephone cable loop used for the demonstration of the impulse transmissions. On the table to the right, the 500-cycle generator of the impulse currents is visible, and by its side is a box with a dial, representing the telephone operator's service position. These two instruments are all the equipment at one end of the line, and by the loaded cable loop mentioned they are connected to the instruments forming the equipment at the other end. Among these we notice a tall box

R 1854 Fig. 15. Tone frequency dialling apparatus exhibited at Düsseldorf.

containing the tone signal receiver (an early model), the dial tone generator, relay sets etc.

The box furthest to the left represents the automatic exchange, by which the trunk line may be connected to any of the 10 lines ending in the 10 jacks visible at the bottom. By a cord, the telephone set seen in the illustration can be plugged in on any of these lines. The equipment functions as follows. When calling the automatic exchange, the operator depresses a plunger key above the dial. When receiving a dial tone in her receiver, she dials the number in the ordinary way. If the called party is not busy by another long distance call—in which case the operator receives a busy tone in her receiver—she now dials a 9, which results in a ringing signal in the instrument of the called party. When the call is over, the connexions are released by the operator again depressing the plunger key above the dial, which at any time will release the connexion.



R 1956

Fig. 16. Tone frequency dialling apparatus exhibited at Brussels.

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The Alpha Company.

The Aktiebolaget Alpha in Sundbyberg, acquired by the Ericsson Concern in Oct. 1929, is a valuable addition to the number of modern and well-equipped workshops of the Concern, and possesses a rich fund of experience in various branches of manufacture extending over several decades. A short account of the progress of this firm will be given below.

The Alpha Works, situated in Sundbyberg in immediate proximity to another Ericsson associated company, the Sievert Cable Works, were founded in 1888 by Max Sievert. Steam and water fittings, lubricators, etc., were originally manufactured, but a considerable number of special machines required by the Sievert Cable Works for the manufacture of electric wires and cables were later constructed in the Alpha shops. A new line was taken up in 1905 with the design and manufacture of machines for testing metals.

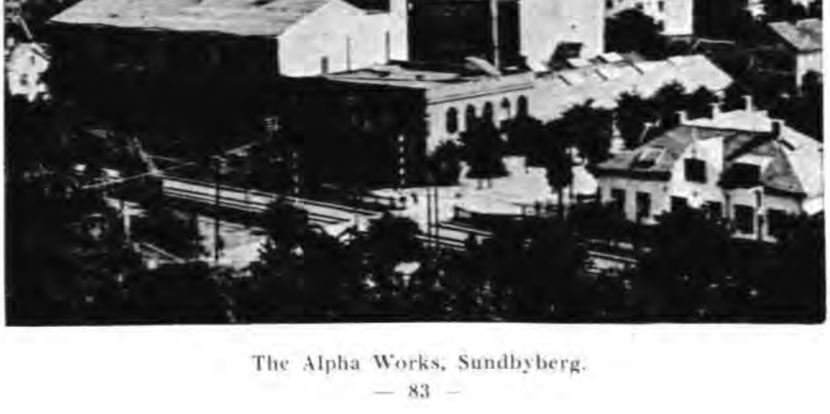
The principal item in this particular branch was, to start with, the Brinell press for determining the hardness of metals, so named after the famous Swedish steel expert J. A. Brinell. Gradually the reputation of the Works for care and exactitude became established, and the manufacture of a variety of machines for testing other materials was taken up, e. g. apparatus for tensile tests, impact tests, rotary endurance tests, wearing tests, bending tests, etc.

R 1293

Max Sievert.

Beyond the Brinell press mentioned above, the Durometer, also used for determining the hardness of metals, and the Carbometer are the most important material testing appliances at present manufactured. The last mentioned apparatus, designed in cooperation with the engineers Malmberg and Holmström, is of great utility in steel works and steel foundries for the rapid and reliable determination of the carbon content of a steel bath, thus obviating detailed chemical analyses and eliminating the uncertain estimates of the furnacemen.

The manufacture of bakelite articles carried on by the Alpha factories was the principal reason why the Ericsson Concern acquired that company. To an outsider, this branch of manufacture would seem to have little to do with the kind of mechanical work required for making testing machinery, but those more initiated will see



The Alpha Works, Sundbyberg.

that the skill and care necessary in making moulds or dies of special steel for the production of bakelite goods is of highest value for securing high quality of the moulded articles. The Alpha engineering works satisfy the most exacting demands in this respect, and the bakelite mouldings supplied by A.-B. Alpha enjoy the highest reputation both at home and abroad.

As broadcasting gained ground, A.-B. Alpha made its own designs of various Radio components, such as dials, valve holders, etc., and considerable quantities of these articles are now exported to all countries. Many other uses have been found for bakelite, expecially in the telephone industry, and when the Alpha Company joined the Ericsson Concern the bakelite moulding shop of the latter was transferred to Alpha, which thereby obtained additional experience and considerably increased capacity.

R 1934 Workshop for Testing Machines etc.

Another important use of bakelite is for electrical fittings, and rapid progress is at present made in this branch, in intimate cooperation with the Sievert Cable Works.

A.-B. Alpha has also taken over the L. M. Ericsson manufacture of microphone carbon, telephone and wireless condensers, and finally also Railway Signalling and Electric Interlocking Plants, comprising switching machines, cable distribution boxes and the like.

About 300 workmen are at present employed in the Alpha workshops.

Workshop for Bakelite Moulds etc.

Notes on the Design and Use of Bakelite Parts for Insulating Purposes.

By *E. Nylund.*

In telephony, as in all electric industries, insulating materials play a very important part. The long metal wire between two persons speaking to one another on the telephone can not hang free in the air, but must be held up by insulating supports. These supports number thousands in every line. If an apparently very insignificant leakage should occur at each of these the electric energy, barely sufficient at the starting point, would be so reduced as to make the reception of a telephone message impossible. Should the insulation be totally destroyed at just one of all these insulation points, the whole connexion would be broken. It is also important that the insulation should not deteriorate with time or be damaged by sunlight, damp, or heat. Among the insulation materials largely used in telephony are porcelain, ebonite, fibre, and — increasingly prominent during the last 10 years — bakelite. All of these have both advantages and drawbacks. Porcelain, formerly practically the only material used for out of door service or in damp places, has now found a keen competitor in bakelite. Porcelain shrinks considerably in burning, so that exact dimensions are not obtained. It is fairly brittle, and metal inserts cemented to it easily work loose. Ebonite is ruined by sunlight, and fibre is very hygroscopic. Parts made of ebonite and fibre cannot be moulded, but must be cut or turned, and only simple shapes can therefore be made of these materials. Bakelite, on the other hand, very nearly reaches the ideal in all respects. It is of attractive appearance, has good mechanical strength and good insulating properties, and is particularly suitable for large scale manufacture of parts pressed in moulds. Its coefficient of expansion is slightly larger than that of metals, and metal parts moulded into it are therefore firmly held.

The raw material used for the manufacture of bakelite parts is a powdered mixture, composed of bakelite resins, fillers, and colouring matter. A mould must be made for each part to be manufactured. This mould is made of hardened steel and in its simplest form consists of a lower and an upper part. The lower part is filled with the proper quantity of moulding powder, the upper part is placed on top, and the whole is compressed between the heated plates of a bakelite part, measured perpendicularly to the —200° C, and the pressure on the surface of the bakelite part, measured perpendicularly to the direction of pressure, 150—300 kg/cm². While compressed and heated the powder melts and is converted into a solid and homogeneous part which after a certain time may be taken out of the mould. To obtain good mechanical and electrical properties, it is essential that the correct temperature, pressure, and time are maintained in the process.

In choosing a material for a given constructional part, the designer should have a fair knowledge of the materials in question. He should know their respective cost, so as to be able to determine the most economic proportion between the several materials entering into the part. He should know how the material is manufactured, so as not to give the part a shape which is not adapted to the manufacturing process. He should also know the mechanical and electrical properties of the material. But it is not sufficient to know these properties when the part is new alone, he should also know how they change with time, and what is the effect on them of sunlight, moisture, heat and chemicals. In the following we shall briefly discuss these points.

Different Qualities of Bakelite.

A great many moulding compounds exist, of different properties and various names. The usual moulding compounds belong to one of the following 3 main classes:

Class I. The materials of this class consist of phenol-formaldehyde resins with wood-flour or asbestos fillers. These are the most frequently used, and are commonly known to the trade as bakelite, although the name bakelite in several countries is the registered trade name of the products of a certain firm. Its colour is usually dark — black, brown, imitation mahogany or walnut, etc.

Class II. The compounds belonging to this class consist of phenol-formaldehyde resins with a filler of converted, pulverized bakelite. They are more expensive than ordinary bakelite, and will sometimes cause some technical difficulties in manufacturing, but are used when particularly great resistance against moisture is required. As a rule, no colouring matter is used and they are then of a yellowy-brown colour.

Class III. These compounds consist of thio-carbamide aldehyde resins with various fillers and colouring matter. They are known to the trade by many different names, such as Beetle, Pollopas, Alboresin, Aldur and others. They are considerably more expensive to manufacture than normal bakelite, but are employed for certain special purposes, as they may be produced in pure white and in many light, semi-transparent shades. They are also resistant enough to hot water, and sufficiently free of any taste or smell, to be used for tea or coffee cups and similar objects. Special precautions must be taken to prevent the moulds from being affected when such compounds are moulded.

Economic Considerations in the Selection of Bakelite.

The cost of a bakelite part consists of mould- or tool-costs, cost of the material, and manufacturing costs. The tools must be made of hardened steel and are often very expensive. If bakelite is to be used, very large series are usually required, so that the cost of the tool will not be too high when divided between the parts made. The moulding costs can be reduced by making each tool large enough for moulding several parts simultaneously. The problem is therefore to make the tool of such a size that the sum of tool costs and pressing costs will be the lowest possible for a given quantity of parts. The cost of the material being relatively high, the part should not be made larger than necessary, and material should be saved in the design wherever possible. The thickness of the walls of the piece to be moulded should also be as even as may be, as the curing time depends on the thickest portion. With regard to the surface finish, highly polished surfaces should only be demanded where actually essential, as the tool cost naturally largely depends on this.

Notes on the designing of Bakelite Parts.

All costs are to a very large extent depending on the design of a bakelite part. A slight change in the design e. g. a rounded instead of a sharp corner, may frequently simplify the manufacturing. A new design in bakelite should therefore never be sanctioned until it has been approved by the bakelite firm. The following points should be specially considered.

a) *Exterior shape.* Every bakelite piece should if possible be given such a shape that the tool can be made in only 3 parts, see fig. 1. The contours

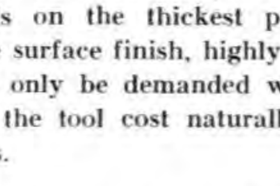


Fig. 1.

of the piece are elaborated in the centre part, and when this is filled with the compound the upper part or plunger is put on top and pressed down. The bottom part serves for simultaneous withdrawal of any pins used. The hole left by the pin *S* in the centre part is used for pushing the moulded piece from the tool.

The shape of the bakelite piece should also be such that the contours in the centre part can be finished in ordinary machine-tools, and no expensive hand work has to be resorted to. Many firms let their workshop first make a model in ebonite or the like, of which the drawing office makes a drawing for the order to the bakelite firm. The workshop usually makes the piece as suits them best, which is therefore often very expensive to make in bakelite. An example of such a piece is shown in fig. 2.

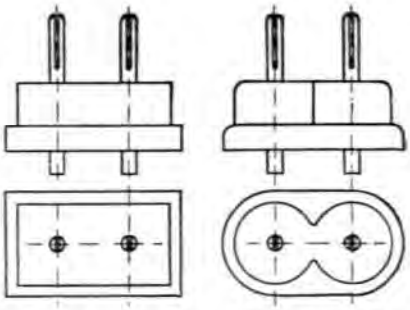


Fig. 2.

The left hand design is the easiest to make by hand from ebonite, while the right hand design is difficult to make by hand, but very easily made from bakelite. If grooves are necessary, they may be made by putting in loose parts in the tool, which come out with the part when this is removed from the tool. In fig. 3 the loose ring is made in two halves, a_1 and a_2, which are taken apart outside the tool.

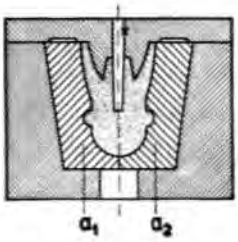


Fig. 3.

As bakelite shrinks in cooling, inside surfaces should be made slightly conical (at least 2°) to facilitate the extraction of the bakelite part from the tool. Fluting should always be straight, not askew or crossed.

b) *Thickness of material.*

The thickness of the walls should be as uniform as possible, preferably not more than 4—5 mm. nor less than 1—1.5 mm. If a large plane

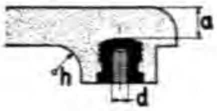


Fig. 4.

piece is reinfored by barriers on one side, these will show on the opposite surface, which will be drawn in above them. To reduce this disturbing effect, the corner between barriers or projections and surface should be generously rounded, see *h* in fig. 4. These and other unevenesses may also be hidden by stripes or other suitable designs.

c) *Holes.*

Holes can easily be made in the direction of the pressure, but weak spots in the tool must be carefully avoided. In fig. 5 weak spots are

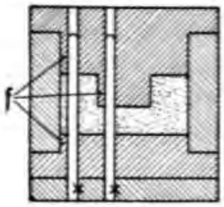


Fig. 5.

marked *f*. Blind holes should not be made deeper than 3 times the diameter, otherwise the pins in the tool may easily be broken. Lateral holes can also be made by inserting pins from the side. If these pins are long, they should be supported so that they do not bend when the compound is compressed.

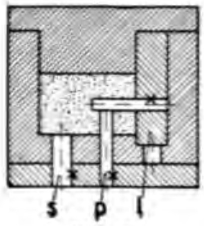


Fig. 6.

d) *Metallic inserts.*

Metal parts may usually be easily moulded in bakelite pieces, but insuperable difficulties sometimes arise. Fig. 7, 8 and 9 show the metallic inserts most commonly used. The contact pins of fig. 7 are inside threaded at both ends. The length of the cylindrical part *A* must be 1.5 to 2 times larger than the length *B*, to prevent the bakelite from flowing out through the hole in the upper part of the tool when compressed. In fig. 7 is shown how ribs can be made between the metal

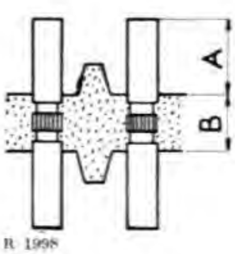


Fig. 7.

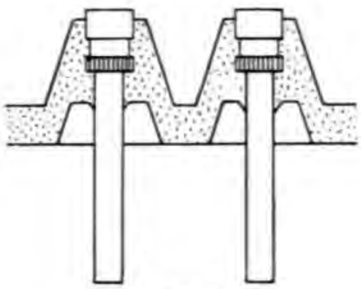


Fig. 8.

parts to increase the length of the displacement of the material. In fig. 8 the distance between the metal parts is lengthened both along the surface and in the bakelite mass. To prevent the bakelite from penetrating into the thread of the metal parts, these may be moulded in with nuts screwed on as shown in fig. 9. It is always difficult to mould in flat strips of metal. If this cannot be avoided, they should be placed parallel to the direction of the pressure so as to offer a minimum of resistance to the movements of the compound (see fig. 9).

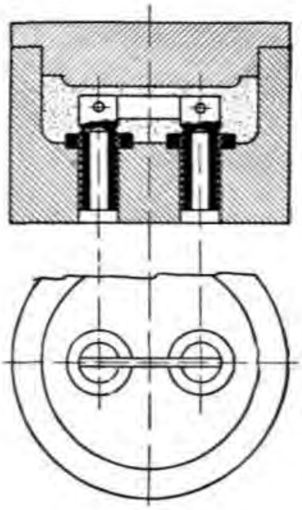


Fig. 9.

Screw holes should in certain cases be provided with a threaded metal bushing, particularly if great pulling force is required when the screw has to be frequently put in and taken out, if the depth of the thread cannot be made at least 3 times the diameter, or if the screw diameter is less than 2.5 mm.

Metal parts on the sides should be avoided, but if they are necessary they may be fixed as in fig. 10 and supported by a pin. Instead of a threaded metal part another piece, as in fig. 11, may sometimes be put in in the direction of the pressure, and the lateral hole bored and threaded afterwards.

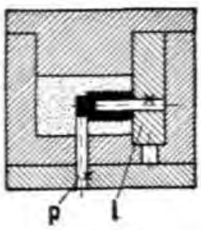


Fig. 10.

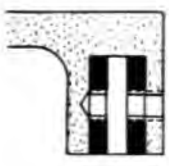


Fig. 11.

e) *Tolerances.*

A bakelite part will shrink about 0.4 per cent in cooling. This shrinkage may, however, be compensated by making the tool 0.4 per cent larger. Smaller tolerances than 0.05 mm. should not be asked for. Certain measurements in the direction of the pressure will always depend on the quantity of powder filled into the mould. In this direction a tolerance of $\pm$ 0.2 mm should be allowed if finishing is to be avoided. Tolerances should always be as generous as possible and stated on the drawings, so that the tools are not made with greater precision than required.

Properties and Testing.

In the following we will describe the most important properties of bakelite and how to test them. The figures given in literature and manufacturer's lists differ widely, and are absolutely valueless unless the testing method is stated. The so-called German tests mentioned below are quoted from the "Vorschriftenbuch des Verbandes Deutscher Elektrotechniker", where they are described in detail. Most of the tests are made on so-called test rods. These test rods are made from the material under the same conditions as the bakelite parts are manufactured, and of the size $10 \times 15 \times 120$ mm. Bakelite cannot be produced with as uniform properties as for instance metals. A variation of 15 per cent. from the figures stated does not imply any neglect in manufacture.

A: *Specific gravity.* The specific gravity of bakelite is 1.35.

B: *Transverse strength.* This is determined according the German methods. A test rod is placed on two supports 100 mm. apart, and loaded at the centre until it breaks. The transverse strength of bakelite varies between 500 and 1000 kg/cm^2. The usual value is 800 kg/cm^2.

C. *Impact strength.* According to the German method, this is determined as follows. A test rod is placed on two supports 70 mm. apart, and a pendulum hammer is allowed to hit its centre. The impact strength of bakelite is 5—10 kgcm/cm^2.

D. *Hardness.* Hardness is determined in a Brinell press at a pressure of 250 kg. and with a 5 mm. ball. The hardness of bakelite is about 45 Brinell units.

E. *Dielectric strength.* This may suitably be measured according to the American standards, (see Am. Soc. for Testing Materials, Standards 1924). The test piece is here a bowl of 2.5 mm. thickness, 63 mm. outer diameter, and 63 mm. in height. Mercury is poured into the bowl, floating in mercury, up to a height of 3 mm. A sinusoidal alternating voltage is set up in the mercury electrodes, and raised gradually by 1000 volt/sec. until puncture occurs. The dielectric strength is about 30 KV/mm.

F: *Specific Resistance.* The resistance is measured between mercury electrodes in a device similar to the one used in the dielectric test. The specific resistance of bakelite is 10^5—10^7 megohm/cm³.

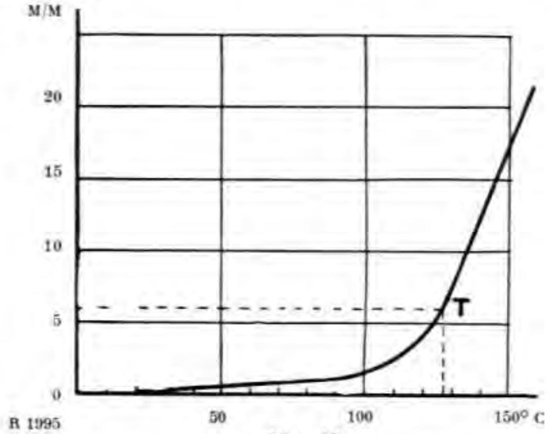


Fig. 12.

The heat-resistance relative to the appearance is the temperature at which the effect of heat manifests itself on the surface of a bakelite part. This is indicated by the surface shrivelling and by the whole part swelling. This will occur at a temperature of 140—250° C.

The heat-resistance of bakelite relative to the mechanical strength is easiest measured according to the German Martens test. It is the result of this test which is most frequently stated in literature, and is obtained by exposing a fixed test rod to a certain constant bending strain while the temperature is gradually raised at a given rate. The rod will at first bend very slowly, but at a certain temperature the deflection begins to increase rapidly. This temperature, *T* in fig. 12, has been adopted as the measure of heat-resistance, and has been found to correspond to a deflection of 6 mm. in the arrangement mentioned. In order to obviate the plotting of the whole curve, the heat-resistance has therefore been defined simply as the temperature at which the deflection is 6 mm. This deflection is reached in bakelite at 120—160° C.

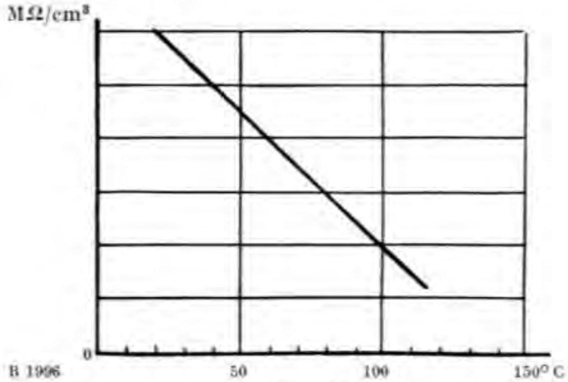


Fig. 13.

G. *Aging.* Bakelite does not deteriorate with time in any way; on the contrary, a gradual increase of strength and insulating capacity has been observed.

H: *Effect of sunlight.* Sunlight does not adversely affect the appearance or properties of bakelite, as is the case with for inst. ebonite.

I: *Effect of heat.* Statements from various sources regarding the heat-resisting properties of bakelite differ considerably. The reason is not that the properties of bakelite vary in different places, but that the heat-resistance is judged from various points of view. It is impossible to indicate the heat-resistance of any material by a single figure, but this property must be subdivided into several classes, of which the following are the principal:

a) Heat-resistance relative to appearance.

b) Heat-resistance relative to mechanical strength.

c) Heat-resistance from the electrical point of view.

The heat-resistance from an electrical point of view is still more difficult to express by a single figure, as the values of the insulation and the dielectric losses vary in all ranges of temperature. As for the majority of the organic substances, the insulation diminishes with the temperature almost according to a logarithmic law. If a logarithmic scale is used for plotting the specific resistance and a regular scale for the temperature, the relation between them will be obtained as a straight line, as in fig. 13.

K: *Effect of moisture and water.* Moisture and water have no appreciable effect on the mechanical strength of bakelite. But they have great influence on the surface resistance. The resistance between metal contacts moulded into a terminal block, for instance, is reduced when the block is kept for some time in damp air. This reduction is caused by moisture being condensed and absorbed in the surface of the material. Even if the material is perfectly non-hygroscopic, the resistance will be reduced by leakage in the layer of moisture. It is not easy to determine to what extent the properties of the material can prevent condensation of water vapour. The specific heat and heat conductivity of the material also affects this. If the material is absolutely non-hygroscopic, the water will soon evaporate when the air becomes drier or warmer. But if the material will absorb water, the reduction of the resistance will be prolonged or possibly permanent. The reduction of resistance caused by absorption of water is measured in the following way according to German methods. Two strips of tinfoil, 100 mm. long and 100 mm. apart, are pressed against one side of a test rod. The resistance between the strips is measured before and after the rod has been immersed for 24 hours in water. All drops of water are carefully wiped off the rod with a cloth before the measurements are taken. For ordinary bakelite, the resistance is about 300 000 megohm before and 4 000 megohm after the immersion in water. For moulding compounds of the classes II and III, on the other hand, the surface resistance is more than 300 000 megohm both before and after immersion.

Fig. 14.

Fig. 15.

Fig. 16.

Fig. 17.

Fig. 18.

L: *Effect of chemicals.* Weak acids do not affect bakelite. Strong acids and weak bases affect it slowly, while strong bases will completely destroy it.

Some Bakelite Parts of Particularly Great Importance to the Telephone Industry.

1) *Hand-microtelephones and telephone sets.* These instruments demand a material of great strength, attractive appearance, and a surface which does not lose its polish when exposed to sunlight, heat, or moisture. Bakelite is an ideal material for these objects. However soiled and dusty a bakelite surface may be, wiping it with a duster will make it as good as new. Bakelite is also pleasant to the touch, as it does not feel cold or absorb moisture.

2) *Terminal blocks.* Terminal blocks of the most varying shapes and sizes are required in telephony. The are most suitably made of bakelite with inserted metallic contacts. If the contacts are correctly designed, they will remain firmly fixed and will not work loose when the terminal screws are tightened. Fig. 16 shows a block with 100 contacts threaded inside at both ends.

The contact block may frequently be made with a base for the whole apparatus of which it forms a part, which will reduce the number of loose parts required. The thermo-contact base shown in fig. 18 is an example of this.

3) *Framework for Coils.* Bakelite has been extensively used for manufacturing frames for resistance, induction, and magnet coil windings, etc. The relay is undoubtedly one of the most important parts of an automatic switchboard. By moulding the coil frame directly on to the iron core a uniformity of manufacture is obtained, greater than any obtainable by the old method with loose end plates. The uniformity of the frames enables the winding to be done with great rapidity in automatic machines, and it is also possible to utilize the winding space better, as the winding can reach right up to the end plates. Fig. 19 illustrates a coil frame without core, and fig. 20 coil frames with iron cores for relays.

Fig. 19.

Fig. 20.

Fig. 21.

Fig. 22.

Fig. 23.

4) *Contact-spring groups.* Insulating parts of many kinds, with contact-springs moulded into them, are manufactured, e. g.: tab groups, spring blocks, contact-spring groups, contact segments etc. Fig. 21 shows some specimens.

5) *Plugs and jacks.* A plug and jack is used for rapidly connecting and disconnecting an electric apparatus and the supply lines. They must be made with great precision, particularly for the higher pole-numbers, to allow the plug to enter the jack without exerting too much force and yet without play. Fig. 22 and 23 show various types of plugs and jacks.

The Alpha Testing Machines.

By *K. Nilsson.*

Prior to the year 1914 the art of testing materials had been brought to a high degree of perfection, fully justifying the vast and important position it occupied in industry. Later the technical experiences in the war, which in its last stage to a large extent became a machine-war, further increased the appreciation of the importance of material testing for technical progress. Great activity is now displayed in improving older testing methods and creating new ones, as well as in designing machines for executing these methods. Without exaggeration it may be said that the safety and speed in air, land, and sea traffic, have been made possible by recent developments in material testing. All Engineers realize that the modern and dependable machines and tools which they use could not have been produced unless careful testing had revealed the properties of the materials in this manufacture.

R 1814 Fig. 1. The "Durando" Brinell Press.

Even comparatively small workshops are to-day equipped with testing machines of some kind or other and employ specially trained persons for testing both raw materials and finished products. No one wishes to lag behind as regards quality, and the best way to improved quality is efficient and reliable testing.

For testing the hardness of iron and other metals, the Brinell Ball Test is universally used, and the only method internationally adopted as standard for such tests. Brinell published his treatise on his method in the year 1900, and extensive investigations have since been made by eminent metallurgists, but so far it has not been possible to improve upon or find a substitute for his method. On the contrary, its wide utility has been further confirmed. According to the famous English steel expert Sir Robert Hadfield, Sheffield, it is still the guiding light for all testers.

A few years after the publication of the Brinell method, the Alpha Works designed an apparatus for executing the Brinell hardness test, which apparatus is now widely used in the largest steel mills and engineering works of all industrial countries. It is found in the most remote parts of the world: China, Japan, Australia, Africa and India.

It is easily understood that an apparatus like the Alpha Brinell machine, which is recognized to give the most exact results hitherto obtained in any testing machine, should be installed in numerous institutes for technical education and in Government Testing Stations. The error at the maximum load of 3000 kg amounts to only 0,1 per cent, which error is of no practical significance.

In spite of all imitations of the Alpha design, and notwithstanding many other hardness-testing instruments of various designs, the Alpha press has not only held but extended its market.

The model "Durando" here illustrated (Fig. 1) is the standard machine in general use. It would be unnecessary and too lengthy to describe its construction, but it may be briefly mentioned that its operation is extremely simple and convenient. The test piece is placed on the table on the top of the elevating screw, which is raised until the test piece is brought in contact with the ball. A release valve is closed, and the pressure produced by means of a handpump until the yoke carrying the weights rises, which indicates that the desired pressure is attained, at which moment the gauge indicates the pressure corresponding to the weights applied. If the gauge should indicate a different pressure, it is faulty, but this has no influence whatever on the test result, since a correct load is ensured by the weights. When the pressure has been applied for the time prescribed for the material under test—about 15 seconds for iron and steel and about 30 seconds for softer metals — the pressure is released by opening the valve, and the test piece is released and can be instantly removed by turning the elevating screw. The diameter of the indentation

B 1815 Fig. 2.
The "Duresta" Brinell Press, for testing large objects.

is measured by means of a microscope, and finally the corresponding hardness number is read off on a table supplied with each press.

Brinell proved that a certain relation exists between hardness and tensile strength of wrought and rolled iron and steel. From a known hardness number the ultimate tensile stress of these materials can therefore be calculated with an accuracy sufficient for practical purposes. The tensile strength values calculated according to the Doehmer and Hadfield formulas are given in the table mentioned.

Special machines are designed for testing large objects; for inst. the "Duresta" model (Fig. 2) with a vertically and horizontally movable arm carrying the testing apparatus, and "Duribal" (Fig. 3) with two pillars to be mounted on a concrete bed with rails for passing the large objects (projectiles etc.) on a trolley through the machine.

Special models are also made according to customers' specifications or designs, if feasible. A machine for testing heavy rollers af 250 to 1200 mm. diameter is shown in Fig. 3 a.

B 1816 Fig. 3.
The "Duribal" Brinell Press, for testing large objects.

The success of the Brinell method and the Alpha machine has been great, but there are of course certain limitations. It has proved impossible to use the ball test for the hardest steels because steel balls cannot be made sufficiently hard to withstand without deformation a high testing pressure.

But these materials also must be tested, and for this purpose various methods and instruments have been tried, but have not proved very suitable, for inst. Scleroscopes, Rebondimeters, Pendulum Testers, and others.

In recent years the Rockwell Test has come to a fairly extensive use for hardened materials. This test is performed by means of a

R 1817 Fig. 3a. Brinell Press for testing rollers.

diamond cone the indentation of which is read on a dial gauge. The point of the cone, however, is slightly rounded, and the test is consequently neither a cone test nor a ball test, but an unnatural combination of both. Another peculiarity of this method is that for softer materials the diamond is replaced by a steel ball (of $^1/_{16}$" diameter) to which a load of 100 kg instead of 150 kg is used. The reading is then made on another scale, because if readings were made on the scale for testing with the diamond and graduated 100—0, negative readings would be obtained. This scale indicates how much the depth of indentation is less than 0,2 mm, and when the depth is greater than 0,2 mm negative values are of course obtained.

The reason why this test has been so extensively used in spite of these drawbacks is that no better method has hitherto been available. A valuable feature is, however, that the result can be read off directly on the dial indicator, thus saving considerable time in routine tests on mass production.

Absolutely to ensure a more uniform method of testing very hard materials, Alpha designed about 3 years ago the "*Durometer*" (Fig. 4) for which a plain diamond cone ground to an angle of exactly 120° was chosen as indentation tool. The actuel *depth of indentation* was adopted as Hardness Number, and the "Alpha" scale was graduated 0—100. The harder the material, the smaller the depth of indentation, and vice versa. The dial indicator has a shorter pointer which indicates the number of complete revolutions made by the long pointer. If the indentation in soft materials exceeds 100, the positive reading is simply continued for inst. 110—120 and so on, which is obviously more rational than to register negatively —10, —20, or to take a ball and a different load for soft metals.

The Alpha Test, with a plain diamond cone (Alpha A-diamond) can thus be continuously used for both soft and hard materials and with positive readings. The great advantages of this method will readily be appreciated.

The Durometer dial indicator has a red scale also, to carry out Rockwell tests when required. A diamond with rounded point is then used (Alpha B-diamond). For soft materials a $^1/_{16}$" diameter ball and a weight load of 100 kg are used, in which case the red 30 (= 130) division is taken as starting point.

The Durometer can also be used for Brinell Ball tests under small loads up to 250 kg according to British and German Standards. Special weights, ball holders, and balls are supplied for such tests, which can be made with the same accuracy in the Durometer as in the Brinell

R 1818
Fig. 4. "Durometer" for testing hardened steel.

presses. The loads are accurate within ± 0,2 per cent.

When making routine tests, much time can be saved if the relation between the depth and the diameter of the indentations is given in a diagram or table for each kind of material, thus avoiding the lengthy microscopical measuring of the indentation diameters and reading the corresponding hardness numbers in the table.

A test with the diamond in the Durometer takes only about 15—20 seconds, and the apparatus is therefore very suitable for routine hardness control even of finished articles. The marks made by the diamond are insignificant and negligible.

Not only flat and round pieces, but also objects of more complicated shape, for which special supports can be made, may be tested in the Durometer.

R 1819

Fig. 5. "Carbometer" for determination of the carbon content of steel baths.

Although the Durometer has been on the market only a very short time, large numbers are already in use, and the apparatus has been highly appreciated for its convenience, and many favourable certificates confirming its great utility have been given.

Another Alpha apparatus which has attracted much attention from steel experts is the Malmberg—Holmstroem Carbometer (Fig. 5) for which the inventors were awarded the Gold Medal of the Swedish Academy of Engineering Science.

This apparatus is designed for the accurate and rapid magnetic determination of the carbon content of steel baths, and achieves this very successfully.

The "rapid" methods previously used for this purpose did not give sufficiently accurate results, and the more reliable chemical analyses were too lengthy. It was therefore frequently difficult to tap the steel bath in due time, which of course gave wrong carbon percentage, resulting in considerable loss of time and money.

The time required to make a test bar and to determine the carbon percentage in the Carbometer is only $1^1/_2$ and 2 minutes respectively. The accuracy is the same as with chemical analysis, viz. about ± 0,01 % C.

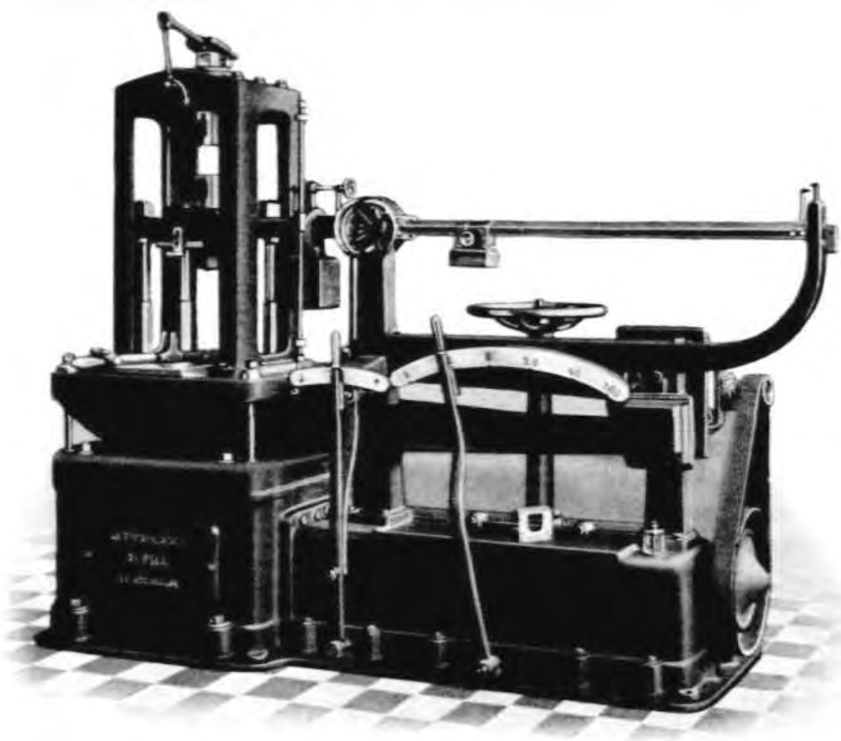
The carbometric testing is based on the known fact that the magnetic properties vary with the carbon content. A cast test bar is exposed to the alternate action of two magnetic fields of different intensity. These are created by means of permanent magnets and an armature driven by a clock-work, which, after having been wound up and started by depressing a button, causes the armature to rotate a certain number of revolutions. A stronger and a weaker induction is then alternately produced in the test bar. By depressing another button the armature rotates the last quarter of a revolution, during which the induction is altered from the higher to the lower value. The test bar is inserted in an induction coil connected to a ballistic galvanometer. The fall of induction creates an electromotive force in the coil generating a small electric surge. This surge causes the pointer of the galvanometer, to deflect, and its deflection corresponds to the carbon content of the test bar.

The relation between the results of chemical analysis of the test pieces and galvanometer indications is plotted in a diagram or table, which is used in routine control of steel decarbonization. For carbon percentages below 0,40 % unhardened test bars are used, and for more than about 0,40 % hardened test bars.

Carbometers are now in use in all leading Swedish and in many of the largest German Steel Works, and have also been supplied to U. S. A., England, France, Austria, Belgium, Norway, Italy, Spain and other countries. Several instruments have also gone to Russia.

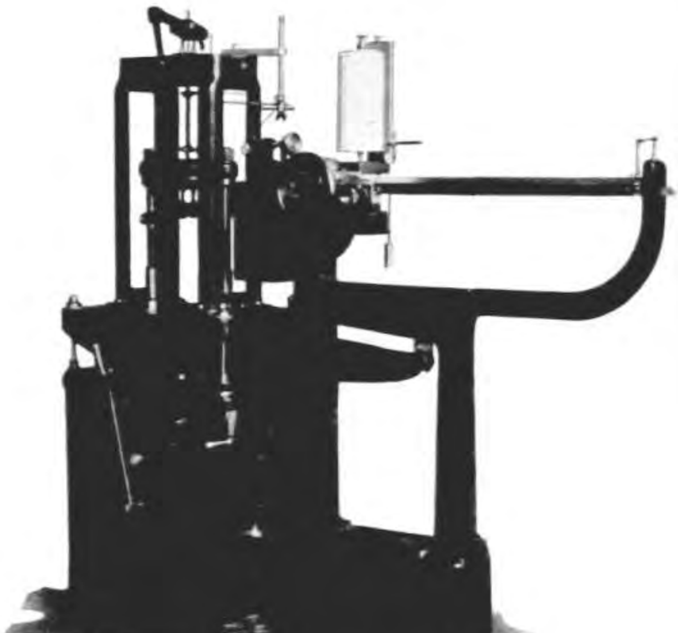
The testing machines described above are the specialities of Alpha, but many other machines for various tests have also been constructed in the past years.

Fig. 6 shows a machine for tensile and compression tests under a maximum load of 50 000 kg. These machines are in use at the Technical University and the Government Testing Institute of Stockholm, as well as in other technical schools, steel works and engineering works in



R 1820

Fig. 6. Machine for Tensile and Compression Tests, 50 tons.



R 1821

Fig. 7.
Machine for Tensile and Compression Tests, 10 tons.

R 1822

Fig. 8.
Machine for Endurance Tests by rotation under load.

R 1824

Fig. 9. "Pendulum Hammer", for Impact Tests.

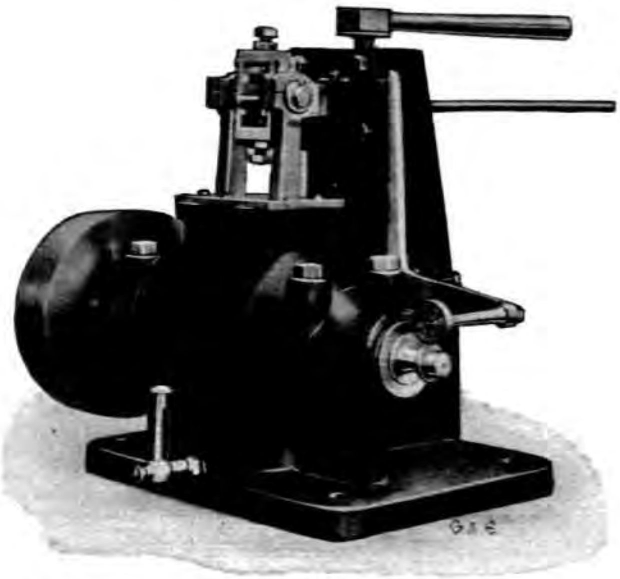
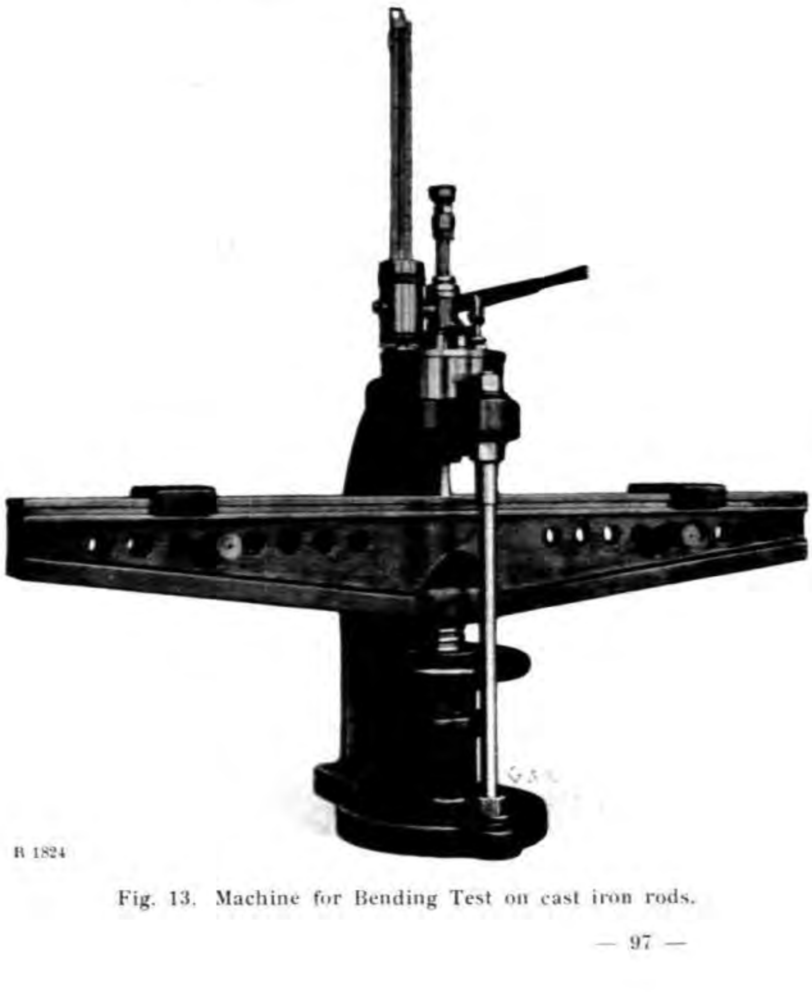


Fig. 10. "Arnold"-Machine for repeated Bending Tests.

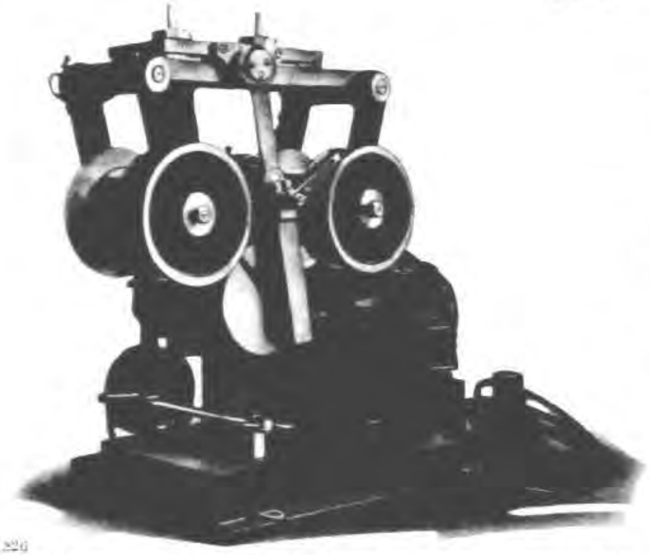
R 1824 Fig. 11. "Veritas"-Machine for Impact Tests.

Fig. 12. Machine for Impact Fatigue Tests.



R 1824

Fig. 13. Machine for Bending Test on cast iron rods.



R 1826
Fig. 14. Machine for testing the wear of linoleum, leather, etc.

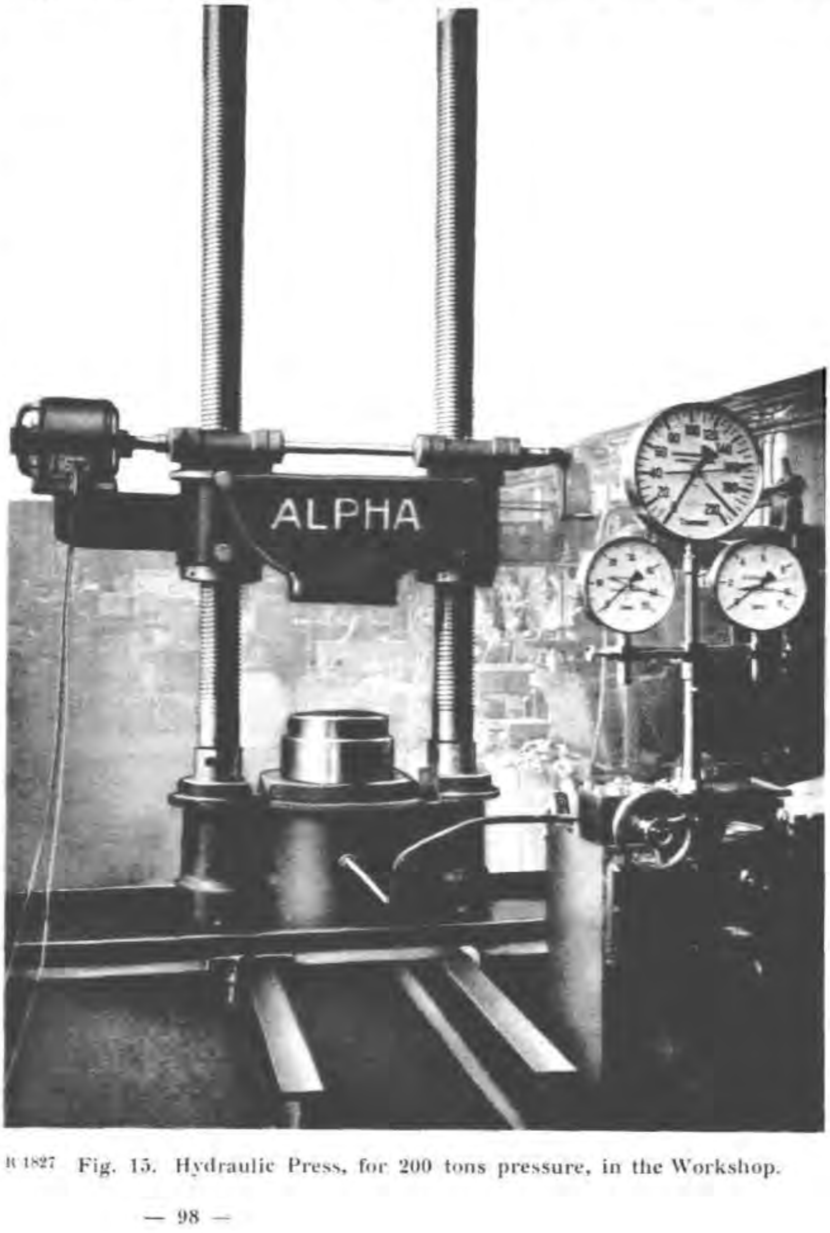
Sweden and abroad. The design fulfills all requirements, and the operation is extremely convenient. These features characterize also the smaller machine for 10 000 kg max. capacity (Fig. 7). By means of special devices other kinds of tests may also be made in these machines, for inst. bending and folding tests, compression and shearing tests etc.

In the machine for fatigue tests under load and rotation (Fig. 8) the capacity of iron and steel to withstand such stresses as, although below the elastic limit, will cause rupture if the stresses are too frequently repeated, is investigated according to the method of Professor Roos af Hjelmsäter. This test is invaluable in the construction of motor cars, airplanes, and the like, which must be of minimum weight, and yet absolute reliability.

A test bar is fixed to each end of the machine shaft, which is rotated by means of an electric motor. The free end of each test bar is loaded by weights suspended in ball bearings. A revolution counter is provided for each test bar. When one of the test bars breaks, its counter is detached, and when the second bar breaks the machine stops automatically. The speed of rotation is 3000 r. p. m.

By means of the "Pendulum Hammer" (Fig. 9) impact tests are made according to the method of Professor Charpy. The pendulum is caught up and then released after the test bar has been inserted. The angle to which the pendulum swings after breaking the bar is read off on a scale and the corresponding energy absorbed is obtained in a table.

The "Arnold test" is made in the machine for repeated bending (Fig. 10). The test bar is gripped in a clamp and is deflected in both directions until rupture takes place. A counter records the number of times the bar is able to withstand



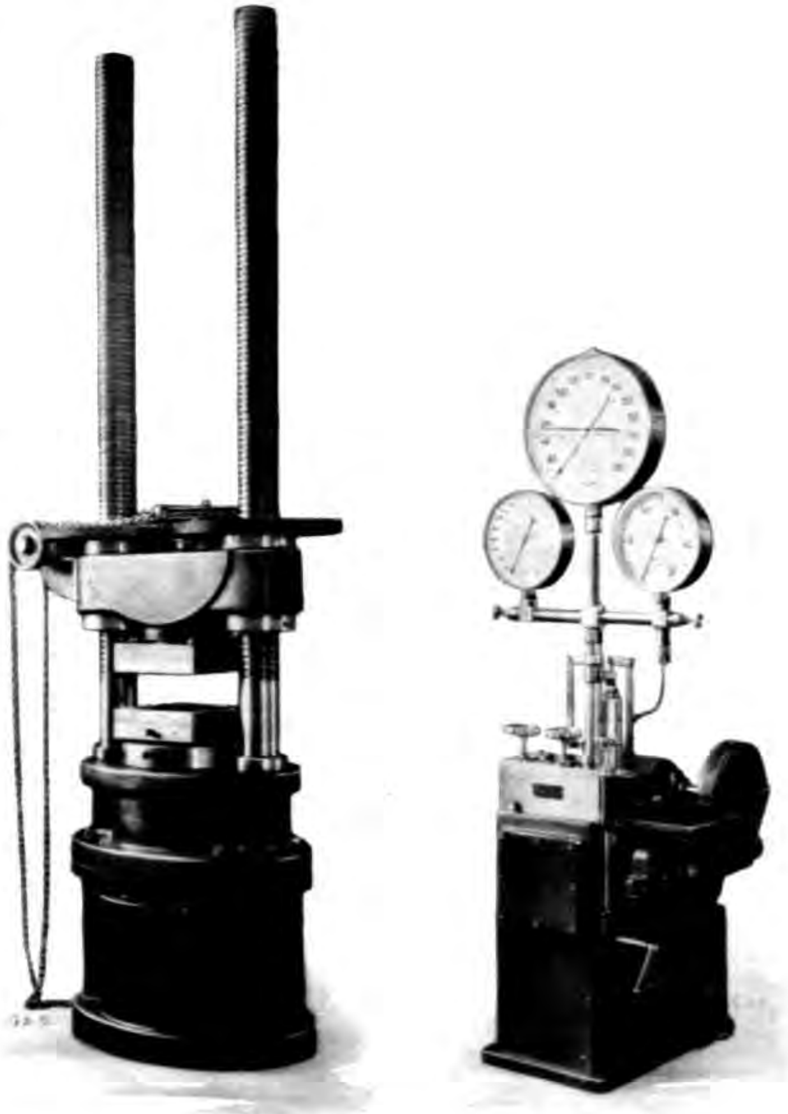
R 1827 Fig. 15. Hydraulic Press, for 200 tons pressure, in the Workshop.

these repeated bendings, which is an indication of the qualities of the material.

According to the specifications of "Bureau Veritas", cast iron should be tested by a weight block freely dropping from different heights on to the middle of a cast iron test bar placed horizontally. The apparatus shown in Fig. 11 is designed for the convenient execution of this test.

The machine for impact fatigue tests (Fig. 12) is intended for investigation of the ability of a material to withstand repeated impacts of such force that the limit of proportionality is not reached by the effect of the blows. The test bar is subjected to 100 double blows per minute and the number of blows is recordered by a counter which stops simultaneously with the machine when the bar is broken.

Fig. 13. This hydraulic apparatus is for transverse tests on cast iron bars of different length under a maximum load of 1500 kg. A mercury gauge indicates the pressure exerted and the deflection of the test bar (maximum 25 mm) is read off on a vernier millimeter scale at the side of the gauge.



B 1828 Fig. 16. Hydraulic Press with pump, (175 tons).

In addition, the Alpha Works have constructed machinery for testing materials other than iron and metals. For example the machine for abrasion tests on linoleum, leather and the like (Fig. 14) is the latest in a series of special machines. The abrasion is produced by means of an endless emery band, advanced over the test piece placed under the disc moving in both directions. The disc is loaded by weights for obtaining the pressure desired. The loss of weight of the test piece after a certain number of turns, when the apparatus stops, is taken as an indication of the quality of the material.

Large hydraulic presses have been supplied to the Technical University and the Government Testing Institute for testing structural materials. The press illustrated in Fig. 15 is designed for a maximum pressure of 200 tons and is used for compression tests of concrete cubes and brick columns. The lower testing table is run in and out on rails on the floor. The upper cross head is raised and lowered by means of an electric motor.

Fig. 16. Hydraulic press for 175 tons maximum pressure.

The preceding summarised account of some of the Alpha Testing Machines will no doubt give a fair idea of the great variety of tests to which it has been found expedient and necessary to subject the materials used in modern industry. Thanks to these careful and elaborate tests, it has been possible to satisfy the continually increasing demands for safety of structures and greater efficiency of machines and tools and the more and more severe specifications for approval of materials delivered.

This development entails of course increased demands also on the quality of the testing machines, and appreciating the fact that in material testing accuracy is the most essential factor, the Alpha Works have always endeavoured to create the most appropriate designs, and bestowed the utmost care on the mechanical construction of the machines, which are made to stand for ages.

Bakelite and its Uses.

By *A. Franchi.*

The inumerable patents for rubber-free plastic substances applied for and granted since the beginning of this century indicate that both the interest taken in and the need for some material which can be moulded and be suitable for mass production must have increased enormously during the last decades. The raw materials chosen for the manufacture of these plastic materials have been of the most varying nature, e. g. asphalt; tar; gelatine; albumens; cellulose-nitrates, cellulose-acetates, and cellulose-formates; as well as natural and artificial resins. Amongst these the synthetic resins, and first of all bakelite, are now extremely widely used, and have been given a unique and fully merited position in industry.

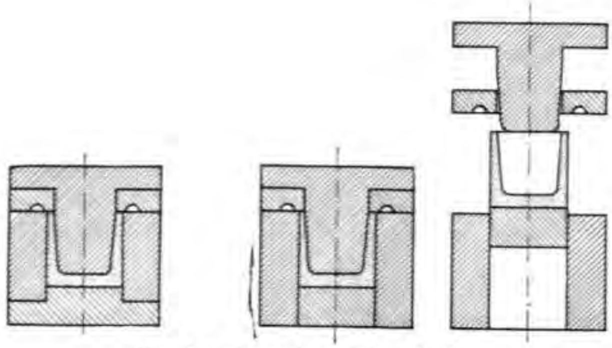
The principal requirements of a plastic substance suitable for large scale moulding are that it must be "plastic" and may be quickly and economically moulded, and that the final product shall be homogeneous, stable and constantly uniform in quantity production. Special demands may also be made, for instance that the material should be non-inflammable and heat resisting, unaffected by water, damp, radiation, gases, oils, acids, and all solvents other than alkalies. Further that it must be non-hygroscopic and non-porous, that it posseses great mechanical strength, and acts as good dielectric, be of unchangeable colour and able to take a permanent, lustrous finish. Bakelite meets these manifold requirements in an excellent manner and in addition possesses other good qualities, to which mention is made below, and which explain its extraordinary success.

If phenols are acting on aldehydes or its homologues in the presence of a catalyzer and under heat, a condensate is formed which, when the water separated has been distilled away, consists in a more or less semi-solid, resinous, colourless or yellow-brown substance—"synthetic resin"—of varying consistency and of very divergent properties. The best known of these resins is bakelite, so named after Dr. L. H. Baekeland, Boston, who first succeeded to isolate the resin and work out manufacturing procedures and methods of treatment, which he endeavoured to protect by a series of patents about 1909—1910.

There are three modifications of bakelite, called A-bakelite, B-bakelite, and C-bakelite respectively, each with distinctly different properties. When subjected to heat A-bakelite—without any definitely determinable point of conversion—will be transformed into B-bakelite and finally into C-bakelite. Of these modifications, only the first mentioned is soluble. It is soluble in alcohol, glycerine, phenol, and soda lye. B-bakelite is insoluble, but will swell in acetone, phenol and turpentine. When heated it fluxes or softens and under further application of heat it is gradually converted into the insoluble and infusible final produkt C-bakelite, commonly called simply "bakelite".

On the basis of these characteristics of the bakelite substances, the moulding procedure is built up, but as pure bakelite is somewhat brittle, it must be mixed with some suitable, chemically inactive filler. Mineral fillers, such as asbestos and mica, as well as fibrous fillers, such as wood flour, shredded paper, or canvas cut to patterns or shredded, are used according to the particular properties required in the bakelite parts. Asbestos bakelite, for instance, is highly heat resisting, mica bakelite has good dielectric properties and paper or canvas bakelite great mechanical strength. The most common and easiest moulded mixture is wood-flour bakelite which, when correctly treated, is equivalent in practically all respects to the other varieties and, moreover, is also less "slow" in moulding than the others. More intricate designs can therefore only be made from wood-flour bakelite. It will be of interest to know that of all kinds of wood-flours that from Sweden is everywhere preferred.

The degree of dryness of the filler, and the



Hand tools and machine tools.

accuracy with which it is mixed up with the bakelite resin, are of vital importance to the quality of the final pressed articles. Commercial bakelite is supplied in the form of powder, either natural—yellowbrown—or of any colour desired from black to white and contains resin, usually in the main converted into B-bakelite. In the moulding operations, the hot mould is filled with powder and subjected to a pressure of 150—400 kilos per sq. cm. (2100—5700 lbs. per sq. inch) of the projected area of the piece to be moulded in a hydraulic press, the plates of which are kept at a temperature of 160—200° C.

The heat makes the bakelite powder doughy and subsequently converts it into C-bakelite. The time required for this process varies from about 1 to 2 minutes per mm. thickness, depending upon the temperature in the press and the proportion of resin in the powder, also upon the extent of the conversion. When eventually cooled, the mould is opened, the bakelite piece is ready, reproducing with exact fidelity the form of the mould. If the design is fairly simple, the same mould may be used up to 100 000 times—and the bakelite parts will all be found of exactly identical dimensions and colour as well as possessing all the properties of the bakelite mentioned above. A real standardization!

The high pressures employed (20—600 tons), and the wide variations of temperature, requires moulds made with the utmost accuracy of special steel. Two types of such moulds are used: hand tools and machine tools. The hand tool type is suitable for small quantity production, and also when more complicated designs require moulds having several loose inserts etc.

In the latter case hand tool moulds may also be used in large quantity production. For real mass production, however, machine tools are most suitable. These are fixed in hydraulic presses and are provided with devices for knocking out the finished pieces from the moulds. Such moulds are generally so made that several pieces may be pressed simultaneously, thus materially reducing the moulding costs. The presses are also sometimes fitted with automatic or semi-automatic devices for filling the moulds with powder or, in special cases, with powder tablets; also with valves for automatically turning off and on the heat or the cooling water, or control the high or low pressure, and devices for hydraulic knocking out of the pressed parts. These arrangements for loading the moulds with powder reduce the possibility of faulty charging and prevent the workman from cutting down, either intentionally or not, the time required for curing, which is of great importance for ensuring the highest quality product.

An object made of first class bakelite immediately attracts attention by its very pleasing

Case for shopkeepers balance. (720 mm. high).

Knobs and dials.

appearance. The surface is dense, lustrous and of a warm and deep colour. Moreover, marble imitation, granulation and encrusting of different shades is possible. Trade marks, lettering, numbers, and decoration in low relief will appear beautifully defined, and by various methods of surface treatment of the mould such as ball hammering, sand-blasting, guilloching or polishing, beautiful effects of dull, brilliant or patterned surfaces are effected. Bakelite has therefore been chosen as the material for many articles in which just such features are desired, e. g. casings and cabinets for wireless sets, compasses, calculating machines, cash registers, shopkeepers balances, measuring and recording instruments, linings for clocks and cameras, photo-frames, boxes, instrument cases, capsules, and innumerable kinds of coverings, for which pressed or cast metals were previously used. Besides improved appearance, the manufacturing processes are simplified and cheapened, as all finishing operations, such as removing burrs, fine-grinding, puttying, lacquering, etc., are eliminated. In addition, bakelite does not crack, there is no paint to flake off, the surface is durable and practically indestructible, takes a high polish when buffed and further, which is frequently of importance, the specific gravity is low (1.35).

A disadvantage of ebonite and hard rubber compounds is that they gradually give off free or uncombined sulphur, thus causing the surface to become dull and discoloured. Bakelite has therefore displaced these materials whenever lasting appearance is desired, as for instance for knobs, dials and panels for wireless apparatuses—shafts and handles of every description—door and furniture fittings—requisites for smokers and writing desks and toilet tables—brush handles and backs, etc. For other articles such as pipes, cigar and cigarette holders, ashtrays, candlesticks, handles for cooking vessels and curling tongs, etc., i. e. where high resistance to heat is required, bakelite, because of its superiority in this respect, has superseded both ebonite and casein as well as the derivates of cellulose and natural resins. Practically every one of the many unique features bakelite has opened for it new fields of use. Its extraordinary plasticity makes it excellent for the manufacture of gramophone records, slide-rules, dental plates, reliefs, medallions, seals, stamps, and plates for artistic printing; being insoluble, it is possible to utilize it for mugs and cups, accumulator vessels, and a multitude of articles for surgical and chemical purposes, and its resistance to wear makes it particularly suitable for washers, rails, rotary parts and bushings, with or without graphite mixed with the bakelite powder.

With a bending strength of 800—1000 kilos per cm^2, and an impact strength of 6—7 kilos cm/cm^2, it is only natural that bakelite should be used for a number of constructional parts, even where the allowable tolerances are fairly rigid. When cooling in the mould, the shrinkage of bakelite is comparatively constant (ca. 0.04 %) so that the dimensions of moulded bakelite can be held if necessary within limits of ± 0.05 mm. in a piece of about 100 mm. in diameter and of fairly regular shape. As it is also possible to produce holes in the parts, to mould male and female threads, and to press parts having metal inserts, and on springs, tubes, or casings etc., the uses of bakelite are enormously extended. The following articles, for example, may be made of ordinary bakelite: motor housings and shields, pulleys, brush plates for

Box for wireless set.

floor polishers, yokes and panels for fittings of various descriptions, parts for violins and other string instruments, castanets, mouthpieces for saxophones and clarinets, keys for pianos, calculating machines and typewriters, W. C., seats, lids and cisterns, knife and gauge handles, etc., and from canvas bakelite: nuts, tool handles, silent gears, and so on. From pure, unmixed, transparent or semi-transparent bakelite are made water level tubes, penholders, sun-goggles, beads, imitations of amber, ivory or precious stones and other fancy goods, ladies' trinkets and toilet articles, shaving brush and razor handles, and so forth indefinitely.

The present range and variety of uses for bakelite is extremely wide, but the possibilities are yet far from being exhausted. The most important use still remains to be mentioned, viz. bakelite as an insulating material. In electrotechnics bakelite now plays an important part, thanks to such excellent dielectric properties as: surface resistance 10^4—10^6 megohm, internal resistance*) 10^4—10^6 megohm, resistance to puncture ca. 30 000 volt per mm. thickness, and specific resistance 10^5—10^6 megohm. The low hygroscopicity and the freedom from porosity of the material, precluding disruptive electrolytic or electroosmotic phenomena, make bakelite a still more suitable dielectric. An enumeration of insulating parts made from bakelite would only take up too much space and even so would not give anything approaching a complete idea of how useful bakelite really is in this field of industry. It is worth noting, however, that there is hardly a single insulating part used in low tension electrotechnics which is not manufactured from bakelite, and that bakelite, particularly in recent years, has gained more and more ground also in high tension electrotechnics. Bakelite insulating materials are making their way into the market, and all household electric appliances will no doubt in the near future be provided with insulating bakelite casings.

Another use of bakelite insulation is based on the solubility of A-bakelite in alcohol. Paper free from glue or canvas is impregnated with such a liquid solution, dried and used for insulating windings. The conversion of the bakelite impregnating liquids is made in autoclaves at a temperature of 90°—160° C, and under a pressure 2 or 3 atmospheres higher than the steam pressure at the temperature used. The bakelite-impregnated paper or canvas may also be wound into tubes of various dimensions, cut to suitable sizes and compressed under heat to sheets up to

*) Measured acc. to „Vorschriften für Prüfung elektr. Isolerstoffe", V. D. E.


Bottom panel for electric mains supply radio set.

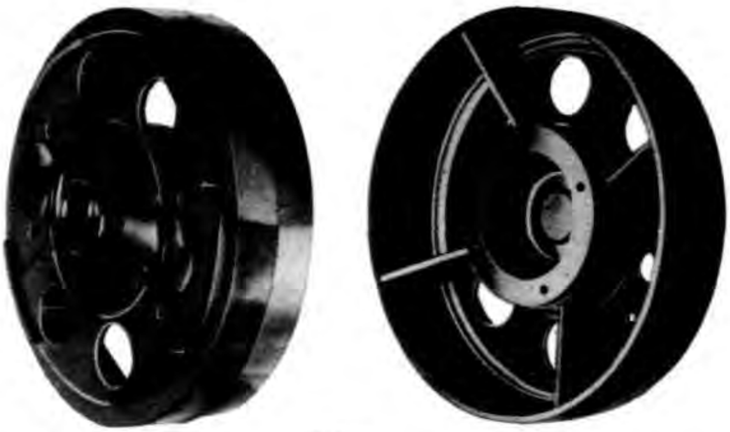
Parts of handle.

Brush plate for floor polisher.

50 mm. (2") thick. Such sheets have great mechanical and dielectric strength, and are used for instrument and wireless panels, punchings etc.

The manufacture of bakelite parts in Sweden was started almost simultaneously about 10 years ago, by the A.-B. Alpha, Sundbyberg, and the L. M. Ericsson Telephone Factory, Stockholm. L. M. Ericsson produced exclusively parts used in telephony, and have brought this speciality to a unique degree of perfection. A.-B. Alpha, on the other hand, manufactured mostly to customers' orders, and in a few years gained a reputation second to none. In the radio market the Alpha types and models of wireless parts have become standard even on the Continent and are widely imitated.

In October 1929 Alpha was merged in the Ericsson Corporation, and soon after the bakelite department of this latter concern was transferred to the Alpha works, the productive capacity of which, previously about 15 mill. pressed pieces annually, was as a consequence nearly doubled. With such resources new conquests may confidently be expected for the material, which in America is known as: "the material for 1001 uses", and in a very real sense truly is so.



Pulleys.

Sockets with metal inserts.

Lightning conductor insulation.

Connecting boxes with joints.

Lamp socket holder.

Various Radio Components etc.

The Use of Thermionic Valves for Generating Multiple Frequencies.

Mauritz Vos.

Håkan Sterky.

At the annual meeting of the Swedish Association of Engineers and Architects on Juni 12th 1930, Dr. Mauritz Vos and Mr. Håkan Sterky, E. E.,—both attached to the Radioaktiebolaget Telephony Department—were awarded the Polhem Gold Medal for a treatise on "The use of thermionic valves for generating multiple frequencies". The distinction thus gained by two members of the Ericsson Concern is the highest reward given in Sweden for technical authorship. The Polhem Fund was established more than 50 years ago, and competitions for this prize have been held on eleven previous occasions, usually every fifth year. Only 13 prizes have been awarded so far.

The Polhem Fund is administered by the Swedish Association of Engineers and Architects, the Committee of which, assisted by special experts, selects the prize-winners. On this occasion H. R. H. the Crown Prince of Sweden distributed the prizes.

The winning paper has recently been published under the above title as No. 8 of the series "Publications of the Swedish Association of Engineers and Architects." As it is far too technical to interest a wide circle of readers, the whole paper will not be published in this Review, but a short summary is given below. A full reprint, however, will be sent to any interested reader on application to Svenska Radioaktiebolaget, Stockholm.

The principle of the new multiple generator is briefly discussed in an earlier article in this journal: "New Swedish carrier current telephone and telegraph systems on telephone lines", by H. Sterky (L. M. Ericsson Review No. 10—12, 1929).

A diagram of connexions for the multiple generator in its simplest form is shown in fig. 1, and its characteristic curve in fig. 2. Starting from the two equations giving the relation of anode current and control voltage in the two valves 1 and 2, viz.

$$\left.\begin{aligned} i_{a1} &= K_{o1} + K_{11}\, v_{R1} + K_{21}\, v^2_{R1} + \\ i_{a2} &= K_{o2} + K_{12}\, v_{R2} + K_{22}\, v^2_{R2} + \end{aligned}\right\} \quad \ldots\ldots\ldots \ (1)$$

the paper shows that the characteristic curve of the multiple generator may be written in the form

$$i_a = i_{a1} + i_{a2} = m_o + m_2\, v^2_g + --- \quad \ldots\ldots \ (2)$$

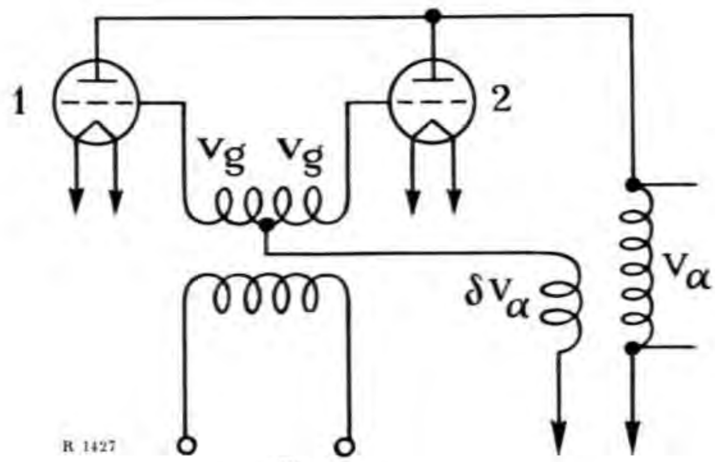


Fig. 1.

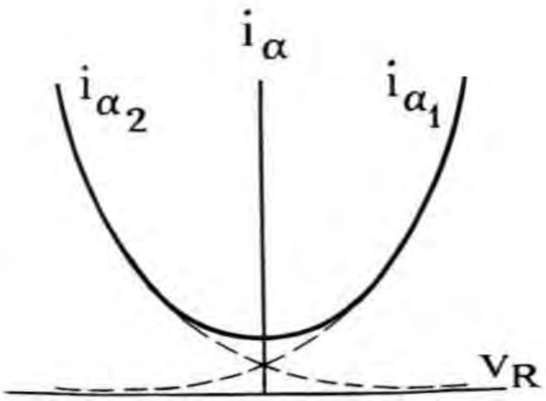


Fig. 2.

The conditions assumed are briefly as follows. The two valves are assumed to have equal static characteristics, i. e. the coefficients K_{o1} and K_{o2} K_{11} and K_{12}, and so on, are alike, which may also be expressed by saying that the amplifying factor μ and the slope S are equal for the two valves. It is further assumed that the working point has been selected so that the control D. C. voltages v_{Ro1} and v_{Ro2} are equal and $= v_{Ro}$ i. e. that by substituting

$$\left.\begin{aligned} v_{R1} &= v_{Ro1} + v_{R\omega1} = v_{Ro} + v_{R\omega1} \\ v_{R2} &= v_{Ro2} + v_{R\omega2} = v_{Ro} + v_{R\omega2} \end{aligned}\right\} \quad (3)$$

in equation (1), we may write

$$\left.\begin{aligned} i_{a1} &= i_{ao} + a_1 v_{R\omega1} + a_2 v^2{}_{R\omega1} + \dots \\ i_{a2} &= i_{ao} + a_1 v_{R\omega2} + a_2 v^2{}_{R\omega2} + \dots \end{aligned}\right\} \quad (4)$$

where

$$\left.\begin{aligned} i_{ao} &= K_o + K_1 v_{Ro} + K_2 v^2{}_{Ro} + \dots \\ a_1 &= K_1 + 2 K_2 v_{Ro} + 3 K_3 v^2{}_{Ro} \dots \\ a_2 &= K_2 + 3 K_3 v_{Ro} + \dots \end{aligned}\right\} \quad (5)$$

The diagram of connexions in fig. 1 shows that a certain portion δ of the A. C. anode voltage v_a produced is impressed on the two grids in the same phase. The voltage v_g introduced to the grid from the outside, on the other hand, is of opposite phase. Consequently we may write for the two control A. C. voltages $v_{R\omega1}$ and $v_{R\omega2}$

$$\left.\begin{aligned} v_{R\omega1} &= v_g + \frac{v_a}{\mu} + \delta v_a, \\ v_{R\omega} &= -v_g + \frac{v_a}{\mu} + \delta v_a, \end{aligned}\right\} \quad (6)$$

One of the principal novel features of the multiple generator design is now that the amount and phase of the re-introduced voltage δv_a is selected so that

$$\delta = -\frac{1}{\mu} \quad (7)$$

which neutralizes or compounds the term $\frac{V_a}{\mu}$ caused by anode reaction.

According to equations (6) and (7) we then get

$$v_{R\omega1} = -v_{R\omega2} = v_g \quad (8)$$

and by substitution in equ. (4) and addition

$$i_a = i_{a1} + i_{a2} = 2 v_{ao} + 2 a_2 v^2{}_g \quad (9)$$

or, if we substitute $m_o = 2 v_{ao}$ and $m_2 = 2_{a2}$

$$i_a = m_o + m_2 v^2{}_g, \quad (2)$$

which is the fundamental equation of the multiple generator.

If we impress on the grids of fig. 1 an A. C. voltage of the amplitude E and the frequency ω, or, in other words

$$v_g = E \sin \omega t \quad (10)$$

we will get an anode current as in equ. (2) of the form

$$i_a = m_o + \frac{1}{2} m_2 E^2 - \frac{1}{2} m_2 E^2 \cos 2 \omega t,$$

which thus consists of a D. C. component and an A. C. component of the amplitude $\frac{1}{2} m_2 E^2$ and of the frequency 2ω, i. e. double the originally introduced frequency. In this way the frequency has been doubled. By means of so-called re-introduction, however, the multiple generator may be made to give off several higher harmonics and combination frequencies of the originally impressed frequency or frequencies. One suggested designs is discussed in detail in the paper. A diagram of the connexions of this is given in fig. 3.

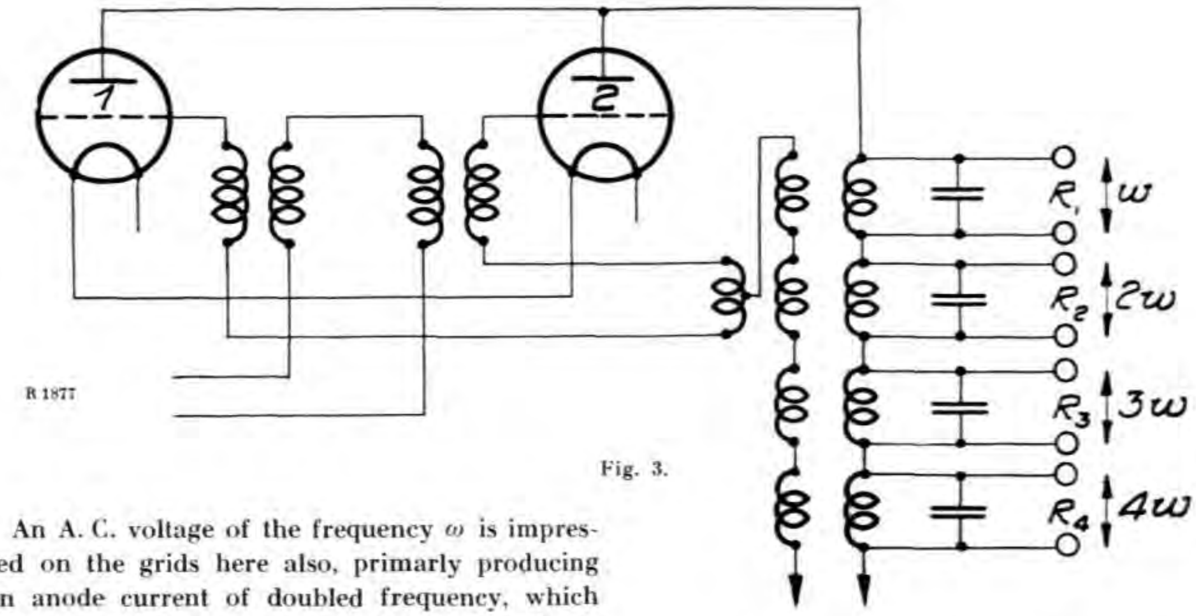


Fig. 3.

An A. C. voltage of the frequency ω is impressed on the grids here also, primarly producing an anode current of doubled frequency, which causes a voltage v_{a2} over a certain impedance R_2 in the anode circuit. This voltage will be

$$v_{a2} = \frac{1}{2} m_2 R_2 E^2 \cos 2 \omega t \qquad (11)$$

By re-introducing two voltages $a\ v_{a2}$ in opposite phases to the two grids, as in fig. 3, currents and voltages of the frequencies ω, $3\,\omega$, and $4\,\omega$ may also be caused in the anode circuit.

The simplification introduced into the equations by re-introduction makes it possible to compute the design of the multiple generator according to fig. 3 with mathematical exactitude for optimum effect at all the stated frequencies. The result of this analysis is given in the competition paper.

The principal characteristics of the multiple generator are:

1. The relation between anode current and impressed grid voltage is a quadratic function. The generated anode A. C. current will therefore contain the sum and the difference of the original frequency or frequencies introduced. (The frequency $2\,\omega$ may be considered the frequency ω added to itself, and the D. C. terms arise in the same way as the difference between two equal frequencies ω.)
2. The anode current of the multiple generator is constant and independent of any reaction from the anode circuit. The anode A. C. voltage arising over a certain impedance in the anode circuit is thus directly proportionate to this impedance.

   The modulator, in other words, gives a constant anode current, independent of the load. The similarity to the compound D. C. generator often used for power production has given rise to the name "compound multiple generator".
3. Thanks to this compounding, and to the quadratic characteristic, the compound multiple generator gives considerably larger useful effects than earlier multiple generators based on thermionic valves.
4. The multiple generator can be used for generating frequencies as low or as high as desired.
5. The mathematical determination of the multiple generator design is comparatively easy, for according to equation (2) the expression for the anode current is an explicit function of the grid A C. voltage. This is not the case in calculations for ordinary valves, as the resulting A. C. voltage is dependent on the anode current, for which the expression is usually implicit and difficult to solve. The paper also describes the best way of connecting and designing resonance circuits or filters in the anode circuit of the multiple generator, to permit oscillations of different frequencies to be taken out.

Some instances of the use of multiple generators in actual practice are given in the paper mentioned above (published in the L. M. Ericsson

Review No. 10—12, 1929 and 1—3, 1930). Other uses are also discussed in the treatise. In broadcasting, telephony, and telegraphy, particularly for synchronous working and for carrier current telephony and telegraphy equipments, multiple generators and modulators built on the principles here described will probably prove of great practical importance.

A REVIEW

of certain new designs of long distance telephony equipment and measuring instruments.*

By *Torsten A. Lundell*, E. E.

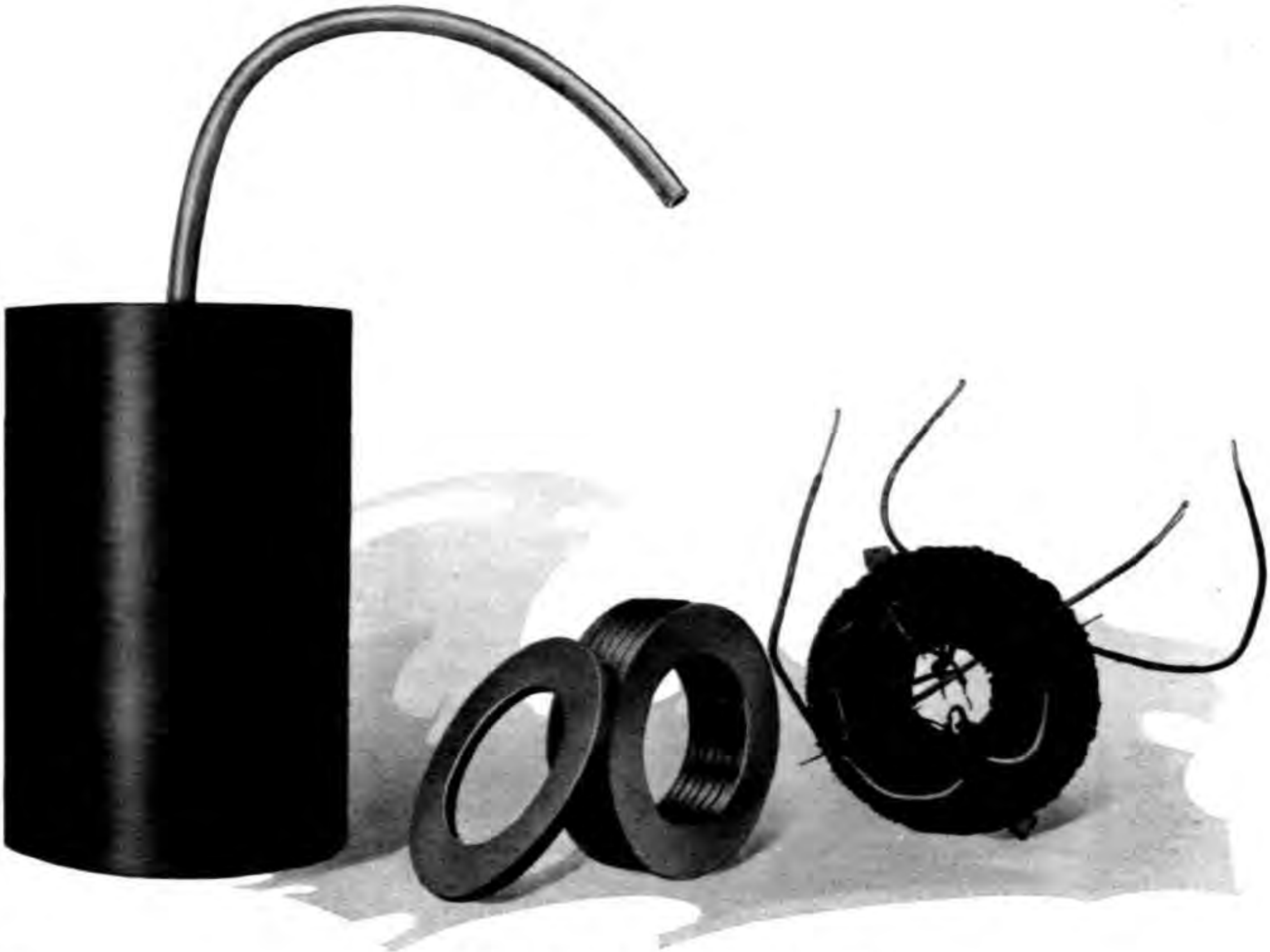
Just over 50 years ago, words were for the first time spoken over a telephone line stretching between two rooms in a small laboratory at Boston. Half a century later, the whole earth is covered by a network of telephone lines, and it is now possible to telephone, not only in one's own continent, but also to other continents, in spite of intervening oceans. Progress has consequently been very rapid in telephony.

The first telephone exchanges were very modest, and were regarded as large if a hundred subscribers or so were connected. The nets were small, and only single wire lines were used. A demand for better service and extended reach soon arose, and the lines were lengthened more and more. As long as distances were comparatively short, satisfactory transmission could be obtained by increasing the diameter and conductivity of the wires, but difficulties cropped up where cables had to be used, e. g. for crossing rivers. It was then found that not only the resistance of the wires, but also the capacity of the cable, affected the transmitting properties of the line. Line capacity plays a part in long aerial lines also, and causes an increase of attenuation. The first far-reaching step towards an increase of the range of telephone communication was the invention of loading coils. During the first decade of the present century, both aerial lines and cables began to be fitted with loading coils. During the war, other inventions were made which have made telephone communication possible across whole continents, namely designs involving what might be called valve and filter devices. Naturally enough, the demand for really long lines first arose in North America, where the greater portion of the continent forms one political unit. The difficulties are greater in Europe, which is divided into many different states with different languages, but the interest in international telephony is great. Some years after the war a permanent commission was appointed — the C. C. I. — to promote standards for international communications. We have also witnessed the recent powerful growth of international telephone communications, which justifies the hope that this is but the beginning of a large international telephone system.

The first *loading coils* used had cores wound from wire. Experiments have also been made with laminated cores with or without air-gaps. The type of core, however, which has vanquished all rivals is the dust iron core, and all modern loading coils now supplied for long distance lines are provided with dust iron cores. The problem in designing a good loading coil is to obtain great stability and small losses in the smallest possible size of coil. Stability is needed to keep the inductance of the coil unaffected by such speech currents, direct current telegraphy, or disturbing currents, as may enter the coil. The losses must not be excessive, or the properties of the line will deteriorate.

Fig. 1 shows the Svenska Radioaktiebolaget design of loading coil. The core consists of six pressed rings glued together in one core. This method of construction is suitable both from the point of view of manufacture and in order to increase the specific resistance of the core. Theoretically, the best core shape is the oval, but measurements and calculations have shown that in practice the resistance in the winding of a core of rectangular section does not exceed the resistance in a winding of the same inductance

* A paper read at a meeting of the Swedish Association of Electrical Engineers.



R 1931

Fig. 1. Loading Coils: details and coil group.

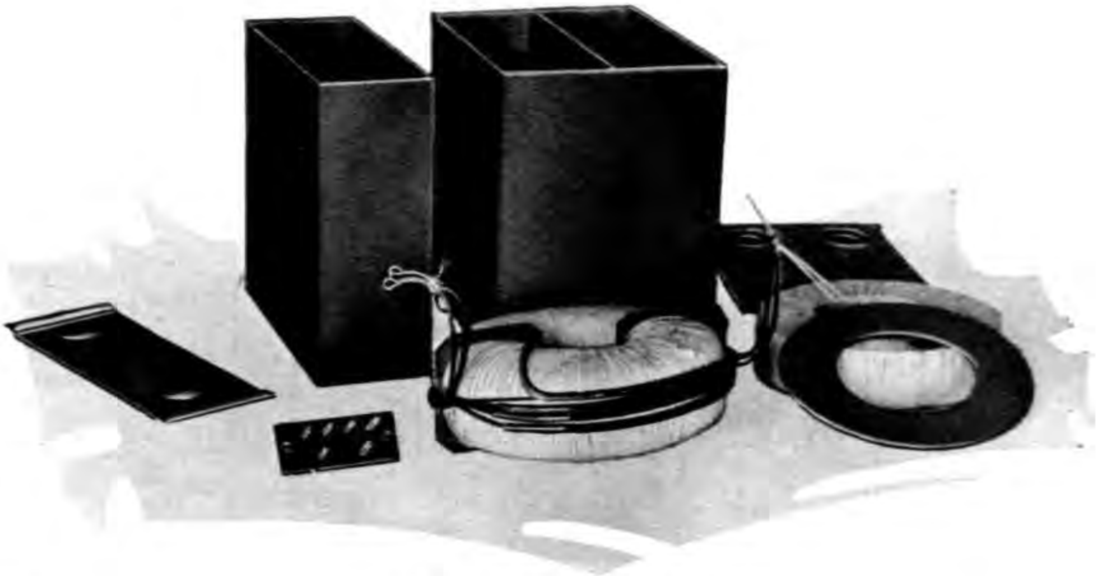
Type of coil.	Inductance H	Ohmic Resistance Ω	Total losses at 1 mA or 0.1 Gauss		Dimensions, m. m.	
			800 cyc.	1800 cyc.	diam.	height
WE No. 584	0.174	6.25	8.38	13.30	120	61
SR, cotton-insulated	0.177	5.85	7.51	10.97	120	52
CCI, standards . .	0.177	—	—	26.6	—	—
Brit. G. P. O. standards	0.177	max. 8.8	—	18.3	—	—

Fig. 2. Properties of Various Loading Coils.

on a core of oval section containing an equal quantity of iron.

The phantom circuit is usually employed in order to get the most out of the long and costly lines. It is necessary to load the phantom circuit also, and for each quad a coil group comprising three coils, one for each of the side circuits and one for the phantom circuit, will therefore be required. The illustration shows such a coil-group consisting of a cylindrical container with three coils and a lead-sheathed connecting cable. This container is well sealed and filled with compound. These coil units are meant to be fitted in the coilboxes, which need not then be filled with compound, as each coil unit is perfectly moisture proof. The cable is securely connected to the coil groups by lead cables.

Fig. 2 is a table giving the properties of some different coils as well as the specifications of the C. C. I. and the British G. P. O. The Western Electric coil included in the table is a loading coil which is extensively used for long distance cables. The table shows that the Svenska Radioaktiebolaget coils come well up to the established standards and can compete as regards dimensions and losses with the Western Electric coil. It is worth noting that the hysteresis losses of the Radioaktiebolaget coil have proved consi-



B 1932 Fig. 3. Line Repeating Coils.

derably less than those of either the Western Electric or the Siemens coil.

Line repeating coils are required when long distance lines enter an exchange, partly to match the impedances of the line and the exchange equipment and to separate them conductively, and partly to tap the phantom circuit. Fig. 3 illustrates a repeating coil made by Svenska Radioaktiebolaget. This has a toroidal laminated sheet iron core. When repeaters are connected to the line, another line repeating coil should be placed on the balance side of the repeater. Double coils, containing two well balanced repeating coils, are therefore supplied. Good balance is demanded from the line repeating coils, and the Radioaktiebolaget coils fulfil all demands made both as regards resistance unbalance and impedance unbalance. In addition, the efficiency of the coil must be the highest possible, with respect to both ringing current and audio-frequency currents. The attentuation of the Radioaktiebolaget line repeating coil is low and amounts to 0.01—0.07 neper for the most important speach frequencies. For ringing current of 20-cycle frequency the attenuation is 0.08—0.1 neper. The figures vary between the limits mentioned for coils with different impedance ratios. These values must be considered quite satisfactory, and are well up to the accepted standards.

To attain a very long range for telephony, other means must be employed than mere loading and increase of the wire diameter. If the loading is increased beyond certain limits, the cut-off frequency of the line would become too low. The possibilities of designing a telephone repeater which could be applied to the line at suitable distances apart, were therefore investigated at an early date. Mechanical repeaters, in principle a combination of a telephone and a microphone, were first tried. These early repeaters gave very high amplification, but were extremely sensitive to disturbances. They were used on the American transcontinental lines, but were entirely superseded by valve-repeaters as soon as the thermionic valves had been perfected sufficiently for practical purposes, which was done during the war.

Some connexions used for *telephone repeaters* are shown in Fig. 5. Certain units, recurring in various combinations, can be distinguished in all these diagrams. In the German system the grids are connected to the secondary winding of the hybrid coil, while the anode circuits are connected to its primary centre taps. The American and the Swedish systems use the reverse connexion. The ringing relays of the German system are connected in shunt on the line direct, whilst the corresponding relays of both the American and the Swedish repeaters are connected between the bridge points of the hybrid coils and the grid circuits of the valves. To facilitate balancing, the repeaters are provided with filters which do not pass frequencies above c. 2750 cycles, as the balance must be good enough to

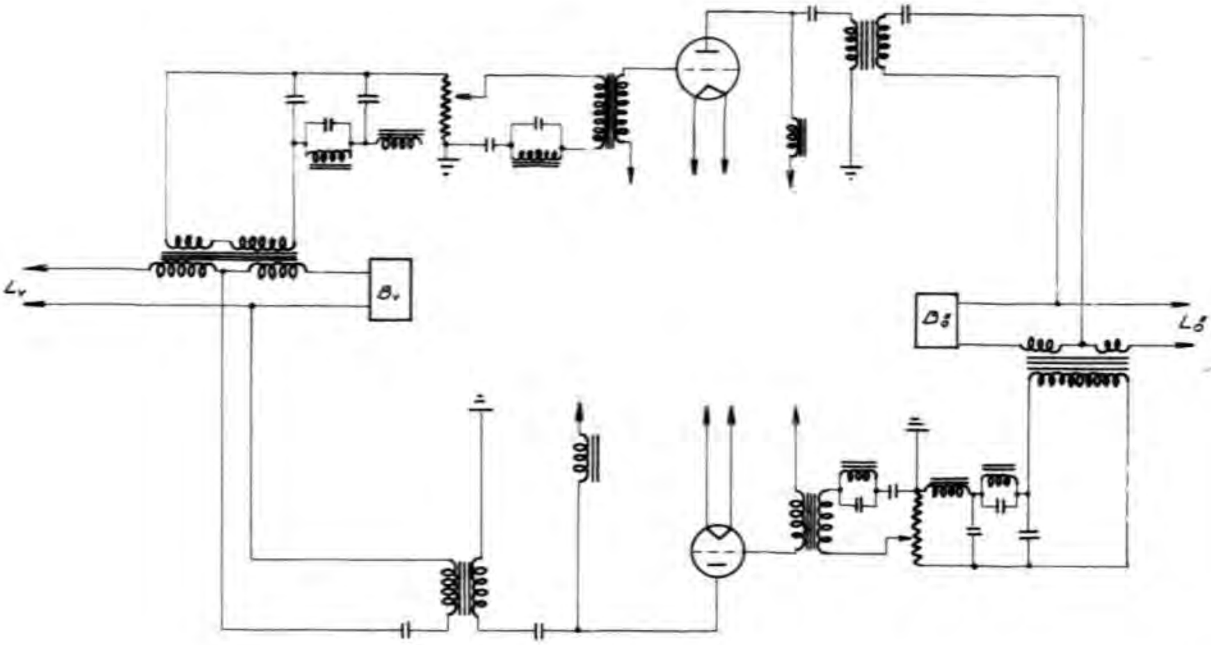
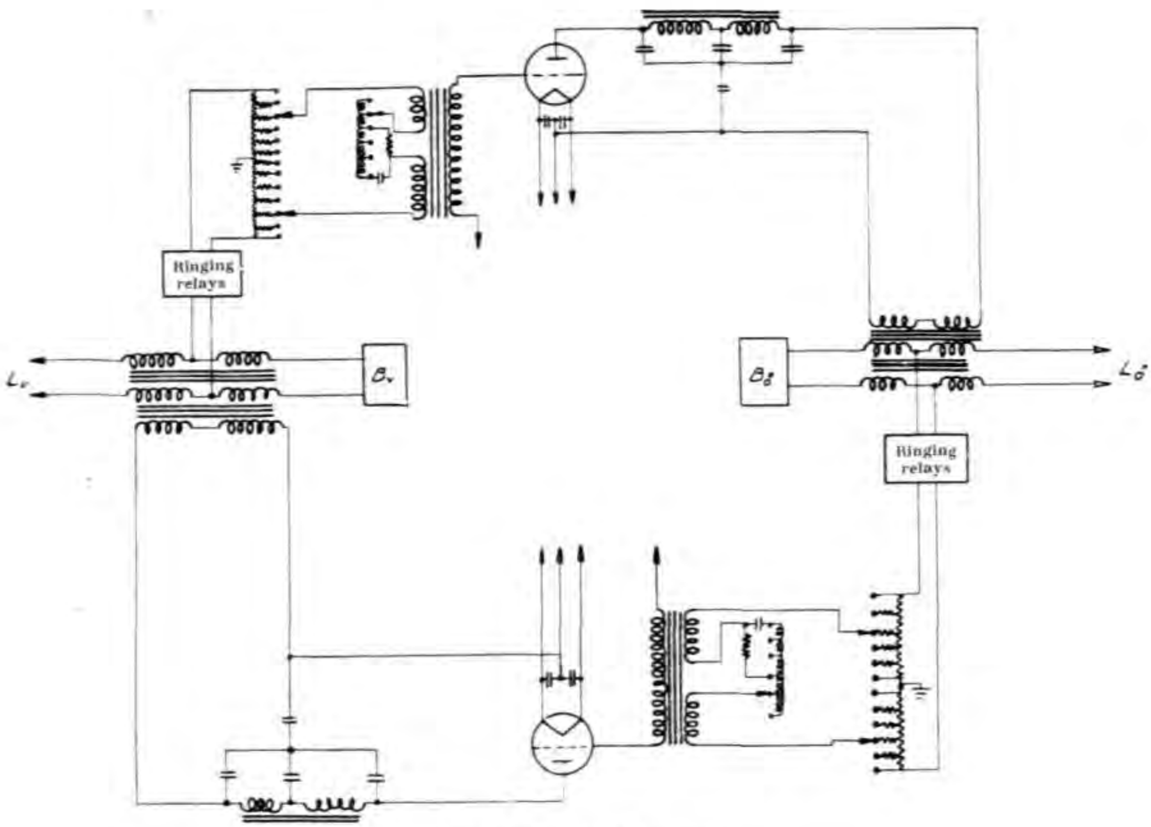


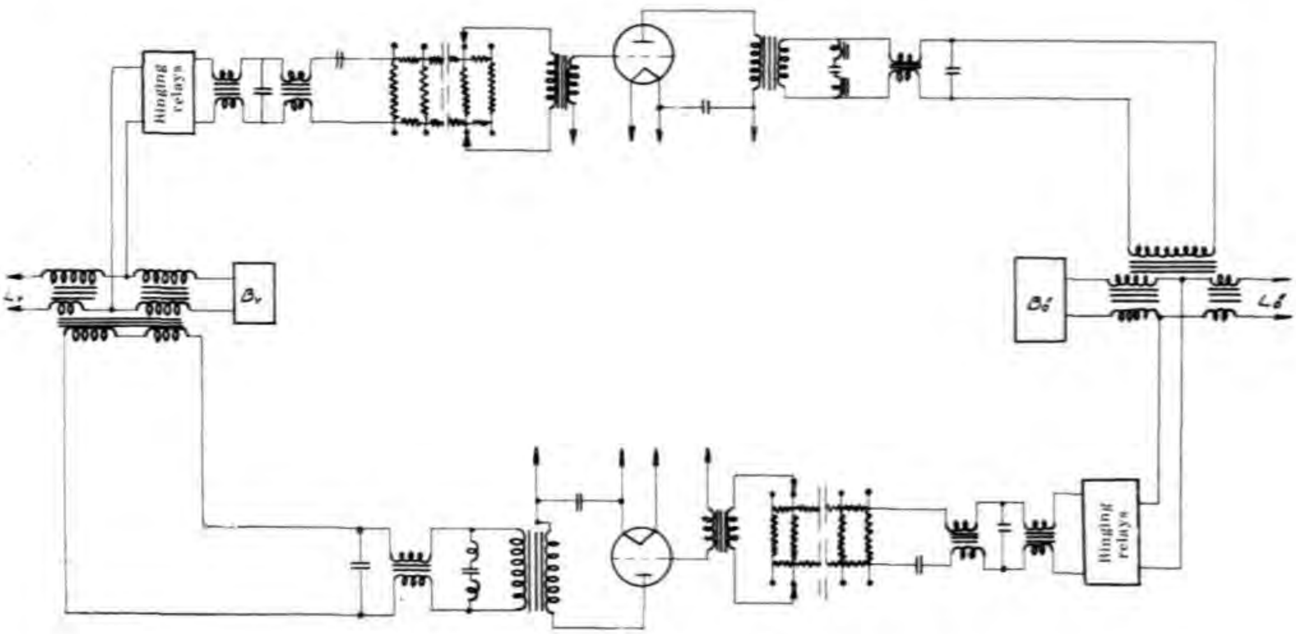
Fig. 5 a. German circuit diagram.



American circuit diagram.

B 1945

Fig. 5 b. Different Connexions of two-wire Repeaters.



Swedish circuit diagram.

B 1945

Fig. 5 c. Different Connexions of two-wire Repeaters.

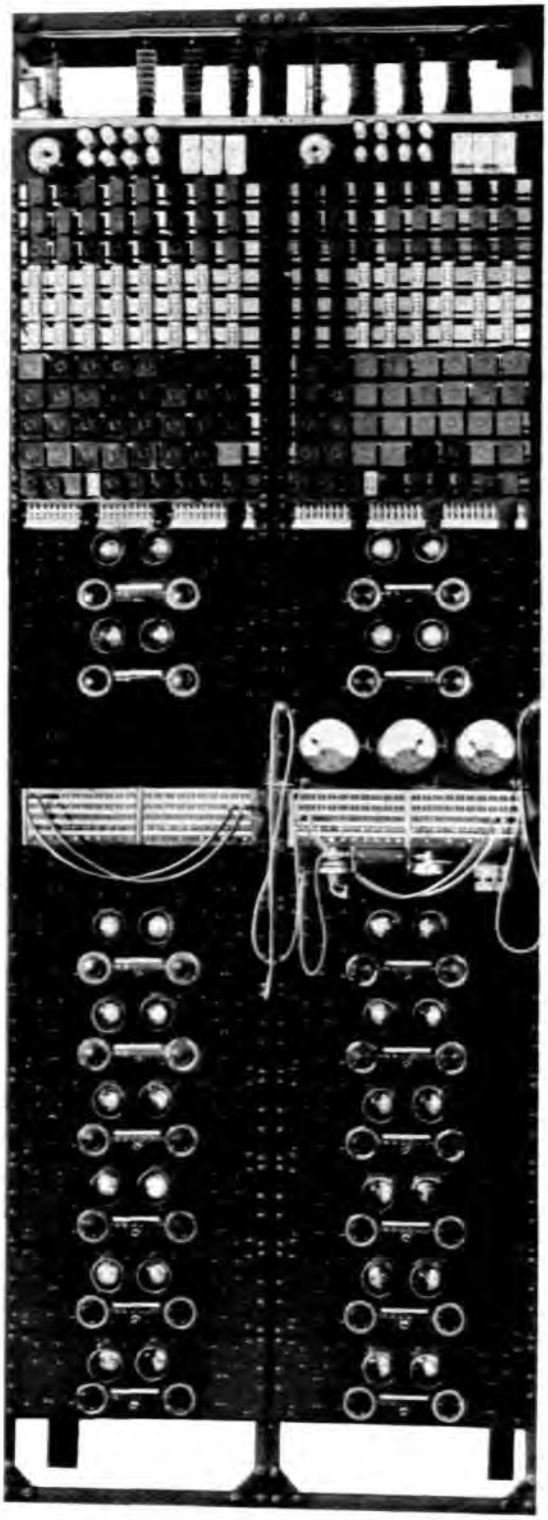
prevent the repeater from reaching the singing point for any and all of the frequencies passed. The German filters are placed in the grid circuits of the valves, and a special anode transformer is used. The Americans place the filters in the anode circuit, and they have designed their hybrid coils to serve simultaneously as output transformers. The Swedish repeater has filters in both the anode and the grid circuits. The reason for this is that by making the filter impedances reciprocal on either side of the hybrid coil, it is both theoretically and practically possible to make the input impendance, measured from the line, perfectly constant for all frequencies, which is shown in detail by Fig. 11. One of the greatest advantages of the Radiobolaget design is that the impedance curve of the repeater becomes even, which eliminates all disturbing reflexions with consequent echo-effects.

The attenuation of a line always increases slightly with the frequency, causing a certain amount of distortion of speech. It is desirable that the repeaters should be able to compensate this distortion, and this is especially important in cables with relatively low cut-off frequency. The repeaters should therefore be fitted with some kind of *correcting network* to increase the amplification at higher frequencies. The Americans have obtained such correction of frequencies by the various taps and connexions shown on the grid transformer in the illustration. Additional frequency correction may be obtained by connecting equalizing networks to the line. A correcting network is introduced in the German repeater, seen close to the grid transformer in the illustration. The Radiobolaget repeater is also provided with devices for correcting the amplification. Potentiometers are provided for adjusting the degree of amplification, differently designed in each of the systems, but all serving the same purpose.

The German repeaters are all mounted on a common rack of the following dimensions: height 2 550 mm., width 1 100 mm. The repeater is here divided into three units: the amplifying unit proper with valves and transformers, the equalizing device with potentiometers and correcting networks etc., and the ringing set. The supervisory apparatus is fitted in the centre of the rack. Normally the rack is made to take 8 repeaters.

In the American system, the repeaters are mounted separately in one bay, and the ringing sets in another bay holding 12 sets. A bay contains a maximum of 12 repeaters in a rack 3 660 mm. high and a panel width of 482 mm. This rack also contains a jack panel and a control panel. The equipment for distributing the current is placed in a separate bay, as in the German system.

Fig. 6 shows repeater rack of the Radiobolaget design. The repeaters shown are of an older design, but the new repeater rack contains the same number of repeaters and is designed on the same principles. Each repeater bay is an independent unit, and all the accessories required for the 8 repeaters are thus fitted into the bay. Besides repeater panels there are a supervisory panel, a measuring panel, a jack panel, and ringing sets for all the repeaters, as well as all the current distributing equipment required for the repeaters mounted in the bay. At the top of the bay we see the main fuse panel, at the back of which the grid batteries are placed. Below, we have 8 rows of ringing sets, distribution-fuse panel, two repeater panels, a measuring panel, a jack panel, a supervisory panel, and six repeater panels. If tone-signal receivers are used, they are placed in a separate bay, but they may be directly connected to the repeater bay. The frame is 3 120 mm. high and the panel width is 550 mm.

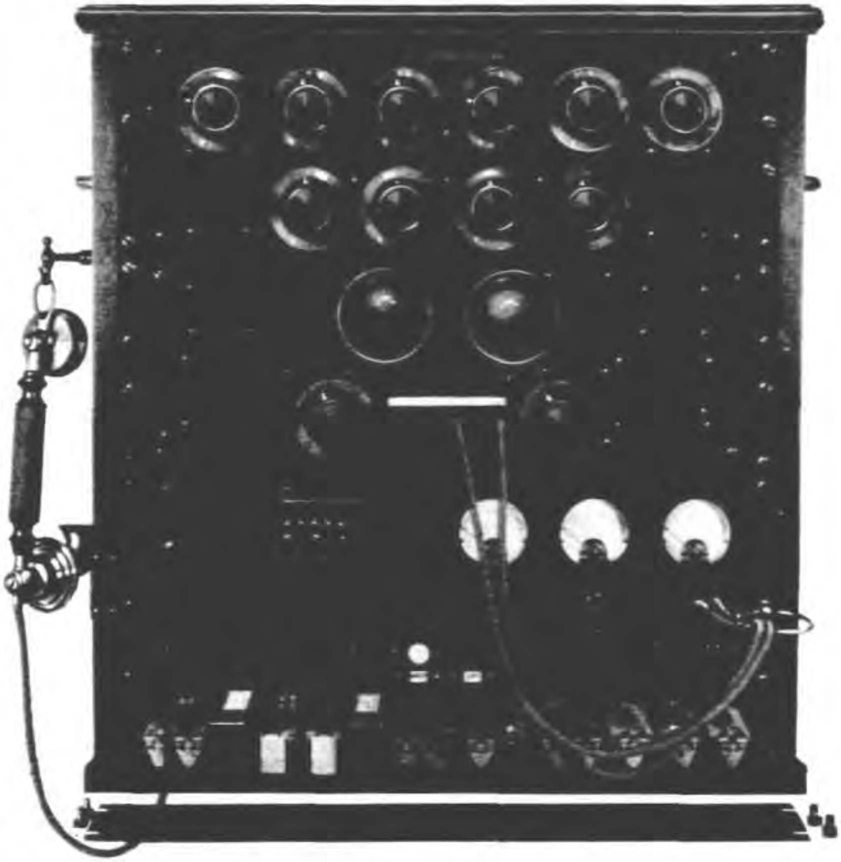


R 1772
Fig. 6. Repeater Rack, with 16 two-wire repeaters.

Fig. 7 shows a portable repeater with one repeater and the requisite auxiliary equipment. The top panel is a balance panel, where the resistances and capacities of the line balance may be continuously varied. This type is specially designed.

The Radioaktiebolaget repeater panel is shown in Fig. 8. Besides the valves, two potentiometers for adjusting the amplification by steps of 0.1 nepers are seen in front. The provision of two additional potentiometers for the repeater is under consideration, to allow fine adjustment by steps of 0.025 nepers to compensate for the gradually decreasing amplifying power of the valves. These potentiometers will be adjusted by tests with a simple valve-testing device which would be incorporated in the repeater panel. By such an arrangement the advantage would be gained that a certain graduation of the adjusting potentiometer scale would always correspond to a given net gain of the repeater. The valves used in the new repeater are of the Marconi LS5 type, which are constant and durable. This type of valve is also used in the British G. P. O. repeater. The repeater panel has a jack strip to allow control of currents and voltages.

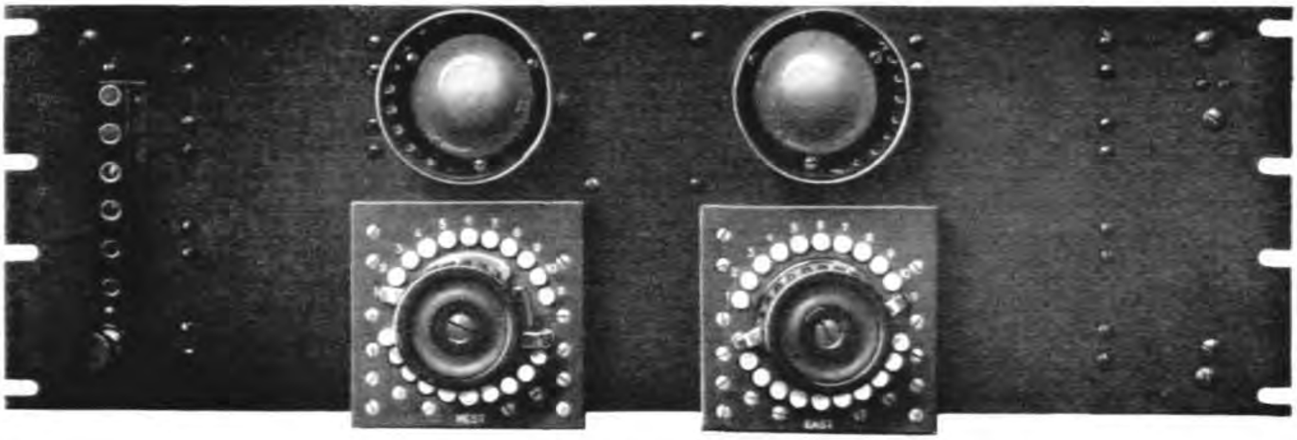
Fig. 9 shows the back of the same panel. It is fitted very compactly, and all the soldering tabs are easily accessible. All coils may easily be filled with beeswax or compound, which is necessary for deliveries to the tropics.



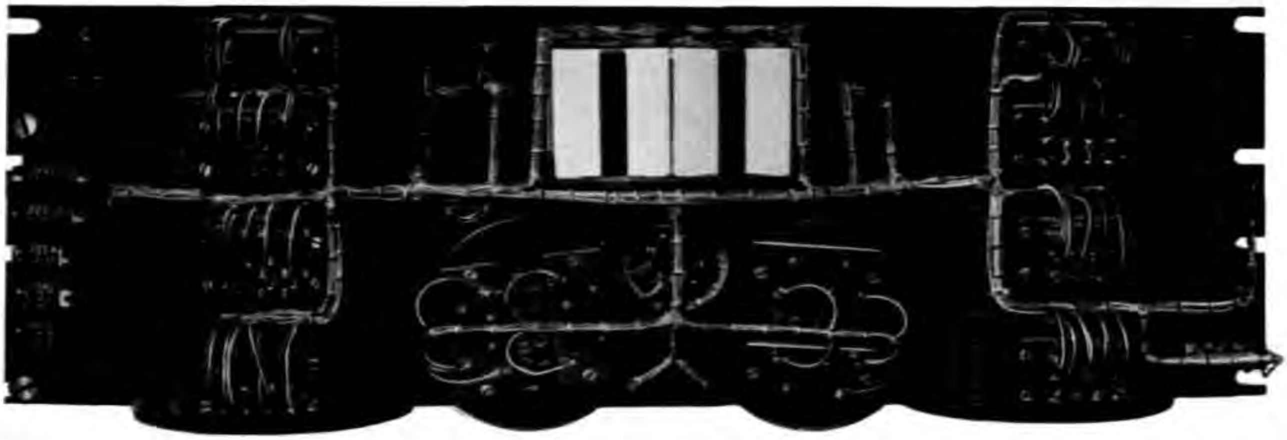
R 1773 Fig. 7. Portable two-wire Repeater.

The repeater panel only contains those parts which need not be adjusted when the repeater is connected to different lines. The correcting networks will thus be mounted in the upper part of the bay together with the ringing sets. Hence no soldering or other operations will be necessary on the repeater unit itself.

Some amplification curves obtained from repeaters of American, German, and Swedish type are shown in Fig. 10. The differences in maximum gain is caused by the respective potentiometer adjustments, but the curve-shape is characteristic for each type of repeater. The German repeater is suited to a relatively heavily loaded



R 1933 Fig. 8. Two-wire Repeater, front view.

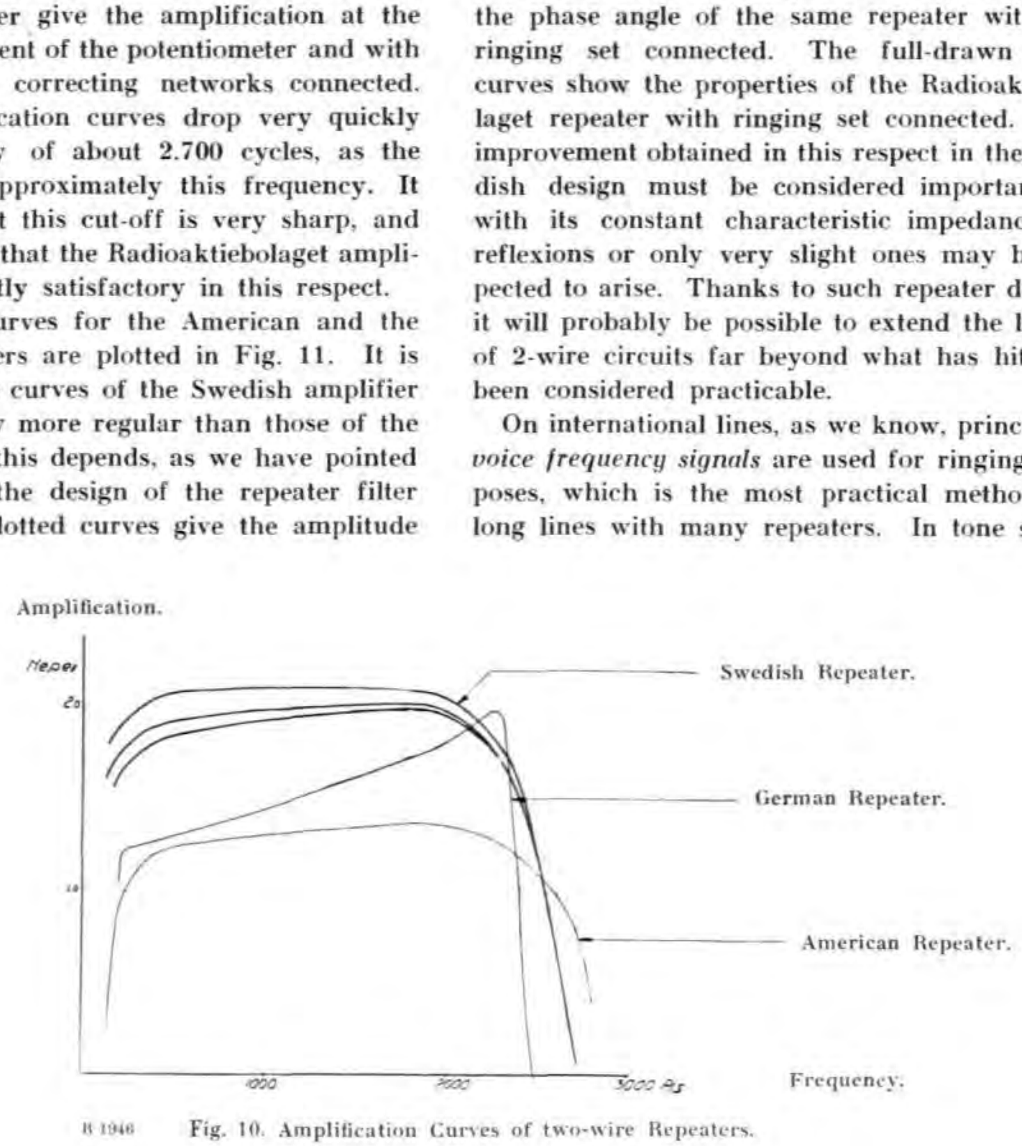


R 1934 Fig. 9. Two-wire Repeater, back view.

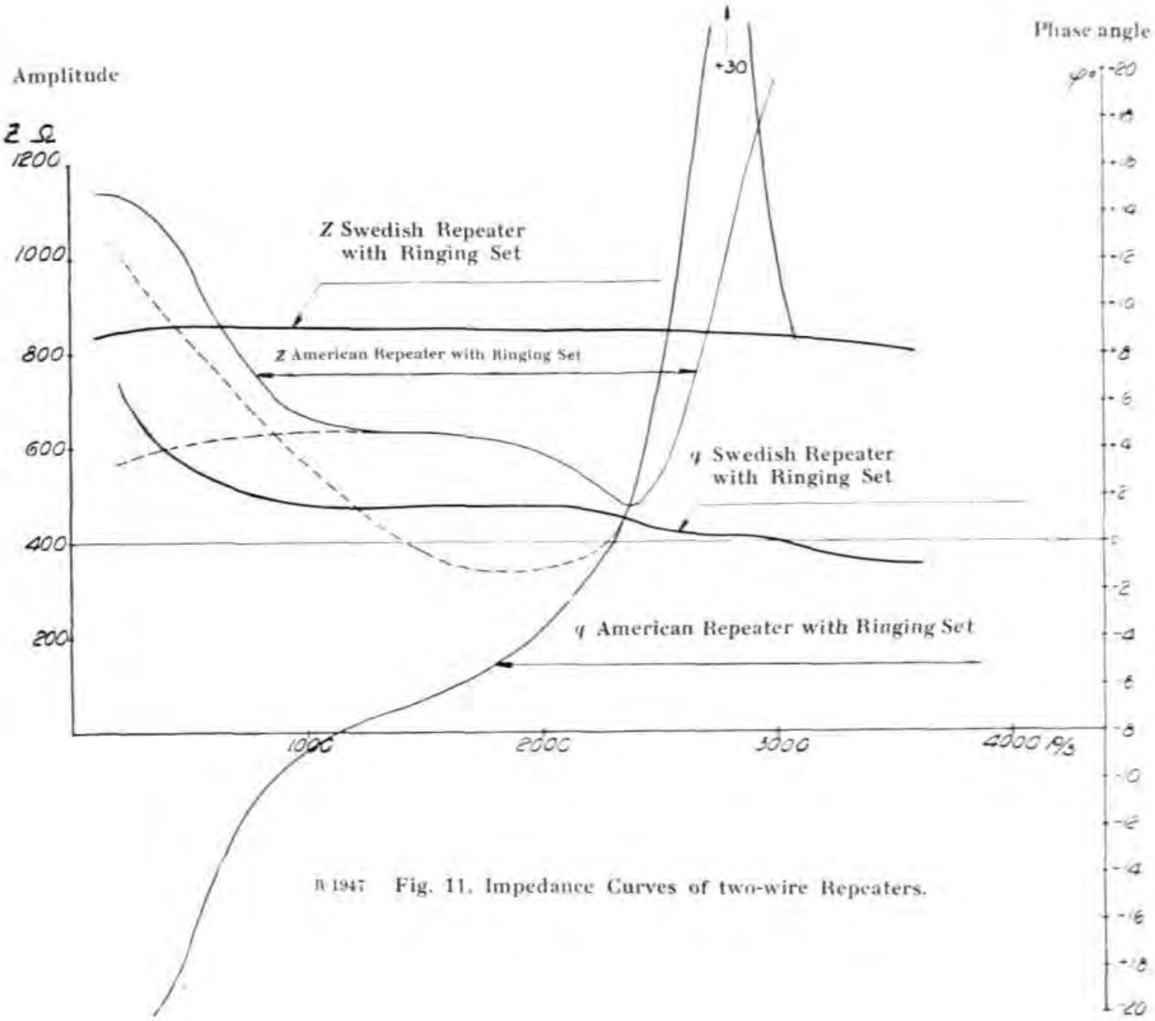
cable, and has therefore a steep slope. A ringing set was connected when the curve of the American repeater was taken. The curves for the Swedish repeater give the amplification at the highest adjustment of the potentiometer and with some different correcting networks connected. All the amplification curves drop very quickly at a frequency of about 2.700 cycles, as the filters cut at approximately this frequency. It is desirable that this cut-off is very sharp, and it will be noted that the Radioaktiebolaget amplifiers are perfectly satisfactory in this respect.

Impedance curves for the American and the Swedish repeaters are plotted in Fig. 11. It is evident that the curves of the Swedish amplifier are considerably more regular than those of the American, and this depends, as we have pointed out above, on the design of the repeater filter circuits. The dotted curves give the amplitude and phase angle of the impedance of the American repeater without ringing equipment, and the thin full-drawn curves give the amplitude and the phase angle of the same repeater with the ringing set connected. The full-drawn thick curves show the properties of the Radioaktiebolaget repeater with ringing set connected. The improvement obtained in this respect in the Swedish design must be considered important as, with its constant characteristic impedance, no reflexions or only very slight ones may be expected to arise. Thanks to such repeater design, it will probably be possible to extend the length of 2-wire circuits far beyond what has hitherto been considered practicable.

On international lines, as we know, principally *voice frequency signals* are used for ringing purposes, which is the most practical method for long lines with many repeaters. In tone signal



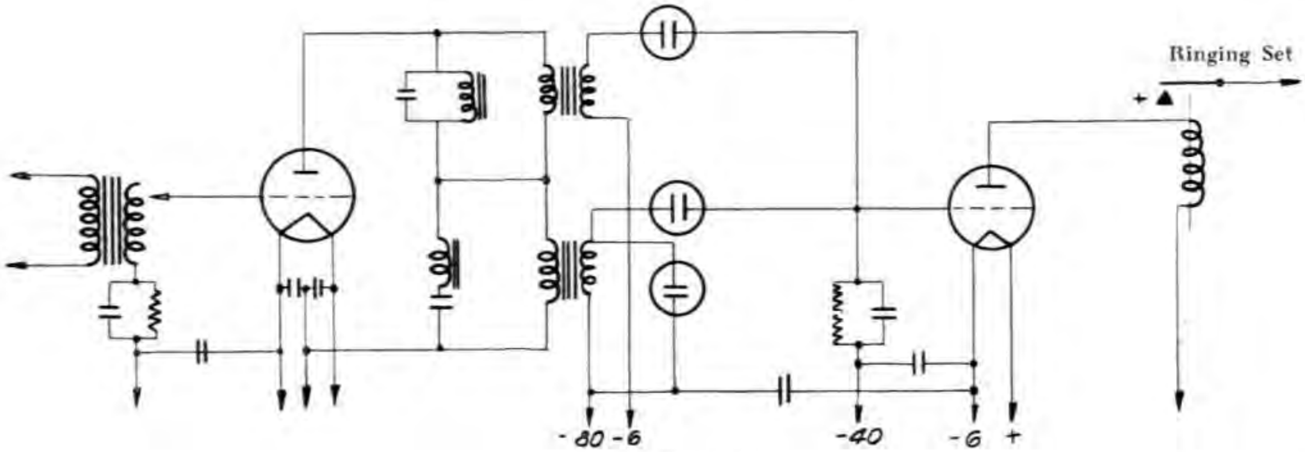
R 1946 Fig. 10. Amplification Curves of two-wire Repeaters.



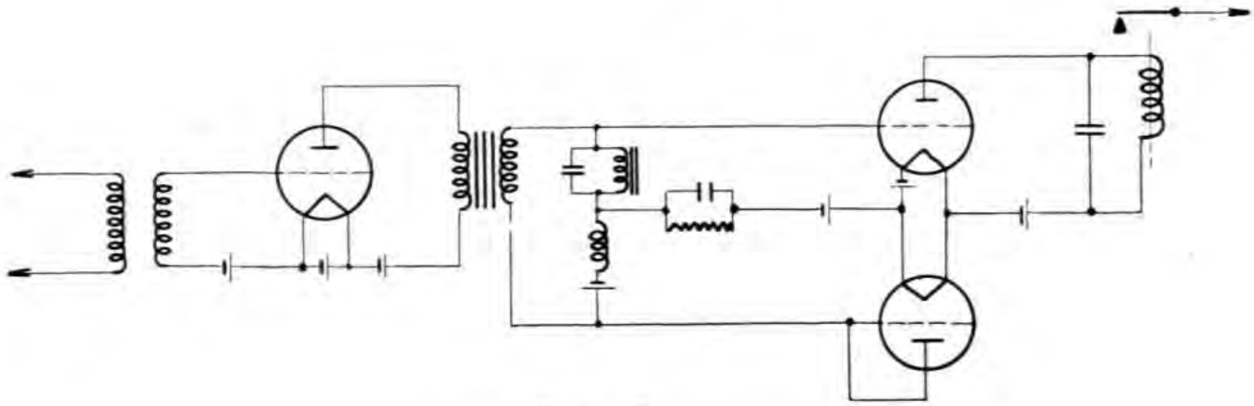
B 1947 Fig. 11. Impedance Curves of two-wire Repeaters.

systems, the difficulty is to design a receiver which is sensitive to the calling signal but insensitive to voice currents of ringing current frequency — usually 500 cycles. It is conceivable that the selectivity of the tone signal receiver be based on the difference in amplitude between the ringing and the speaking current, in such a manner that the tone signal receiver is insensitive to amplitudes of the magnitude occurring in incoming voice currents, while ringing currents of 500-cycle frequency would be sent out with considerably larger amplitudes. It is, however, not permissible to increase the ringing amplitude too much, as this would cause a risk of cross-talk to neighbouring lines. A principle which has been applied in practice is founded on frequency selectivity by means of differently tuned circuits and modulated signal frequency. Experiments made with tone signal receivers of this type, however, have not proved satisfactory in every respect. The tone signal receiver which hitherto has given the best results is founded on the following principle. If a pure signalling frequency is sent out on the line, e. g. with a frequency of 500 cycles, the tone signal receiver will function, but if other frequencies occur simultaneously on the line, for instance the frequencies composing the speech currents, the tone signal receiver will be blocked. The 500-cycle speech frequencies are always mixed with other frequencies, and the tone signal receiver will, therefore, always be blocked whenever speech currents are transmitted on the line.

Fig. 12 shows two connexions on this principle. A parallel resonance circuit and a series resonance circuit, both tuned to a 500-cycle fre-



Swedish Type.



German Type.

B 1950

Fig. 12. Connexions of Tone Signal Receivers.

quency, are characteristic of these designs. The tone signal receiver, which has a very high input impedance, is connected in shunt to the line. When currents pass through the line, a small portion of them is tapped and amplified in the first valve. If the current of the line is of pure 500-cycle frequency, the parallel resonance circuit will act as a very high impedance to this frequency, whilst the impedance of the series resonance circuit will be low. The voltage of the transformer winding connected over the parallel resonance circuit will therefore be high, while no appreciable voltage will be induced in the transformer connected in parallel to the series resonance circuit. Neon-lamps are connected in the secondary windings of each of the above transformers, and these lamps are given certain biases from batteries, but these are less than the lighting voltage of the lamps. By means of superimposed A. C. voltages from the secondary windings of the above transformers the lamp voltage, however, can be increased sufficiently to allow current to pass through the lamps. In the case just described, with an incoming pure frequency of 500 cycles, the neon-lamp of the parallel resonance circuit will be lit, but the neon-lamp of the series resonance circuit will not receive sufficient voltage to function. The result will therefore be that the condenser will be charged, and the grid bias of the last valve becomes positive or, at any rate, less negative. That will allow anode current to pass this valve, which, before the process just described, was blocked by high negative grid bias. The anode circuit relay of this valve will then be energized, and a signal will pass through.

But if, instead, the voltages coming from the line contain both the 500-cycle ringing frequency and some other frequency within the audio-range, the 500-cycle currents would, as in the previous case, have caused the neon-lamp of the parallel resonance circuit to be lit, while the currents of

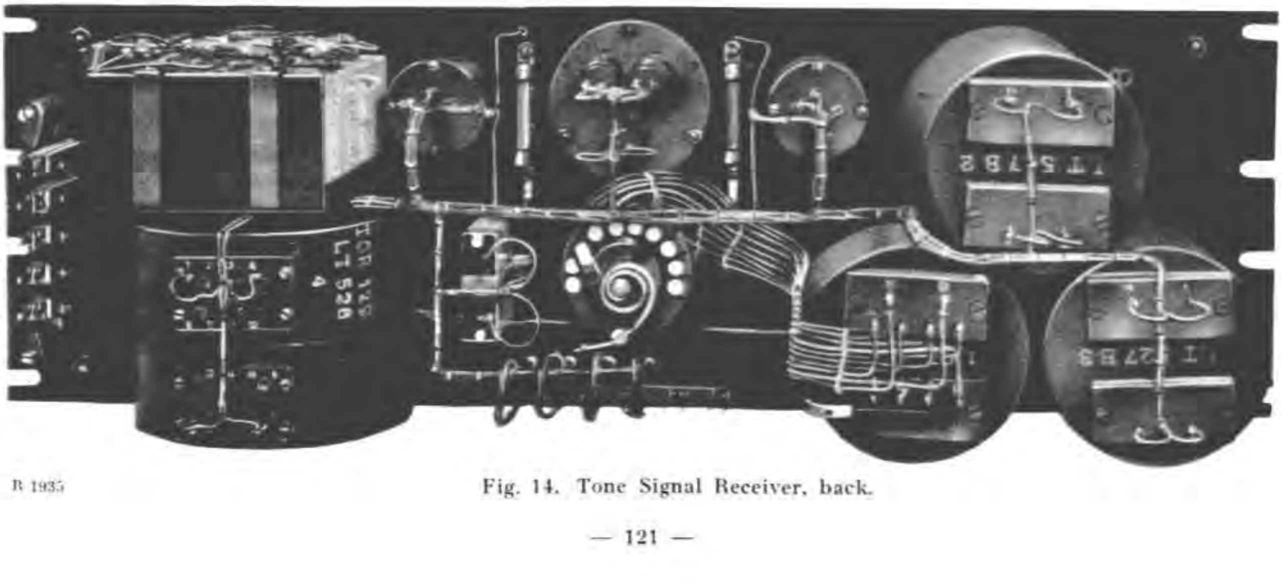
R 1936 Fig. 13. Tone Signal Receiver, front.

other frequencies would simultaneously have increased the voltage of the neon-lamp in the series resonance circuit sufficiently to light this also. In that case the last electrone valve will retain such a high negative grid bias that no anode current can pass, and this depends on the high negative grid bias added by the neon-lamp of the series resonance circuit. The tone signal receiver will thus be blocked. The principal object of the above-mentioned condenser is to make the tone signal receiver independent of the incoming signal voltage. The third neon-lamp is introduced to limit the voltage over the transformer in the series resonance circuit, which may be high, as when ringing currents of the 20-cycle frequency pass the line.

The system just discribed is used by the Swedish Board of Telegraphs, which was the first to adopt the principle. The patents for the system are the property of Telefonaktiebolaget L. M. Ericsson.

The German system is based on the same principle, the only difference being that neon-lamps are not used, but a thermionic valve co-operates with the series resonance circuit to block the tone signal receiver.

The tone signalling system described can also be advantageously used for voice frequency dialling over lines, especially such as are fitted with repeaters, and will certainly be largely used for such purposes in the near future. The time will soon come when the automatic system will be extended beyond the limits of local nets, and automatic calls to subscribers of even distant exchanges will be possible. The first step towards this goal will be that the operator in the local long distance line exchange will dial the number of the subscriber in the distant exchange, and thereby make the "B"-operator in that exchange superfluous. The greatest advantage of the swedish system is that slow action can be re-



R 1935 Fig. 14. Tone Signal Receiver, back.

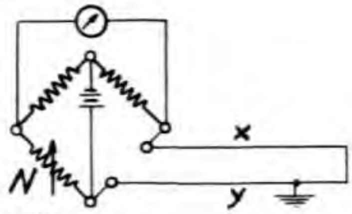
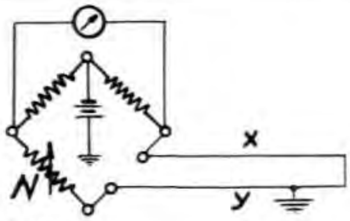
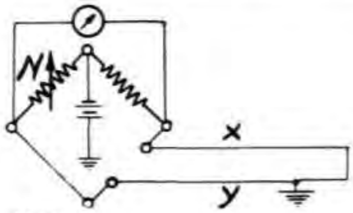
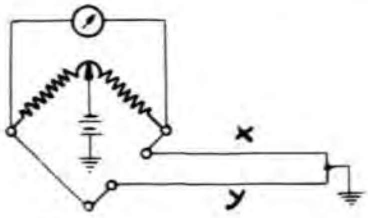
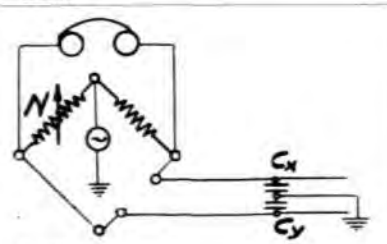
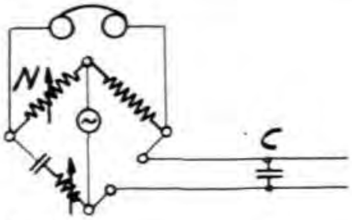
Measurements	Circuit diagram	Settings of			Readings
		Push button J	Knife switch K_1	Switch O	
Total resistance measurement $x+y$	 R 1522	Out	In	5	$x+y=10\,N\,\Omega$
				6	$x+y=N\,\Omega$
				7	$x+y=\frac{N}{10}\,\Omega$
Difference measurement $x-y$	 R 1523	In	In	5	$x-10y=10\,N\,\Omega$
				6	$x-y=N\,\Omega$
				7	$x-\frac{x}{10}=\frac{N}{10}\,\Omega$
Ratio measurement $\frac{y}{x}$	 R 1524	In	In	1	$\frac{y}{x}=\frac{N}{10}$
				2	$\frac{y}{x}=\frac{N}{100}$
				3	$\frac{y}{x}=\frac{N}{1000}$
Resistance unbalance measurement $\frac{y}{x}$	 R 1525	In	In	4	Direct reading
Capacity ratio measurements $\frac{C_x}{C_x}$	 R 1526	In	In	1	$\frac{C_x}{C_y}=\frac{N}{10}$
				2	$\frac{C_x}{C_y}=\frac{N}{100}$
				3	$\frac{C_x}{C_y}=\frac{N}{1000}$
Absolute capacity measurements C	 R 1527	Out	Out	1	$C=\frac{N}{100}\,\mu F$
				2	$C=\frac{N}{1000}\,\mu F$
				3	$C=\frac{N}{10000}\,\mu F$

Fig. 15. Connexions for different measurements by resistance and capacity bridge.

duced to a minimum on account of the great selectivity of the system.

Fig. 13 shows the Radioaktiebolaget tone signal receiver panel. Besides the two thermionic valves, we see the three neon-lamps, which between them do not take up more space than one ordinary valve. Fig. 14 gives a back view of the same panel.

Apart from the equipment mentioned above for long distance lines, modern telephony employs *four-wire repeaters, echo suppressors, automatic transmission regulators,* and other instruments, which will not be discussed here. In some instances, Radioaktiebolaget has manufactured such apparatus, for some of them research work is being carried on. The Radioaktiebolaget *carrier-frequency systems* have been described in earlier issues of the L. M. Ericsson Review.

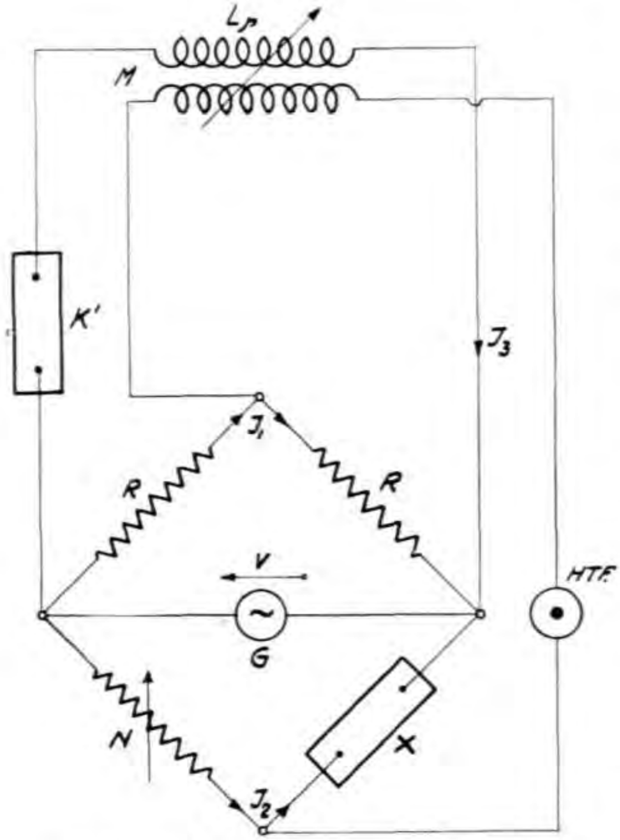
Whilst only short lines were used in telephony, comparatively modest demands were made on *measuring instruments* for the lines. D. C. measurements and determination of the position of faults by means of D. C. instruments were the only essentials. But as long distance lines grew to their present lengths, such simple methods were no longer sufficient. The importance of transmission measurements and other measurements with A. C. of audio-frequency is growing with the extents of the lines and the C.C.I. is also prescribing a whole series of routine measurements for international lines. A great need for various measuring instruments has thus arisen in late years, and manufacturers have designed complete sets of measuring instruments for long distance and trunk line exchanges. There are three distinct types of equipment: for D.C. measurements, for audio-frequency measurements, and for high frequency measurements.

The Wheatstone bridge is still used, connected in various ways, for D. C. measurements. Fig. 15 is a schedule of the measurements which can be made with the Radioaktiebolaget *resistance and capacity bridge.* The various connexions are set by a seven-way switch in accordance with the diagrams and schedule given in the figure. It is thus possible to make, with three different resistance ratios, total resistance measurements, difference measurements, and ratio measurements. Measurement of the resistance unbalance has also been made possible. This measurement is intended to take the place of the usual resistance ratio measurement, and is preferred on account of its simpler procedure, the more convenient reading of the setting, and the freedom from any contact resistances in the bridge, to which the ratio measurements in particular are sensitive. The resistance unbalance expresses a disturbance of the balanced state of a telephone line, which is easily affected by the least alteration of line resistance or leakage, and it is therefore a sensitive indicator of the condition of the line. Resistance unbalance measurements are thus important as control measures which can be easily carried out as a matter of routine.

By connecting an A. C. supply to the bridge, and using a telephone receiver as an indicator, measurements of capacity and capacity ratios can be made. These are important in the localization of breaks in the line which have no connexion to earth, such as for instance in cables where a pair is broken at a faulty joint.

Fig. 16 is a photograph of the Radioaktiebolaget resistance and capacity bridge. The large switch in the centre at the top of the instrument is the above-named switch to set the bridge for the various measurements. Below, the four switches of the decade resistances $10 \times (0.1 + 1 + 10 + 100)$ ohm are seen. One of the other dials seen is used for resistance unbalance measurements, and the other for capacity measurements.

R 1550 Fig. 16. Resistance and Capacity Bridge.



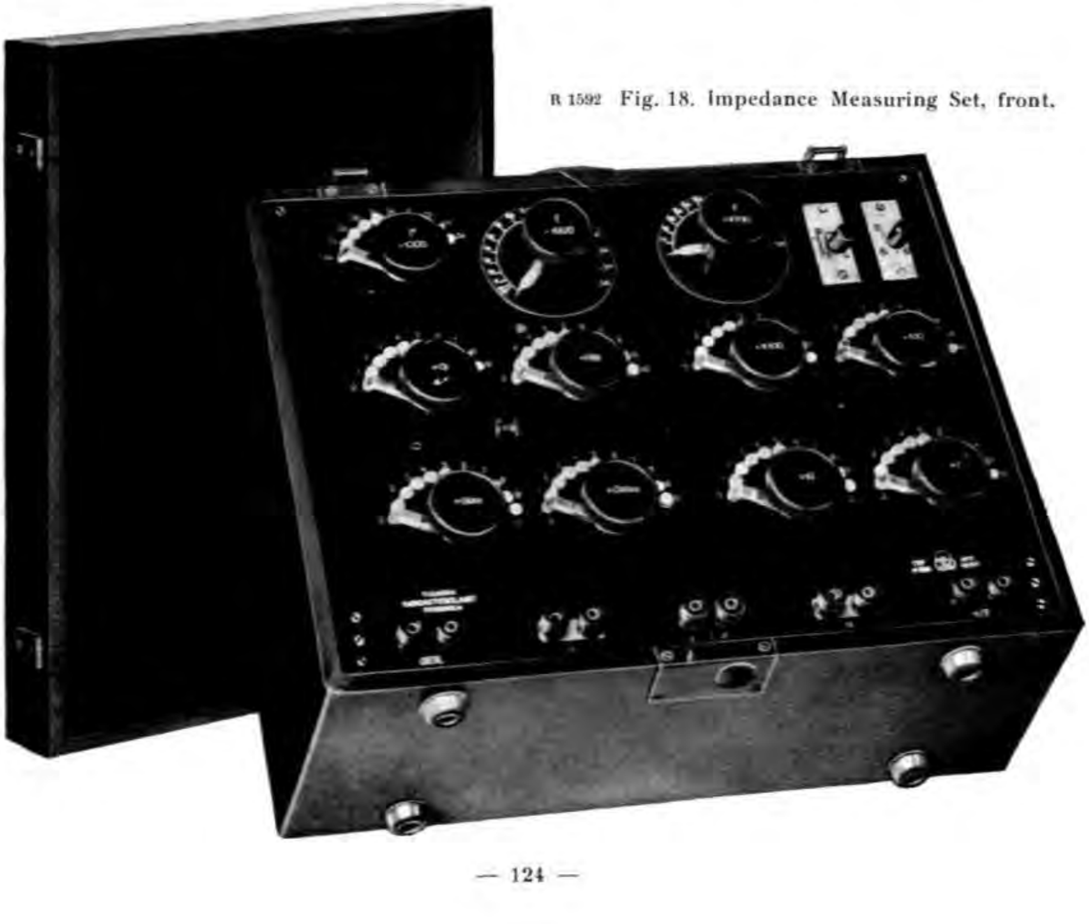
R 1605 Fig. 17. Diagram of Impedance Measuring Set.

The *insulation* of lines and cables is generally determined by current- and voltage measurements, from which the resistance can be computed. A sensitive instrument is required for measuring the weak leakage currents, and for this purpose Radioaktiebolaget uses the Cambridge Universal Testing Set Pattern 0 which is mounted in the test rack shelf made by the company. This instrument is very sensitive, and provided with a universal shunt and switches for the various measurements.

There are also other methods in use for insulation measurements. The Germans, for instance, use a method based on the grid bias of a valve being produced by the voltage drop over a resistance connected in series with the insulation resistance, and through which the leakage current passes. When the voltage of the measuring battery is known, the resistance may be determined by changing the taps of the resistance in the valve grid circuit until a normal reading is obtained on the instrument connected in the anode circuit. The exactness of this instrument, however, is not greater than c. 10 per cent.

When computing the primary constants of a line, measured values of the line impedances for

R 1592 Fig. 18. Impedance Measuring Set, front.



R 1593 Fig. 19. Impedance Measuring Set, back.

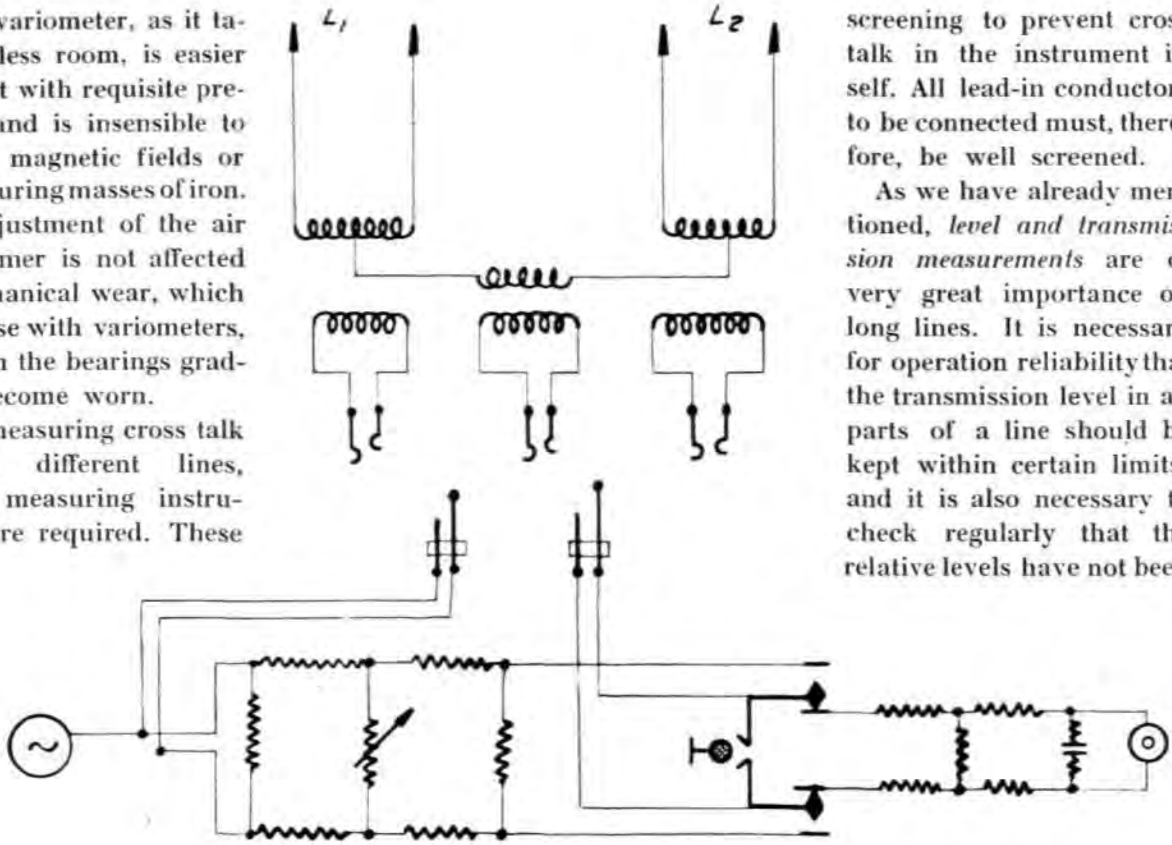
the line with the distant end open and short-circuited are generally used as a basis. To obtain these quantities, impedance measurements must be made on the line. When determining the position of a fault which cannot be detected by D. C. measurements, impedance measurements must also be resorted to. An instance of this is the localisation of points of reflexion caused by in-homogeneity of impedance. For this purpose Radioaktiebolaget has designed an *impedance measuring set,* a diagram of which is shown in Fig. 17. The ordinary impedance bridges are designed to give the result in the form a + jb, i. e. the bridge gives the resistance and reactance of the impedance measured. In impedance calculations and in estimating impedance matchings one is, however, compelled to transpose these values into the form $R e^{j\varphi}$, i. e. amplitude and phase angle have to be determined. The impedance curves of a couple of repeaters described in connexion with Fig. 11 provide an example. The inequalities in matching would not be as distinct by a long way if the curves were plotted as resistance and reactance.

The Radiaktiebolaget impedance measuring set is designed to permit direct reading both of the amplitude and of the tangent of half the phase angle. A variable resistance and a variable mutual inductance form part of the bridge, the inductance consisting in an air transformer with decade taps in is secondary winding. The sound minimum is obtained in the telephone by varying these quantities, and direct readings may then be taken on the dial scales. The principle of this bridge has already been discussed in the L. M. Ericsson Review. This impedance set can also be used for *frequency measurements* by connecting an impedance of a known value. If this be selected as an inductance coil of the value $\frac{1}{2\pi}$ Henry, the frequency will be obtained directly in periods per second.

Fig. 18 is a photograph of the impedance set. The four lower dials to the right are the dials by which the normal resistance is set, and by the four lower dials on the left the mutual impedance is adjusted. The setting of the first named dials gives the amplitude of the impedance sought, and the last named its phase angle. The other dials visible in the photo serve to set the instrument to the frequency employed for measuring.

Fig. 19 shows the back of the impedance set. The distinguishing characteristic of the design is the air transformer with its secondary taps. It is better to use an air transformer of this type than a variometer, as it takes up less room, is easier to adjust with requisite precision, and is insensible to exterior magnetic fields or neighbouring masses of iron. The adjustment of the air transformer is not affected by mechanical wear, which is the case with variometers, in which the bearings gradually become worn.

For measuring cross talk between different lines, special measuring instruments are required. These are generally based on a comparison of the strength of the tone heard in the disturbed line with the strength of a tone from the generator, attenuated in an artificial line. Fig. 20 is a diagram of connexions for the Radioaktiebolaget *cross talk meter*. A tone is sent out on the disturbing line, *e. g.* L_1. from the generator, as well as to the artificial line. The measurement is taken by listening in on the disturbed line, *e. g.* L_2, and comparing in the telephone receiver this tone to the strength of the tone heard from the output terminals of the variable artificial line. When the sounds are of equal strength the artificial line setting will thus be a measure of the cross talk attenuation. In the artificial line employed by Radioaktiebolaget, only the central shunt resistance need be varied, as the properties of the line are not appreciably changed by the large attenuation (at least 4 nepers) which always occurs in cross talk measurements.

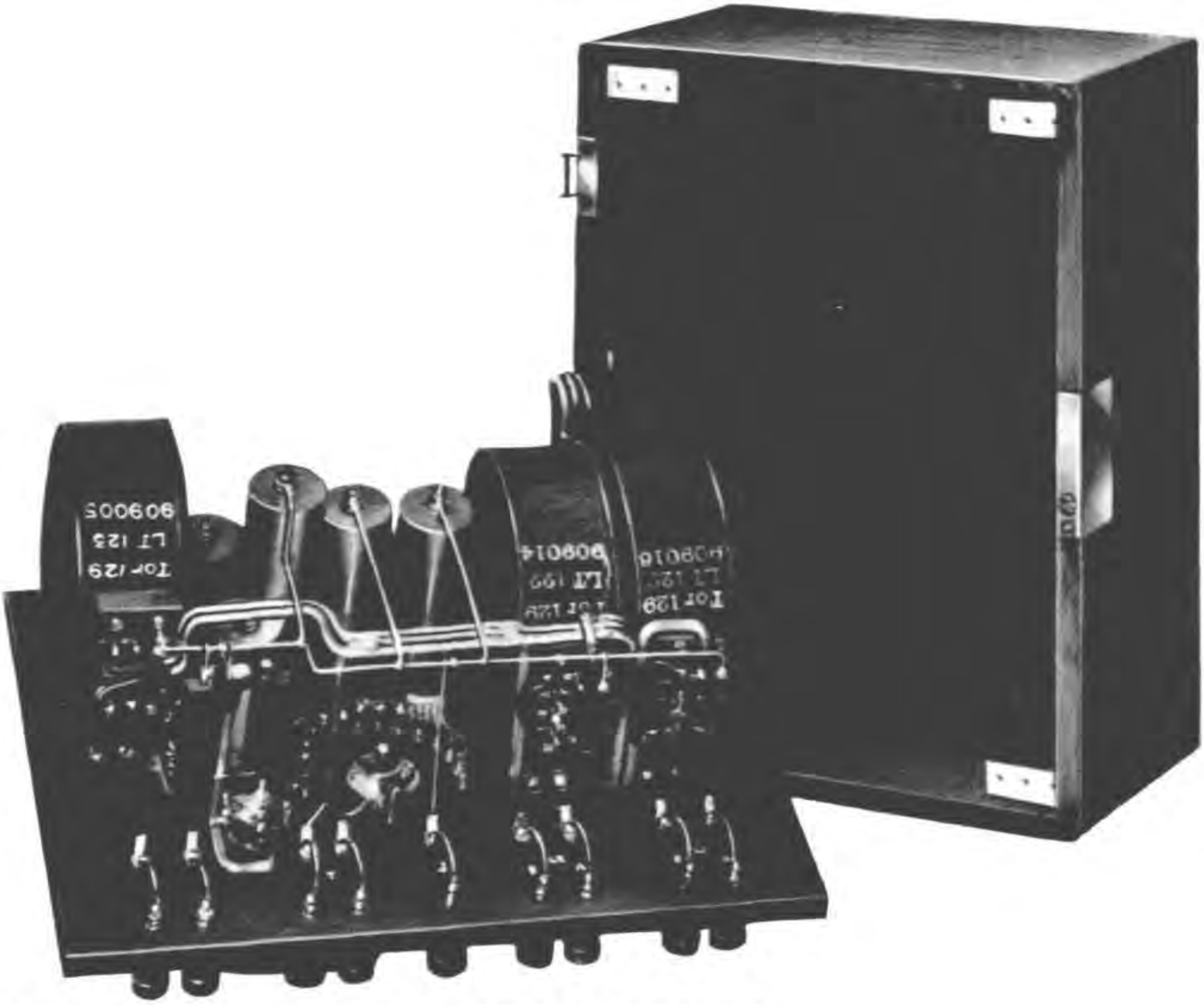


R 1952 Fig. 20. Diagram of Cross Talk Metering.

Fig. 21 is a photograph of the cross talk meter, and Fig. 22 shows the back of the same instrument. The difficulty of designing a cross talk meter principally consists in obtaining sufficient screening to prevent cross talk in the instrument itself. All lead-in conductors to be connected must, therefore, be well screened.

As we have already mentioned, *level and transmission measurements* are of very great importance on long lines. It is necessary for operation reliability that the transmission level in all parts of a line should be kept within certain limits; and it is also necessary to check regularly that the relative levels have not been

R 1999 Fig. 21. Cross Talk Meter, front.

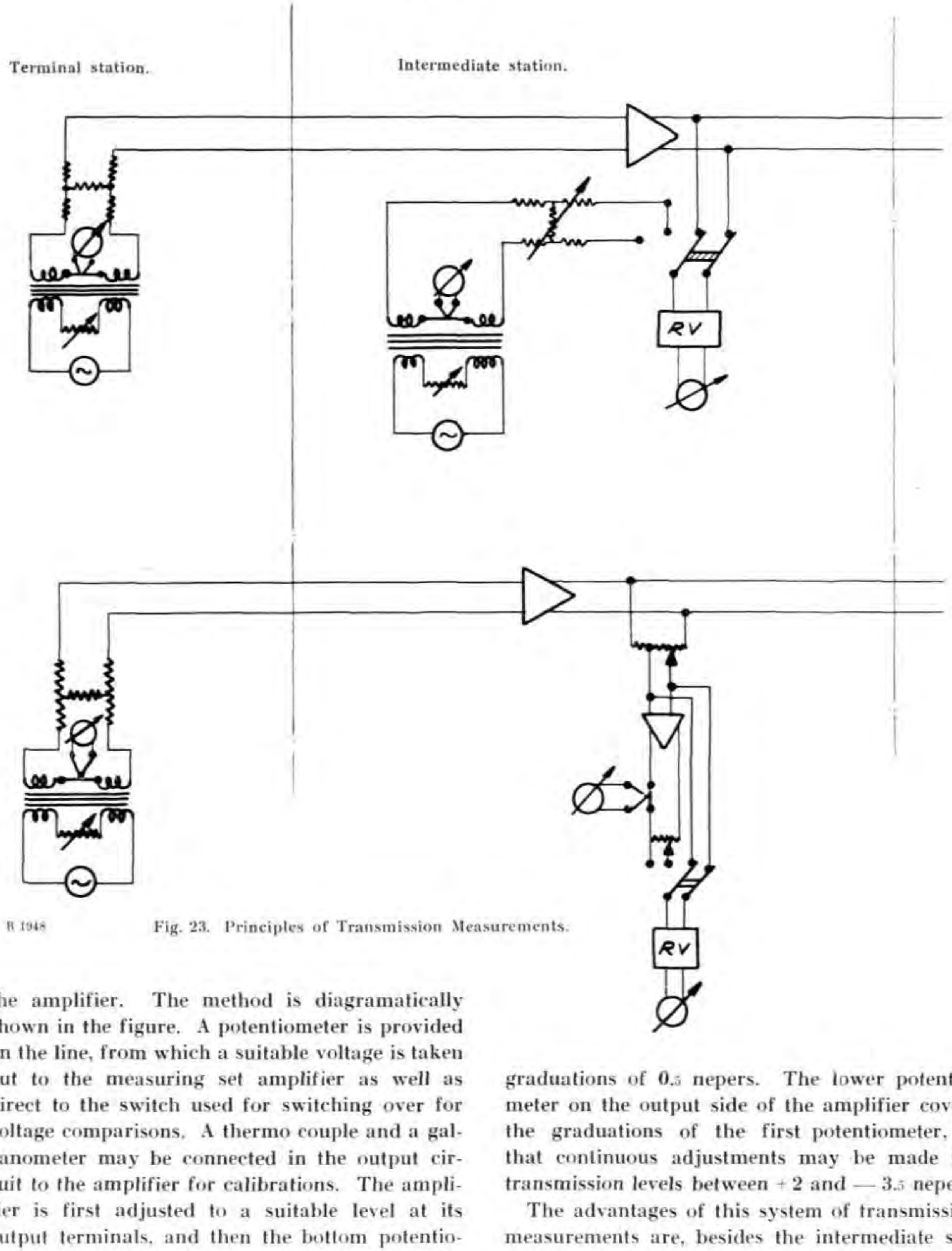


R 1853

Fig. 22. Cross Talk Meter, back.

changed, for instance by variations of the amplification in the intermediate repeater stations or the like. Fig. 23 gives the principle of transmission measurements. An audio-frequency current of zero-level is sent out from the terminal, defined as a power of 1 mW. This power is supplied by an adjustable audio-frequency generator, and the current is measured by means of thermo couple and galvanometer. Thanks to the line attenuation, a voltage will arrive in the intermediate station which is lower than the voltage impressed at the end of the line. It is now desired to measure the voltage level at the intermediate station. This may be done by comparing the voltage received from the line to the voltage of a local audio-frequency generator adjusted to supply a level of known magnitude. Usually, the voltage level is determined at the output terminals of the repeater connected to the line at the intermediate station. For level-measurements made according to this principle, audio-frequency generators are consequently required both at the terminal and at all intermediate stations where levels will be measured.

A somewhat modified principle, shown in the lower diagram of Fig. 23, has been employed by Radioaktiebolaget in the design of their transmission and level measuring sets. Obviously, it is not by any means necessary for the voltage used for comparisons in an intermediate station to be generated by a separate oscillator. It is also possible for the voltage of the line itself to be taken out and amplified up to zero level. The voltage taken directly from the line can then be compared to the voltage — corresponding to the zero-level — obtained at the output terminals of

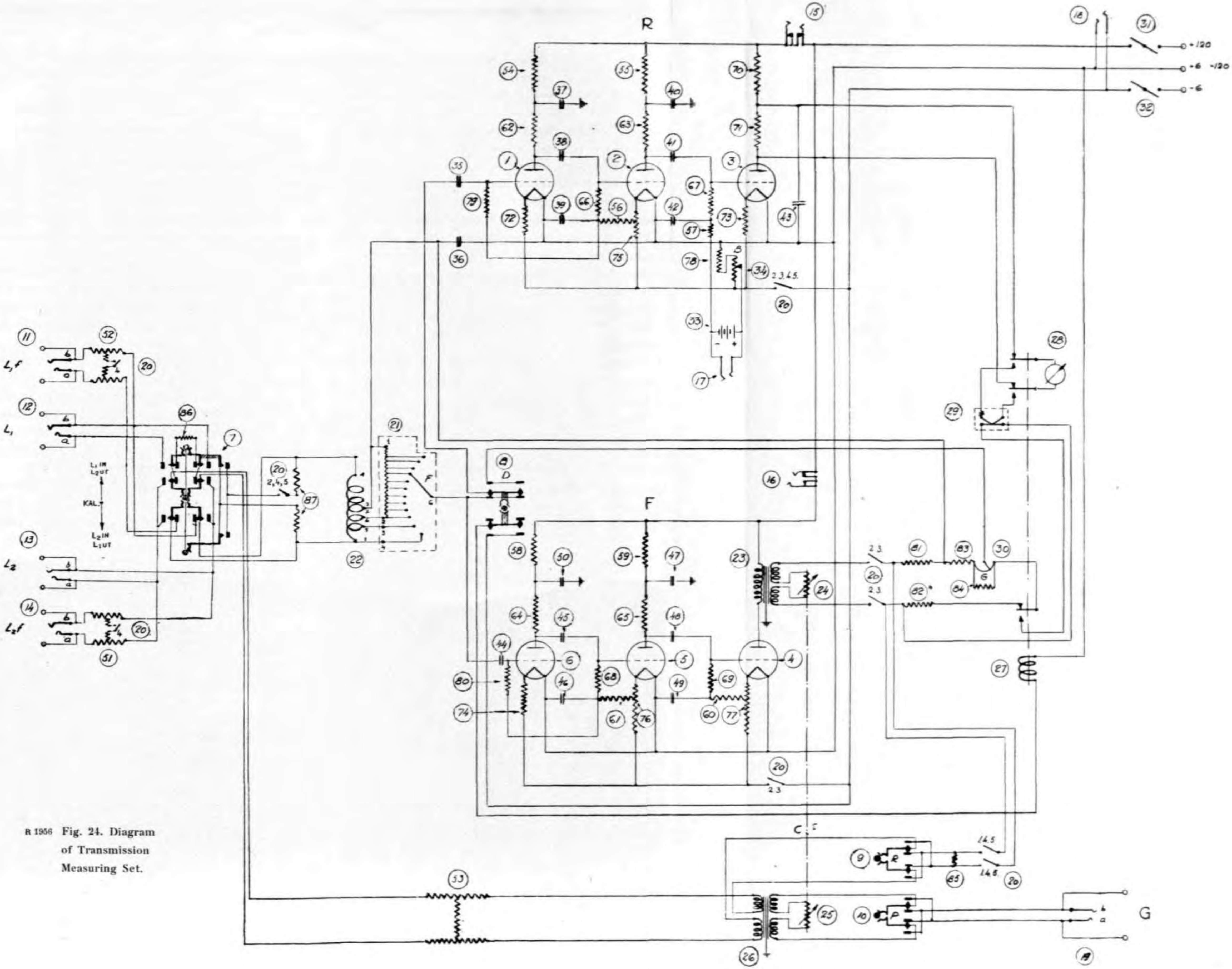


R 1948

Fig. 23. Principles of Transmission Measurements.

the amplifier. The method is diagramatically shown in the figure. A potentiometer is provided on the line, from which a suitable voltage is taken out to the measuring set amplifier as well as direct to the switch used for switching over for voltage comparisons. A thermo couple and a galvanometer may be connected in the output circuit to the amplifier for calibrations. The amplifier is first adjusted to a suitable level at its output terminals, and then the bottom potentiometer is adjusted until the same reading is obtained in both switch positions. The scales of both potentiometers are then read, the upper one, connected to the line, will indicate the level in graduations of 0.5 nepers. The lower potentiometer on the output side of the amplifier covers the graduations of the first potentiometer, so that continuous adjustments may be made for transmission levels between + 2 and — 3.5 nepers.

The advantages of this system of transmission measurements are, besides the intermediate stations not requiring any audio-frequency generators of their own, that when making a series of level measurements a change of frequency need only be made at the terminal from which the



R 1956 Fig. 24. Diagram of Transmission Measuring Set.

zero level is sent out. Thus no time is lost adjusting auxiliary generators at the intermediate stations. In a system with separate generators in each exchange it is also necessary, in order to get reliable results, that the local oscillator generates a voltage of the same curve form as the line voltage, which is not always the case. With the Radioaktiebolaget transmission measuring set an auxiliary voltage of correct frequency and curve shape is automatically obtained.

The transmission measuring set is used for sending out zero levels, for measuring the levels of incoming and passing currents, for amplification measurements, and for measuring loop-attenuation.

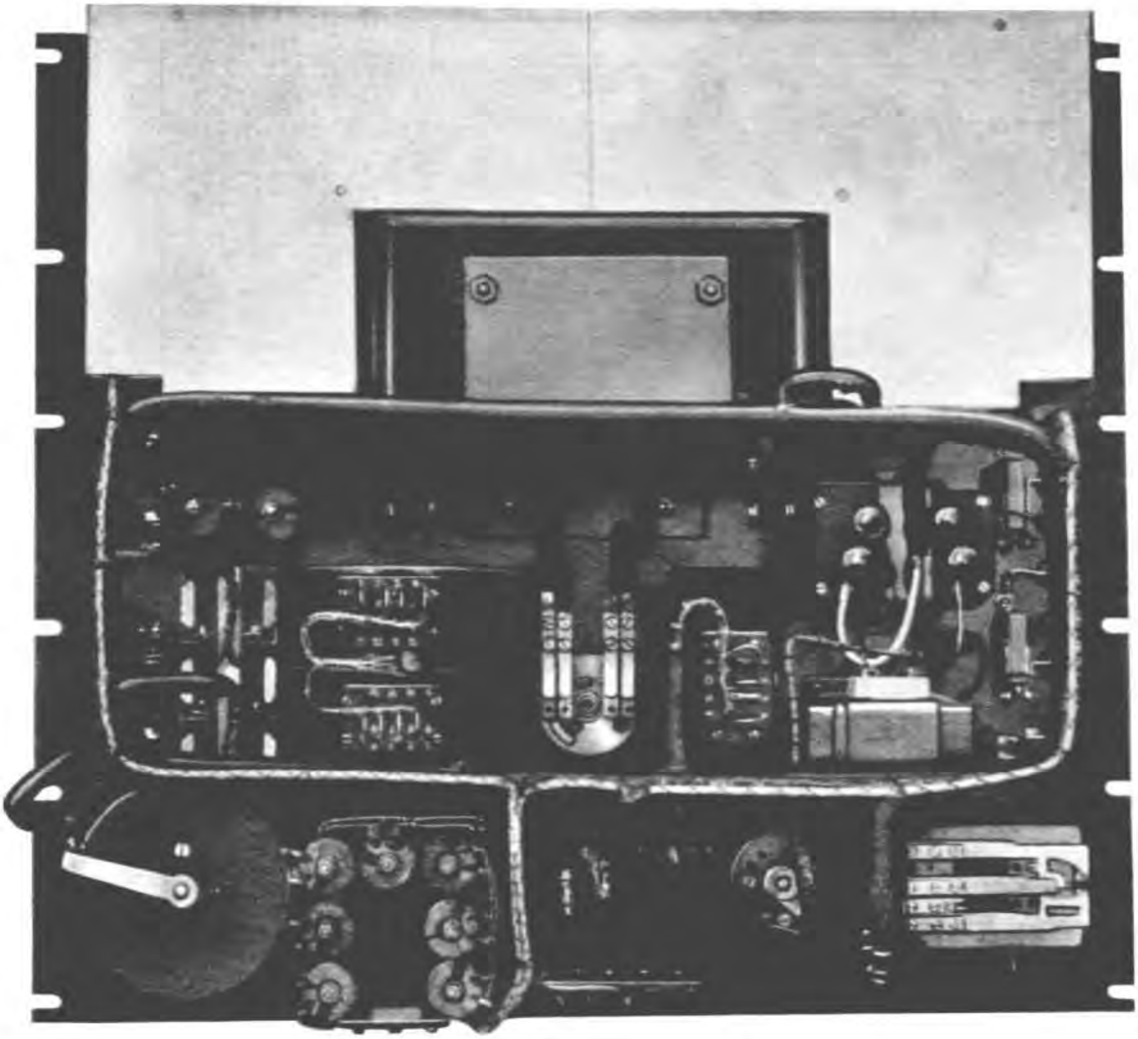
Fig. 24 is a diagram of the transmission measuring set. The line is connected to one of the jacks L on the left of the diagram. By means of the potentiometer F a suitable portion of the line voltage is taken out and passed partly to the valve-volt-meter, consisting of the three resistance-coupled valves at the top of the diagram, and partly to the amplifier, which consists of the three resistance-coupled valves in the centre. The thermo couple and the instrument appear on the right in the diagram. The potentiometer for fine adjustments is seen on one side below the thermo couple and is marked G, and the measuring switch is seen on the left on the valve volt-meter, and is marked D.

Fig. 25 is a photograph of the transmission measuring set. The instrument employed is a sensitive galvanometer of Cambridge manufacture. Below this instrument we see the switch by which the transmission measuring set is set for the various connexions, e. g. for sending out zero-levels, level measuring, etc. The two dials at the bottom on the right are those by which the above mentioned potentiometers are adjusted and on the scales of which the transmission level is read. The two dials at the bottom on the left are used for adjusting the grid bias of the valve in the last step of the valve volt-meter in order to obtain suitable sensitivity, and to adjust the amplifier. Below, in the centre, two switches are seen, the left of which is the measuring switch. The right hand one is used for changing input- and output sides when gain and loop-attenuation is measured, so that rapid measurements in both directions of a two-wire connexion can be taken.

Fig. 26 shows the back of the transmission measuring set. The valve volt-meter and the amplifier are well screened off in copper com-

R 1938

Fig. 25. Transmission Measuring Set, front.



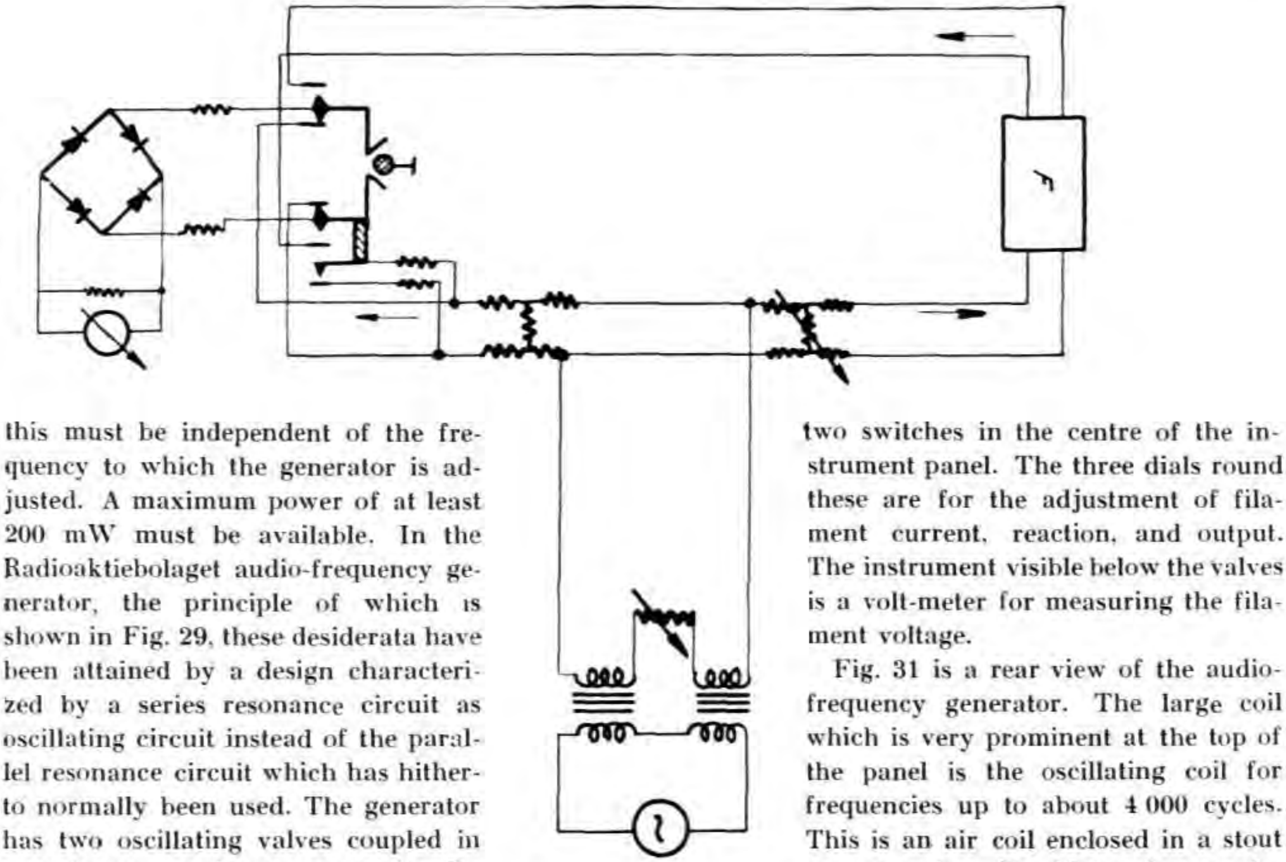
R 1939 Fig. 26. Transmission Measuring Set, back.

partments, seen at the top of the illustration. Below we see the galvanometer, and to the right below this is the thermo couple. A relay has had to be introduced in the panel to cause the circuit changes required during measuring operations.

The Siemens instrument for level measurements chiefly consists of a valve volt-meter with three amplifying valves and a rectifying valve. A thermo couple is used also in this apparatus for calibrating purposes. The instrument is graduated in nepers direct, hence in this instrument transmission level readings are taken on the instrument and not on the potentiometer scales, as is the case with the Radioaktiebolaget and the Western Electric transmission measuring sets.

Although amplification measurements can be taken by the above measuring set, it may be convenient to have a special *gain measuring set* for smaller exchanges with telephone repeaters. Fig. 27 is a diagram of a gain measuring set made by Radioaktiebolaget. The characteristic of this set is that a bridge coupling of copper-oxide rectifiers is used for rectification. Measuring is done by comparing the voltage obtained direct from an audio-frequency generator to that obtained at the output terminals of the amplifier. Fig. 28 is a photograph of the gain measuring set.

To measure alternating currents, an *audio-frequency generator* is required which must be continuously variable between 200 and 10.000 cycles. The current supplied must be practically sinusoidal, and the frequency independent of the properties of the valves and of voltage variations in the batteries. Furthermore, the frequency must not vary with the power taken out, and



R 1949 Fig. 27. Diagram of Gain Measuring Set.

this must be independent of the frequency to which the generator is adjusted. A maximum power of at least 200 mW must be available. In the Radioaktiebolaget audio-frequency generator, the principle of which is shown in Fig. 29, these desiderata have been attained by a design characterized by a series resonance circuit as oscillating circuit instead of the parallel resonance circuit which has hitherto normally been used. The generator has two oscillating valves coupled in cascade over a resistance connexion. By using two valves, the reaction phase is so turned that the conditions for oscillation are obtained without the use of inductive reaction. By this means the natural frequency of the generator is determined solely by the current resonance between the capacity and the inductance of the oscillating circuit. The losses in the condenser and the inductance coil are small and chiefly consist of the D. C. resistance of the coil. By resistances connected to the various taps of the coil, this resistance is made constant for all frequency adjustments. All voltages and currents in the oscillating system will consequently be independent of the frequency adjustment, i. e. the degree of reaction, and the power output will not be affected by different adjustments of the frequency. The audio-frequency generator has three amplifying valves, arranged in two steps, for the last of which two valves are connected in push-pull.

Fig. 30 is a view of the audio-frequency generator. The size of the condenser is varied by the four dials at the foot of the instrument. Different taps in the coil of the oscillating circuit may be used according to the different positions of the two switches in the centre of the instrument panel. The three dials round these are for the adjustment of filament current, reaction, and output. The instrument visible below the valves is a volt-meter for measuring the filament voltage.

Fig. 31 is a rear view of the audio-frequency generator. The large coil which is very prominent at the top of the panel is the oscillating coil for frequencies up to about 4 000 cycles. This is an air coil enclosed in a stout copper casing. For higher frequencies the smaller coil on the right of the panel, wound with stranded wire, is used. The condensers at the bottom of the panel are precision type mica condensers.

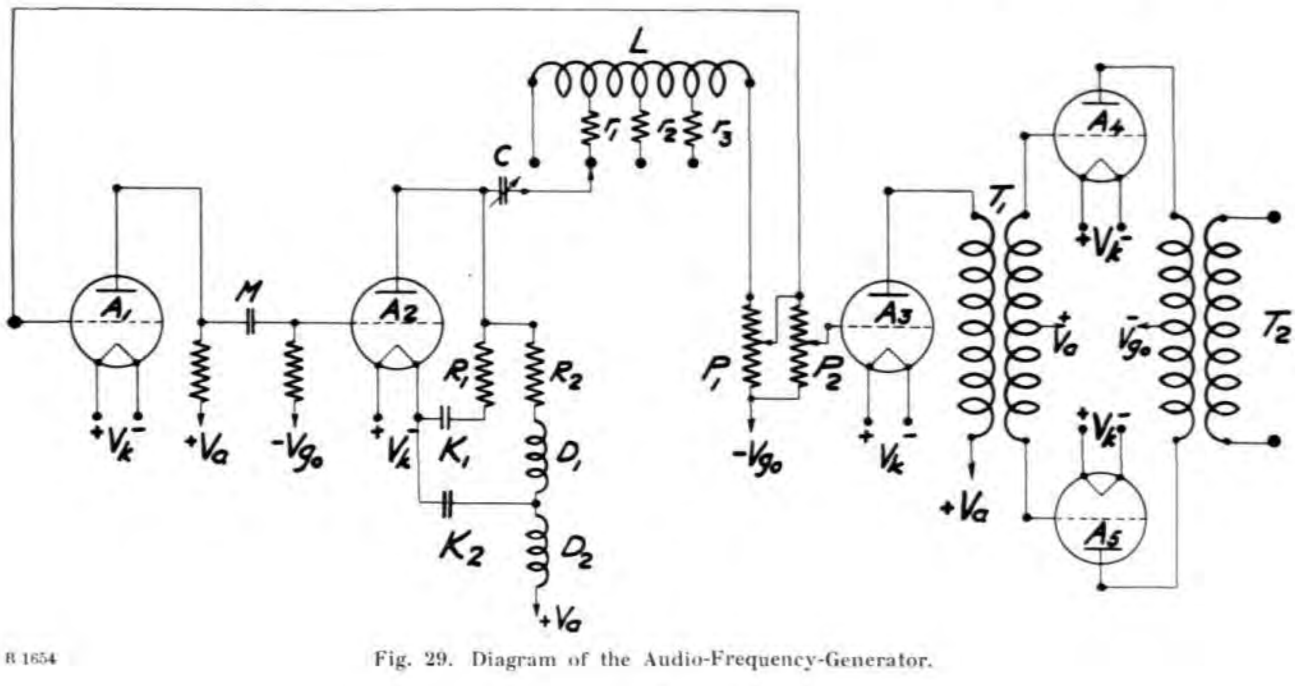
Besides audio-frequency generators of the above or similar types, interference generators are also used, particularly in Germany. The two oscillator valves oscillate at frequencies in the neighbourhood of 150 000 cycles. The beat frequency between the generated frequencies is taken out and amplified by a rectifier valve and an amplifier valve. Variation of frequency is obtained by changing the frequency of one of the oscillating valves.

All the above designs of the various measuring instruments are portable, i. e. the instruments are in separate boxes. In large long distance line exchanges, however, the instruments should be easily accessible in test boards or racks. Radioaktiebolaget has therefore designed a *test rack*, permanently incorporating all the instruments described above. Fig. 32 shows a test rack for D. C. and audio-frequency measurements. The left shelf accommodates the resistance and capacity bridge, the insulation measuring instru-

R 1940

Fig. 28. Gain Measuring Set.

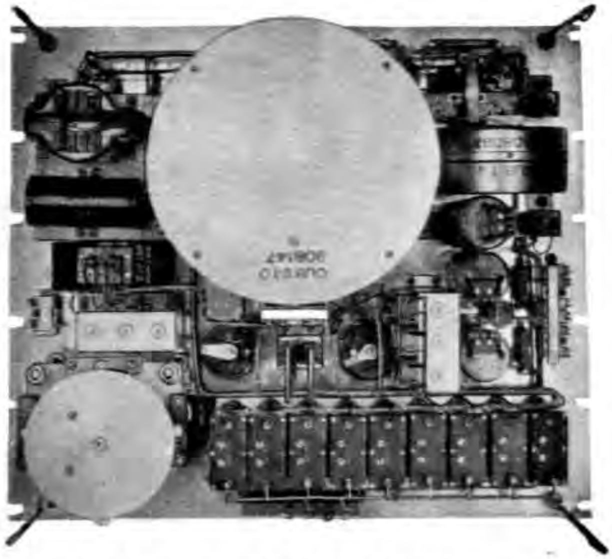
ment, and a Weston galvanometer which in certain cases is used as a bridge indicator. Operator's set and plugs for connecting to lines which are to be tested are also provided. In the right hand shelf the impedance measuring set and the cross talk meter are placed, and in this shelf there are also cords with plugs for line connexions, as well as an operator's set. One of the bays has in its vertical part the jack panels to which all long distance lines arriving in the



R 1654

Fig. 29. Diagram of the Audio-Frequency-Generator.

R 1652 Fig. 30. Audio-Frequency Generator, front.



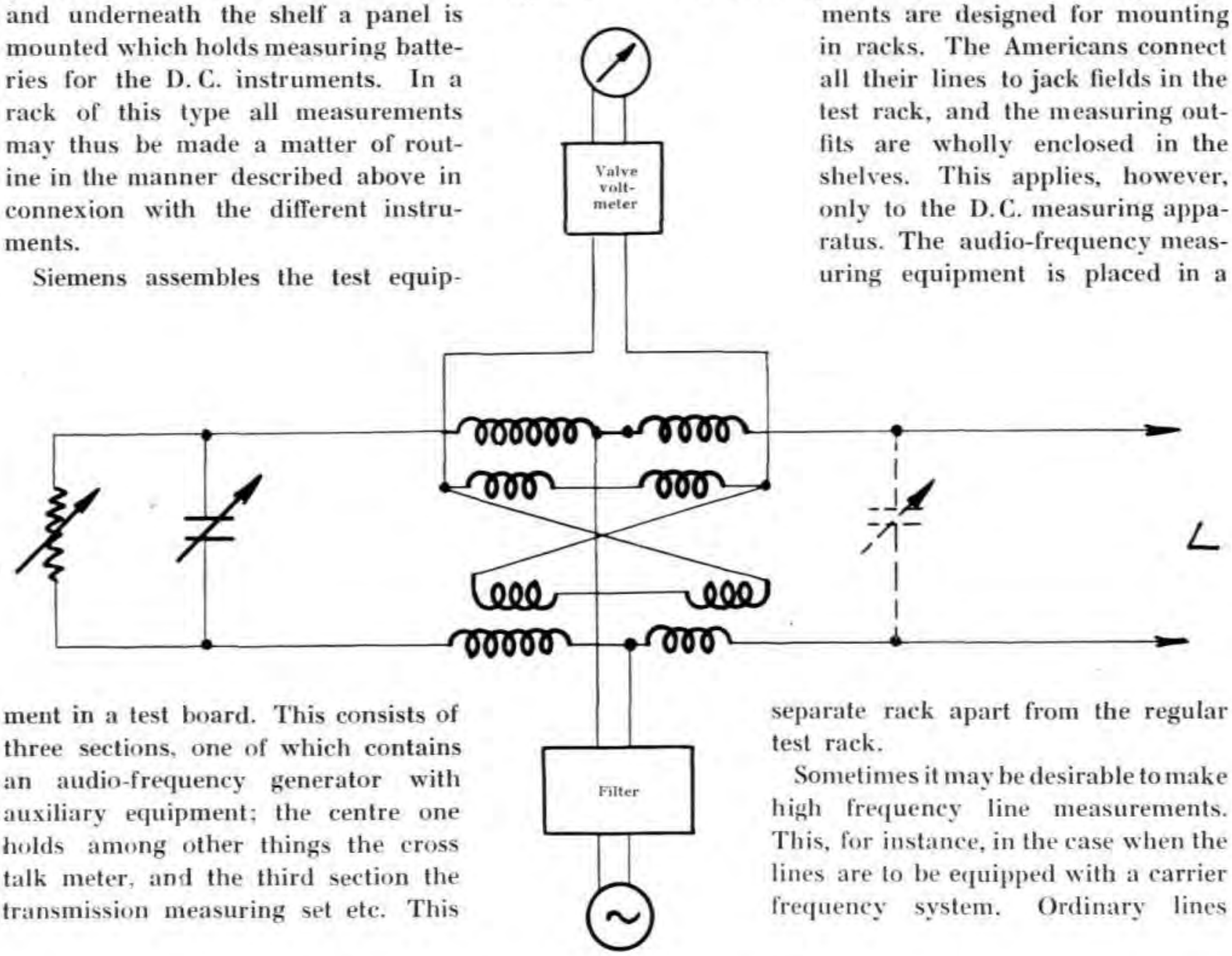
R 1653 Fig. 31. Audio-Frequency Generator, back.

exchange are connected. In the vertical part of the other bay we find the audio-frequency generator and the transmission measuring set, and underneath the shelf a panel is mounted which holds measuring batteries for the D. C. instruments. In a rack of this type all measurements may thus be made a matter of routine in the manner described above in connexion with the different instruments.

Siemens assembles the test equipment in a test board. This consists of three sections, one of which contains an audio-frequency generator with auxiliary equipment; the centre one holds among other things the cross talk meter, and the third section the transmission measuring set etc. This test board has no jack field, but lines must be specially connected to the board for testing.

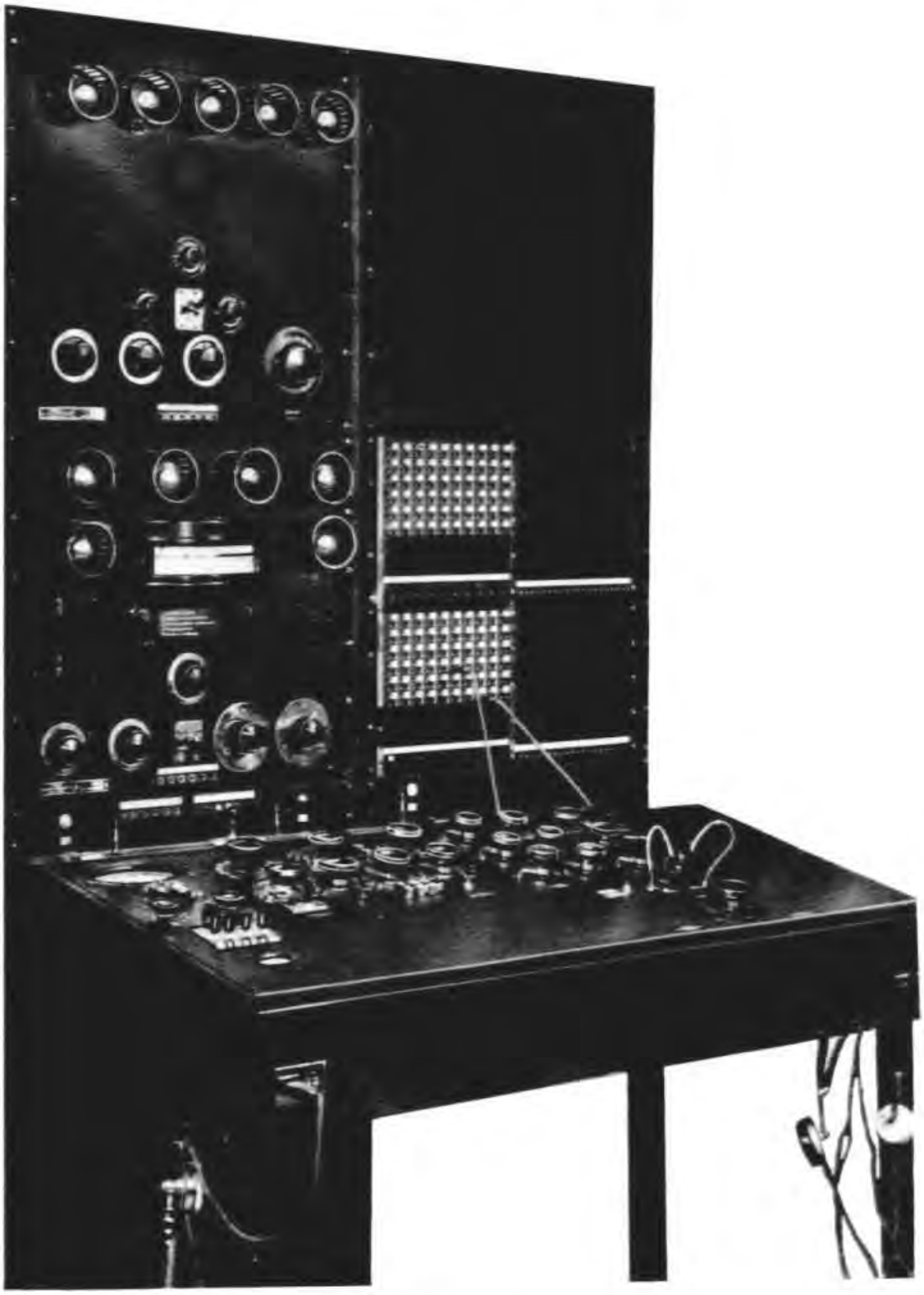
The most up to date American testing equipments are designed for mounting in racks. The Americans connect all their lines to jack fields in the test rack, and the measuring outfits are wholly enclosed in the shelves. This applies, however, only to the D.C. measuring apparatus. The audio-frequency measuring equipment is placed in a separate rack apart from the regular test rack.

Sometimes it may be desirable to make high frequency line measurements. This, for instance, in the case when the lines are to be equipped with a carrier frequency system. Ordinary lines

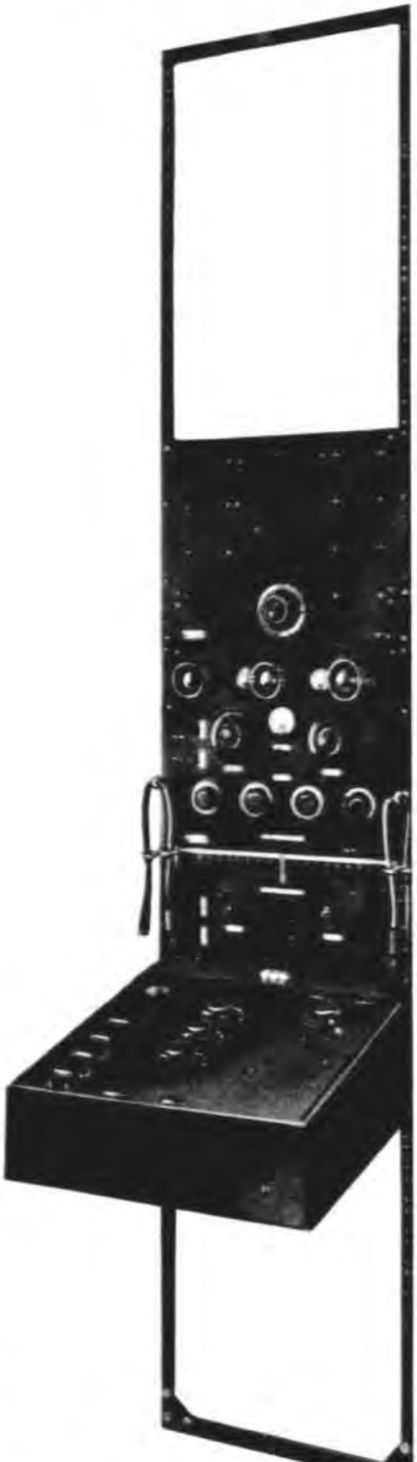


R 1953 Fig. 33. Diagram of High Frequency Impedance Measuring.

may also be advantageously measured by high frequency when tracing in-homogeneities etc. It is easier to determine the position of these by the use of high frequency, as the curve showing impedance as a function of frequency will have a greater number of peaks and depressions than if audio-frequency were employed. Radioaktiebolaget has therefore designed a *high frequency test rack*, a diagram of which is given in Fig. 33. The equipment consists of a specially wound hybrid coil, a balancing network consisting of a decade resistance and a decade condenser, a high frequency generator (frequency range 8 000—50 000 cycles), a filter, a valve volt-meter,



R 1771 Fig. 32. Test Rack for Long Distance Line Exchange, equipped for D. C. and audio-frequency measurements.

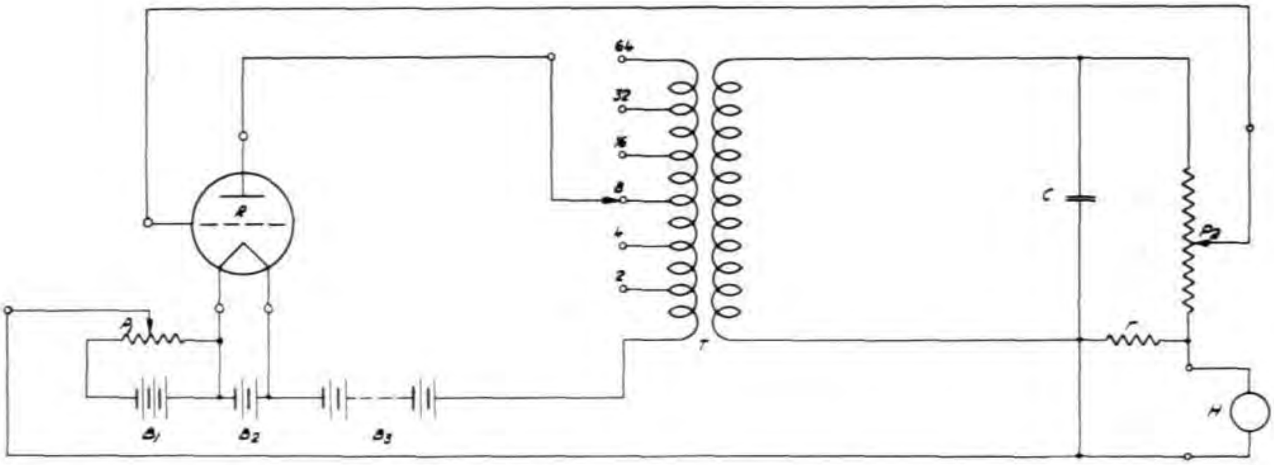


R 1782 Fig. 34. High Frequency Test Rack for Long Distance Line Exchanges.

R 1042 Fig. 35. High Frequency Generator for the 8 000—50 000-cycle range.

and an indicating instrument. When the impedance of the variable balance coincides with the line impedance, this instrument will be in zero-position. The high frequency generator is continuously variable, and with the assistance of this measuring equipment impedance curves for frequencies up to c. 50 000 cycles may, therefore, be plotted.

Fig. 34 is a photograph of a high frequency test rack. In the shelf we can see the decade resistance, the decade condenser, and the instrument, and in the vertical rack we see the high frequency generator and the filter panel. This is essential for matching the impedance of the generator and the measuring bridge. The filter panel consists of five different band filters



R 1657 Fig. 36. Diagram of Valve-Testing Set.

which may be connected alternatively. Fig. 35 is a photograph of the high frequency generator itself.

Modern telephony largely employs thermionic valves, which are used in amplifier- and high frequency equipments as well as in other apparatus. The working reliability depends on the quality of the valves, and there must, consequently, be provision for routine tests of the valves used in an exchange. The C. C. I. has also proposed that valve testing sets should be provided for all exchanges using valves. Radioaktiebolaget has, therefore, designed a *valve testing set*, a diagram of which is shown in Fig. 36. The connexion is in fact that of an oscillator, in which the valve to be tested is made to oscillate by reaction from the anode circuit to the grid circuit. It will be remembered that the amplifying power of the valve and the amount of reaction are factors in the oscillating conditions. The minimum value of the reaction required for oscillation will be a function of the amplifying power of the valve, and the design of the valve testing set is based on this principle. The anode transformer shown in the diagram has several taps which correspond to the different anode load impedances. When testing a certain valve, that tap is selected which best corresponds to the internal resistance of the valve. The reaction is varied by the potentiometer P_2 until the valve begins to oscillate, which can be heard in the telephone receiver H. The grid bias of the valve is adjusted by means of the potentiometer P_1. The adjustment of the potentiometer P_2 represents directly a value of the gain of the valve, and this potentiometer can be graduated in nepers directly.

This testing device will consequently give a measure of the effective gain of the valve under conditions corresponding to the working conditions. It is also possible to determine the internal resistance of the valve, its grid voltage space, and the amount of non-linear distortion introduced by the valve. One advantage is that no separate oscillator and no gain measuring set are required for these measurings, which can, therefore, be rapidly and reliably used for routine tests of a large number of valves.

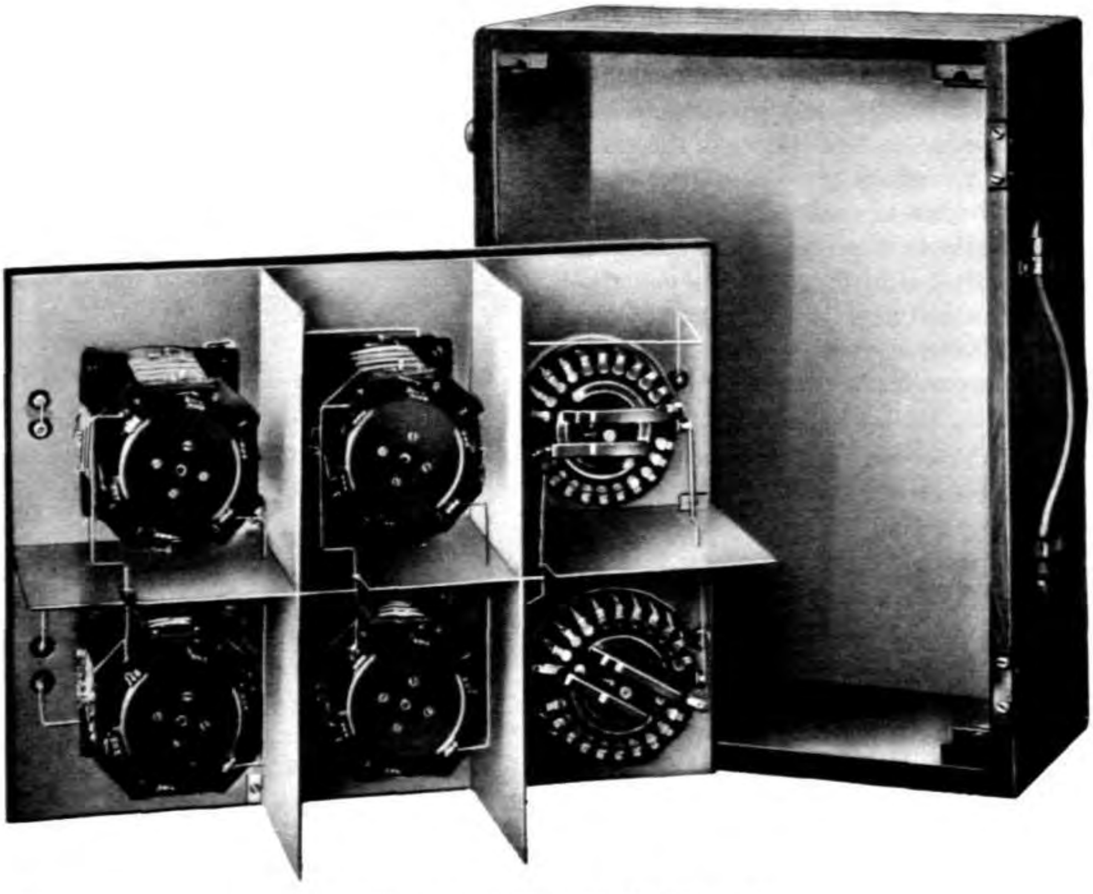
Fig. 37 is a photograph of the valve testing set. In the centre we see the reaction potentiometer, to the right of which is the switch for the several transformer taps, and above that is the valve socket in which the valve to be tested is placed. The plug visible at the foot of the apparatus serves to connect the voltmeter incorporated in the instrument for measuring filament voltage, grid bias, and anode voltage.

Radioaktiebolaget has designed a number of laboratory instruments for its own use, one of which—an *attenuation standard*—is shown in Fig. 38. This is a variable artificial line made from resistances connected in H. The attenuation standard may be adjusted in steps of 0.01 neper for attenuations up to 12.1 nepers. The large attenuation steps are set by the four dials on the left of the instrument, which represent attenuations of 5, 3, 2, and 1 nepers respectively. Tenths and hundredths of nepers are adjusted by the two dials to the right, which control specially designed potentiometers.

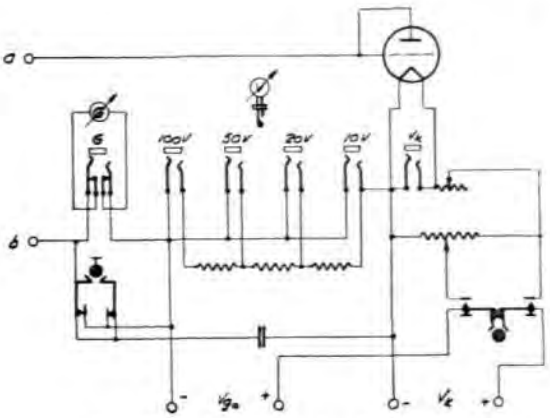
Fig. 39 is a rear view of the attenuation standard. Thanks to symmetrical arrangement of the resistances in the attenuating units, and to the small capacities between the windings, this instrument can be used for measurements with frequencies between 0 and 50 000 cycles.

R 1655 Fig. 37. Valve Testing Set.

R 1781 Fig. 38. Attenuation Standard, 0.01—12.1 nepers.



R 1943 Fig. 39. Attenuation Standard, back view.

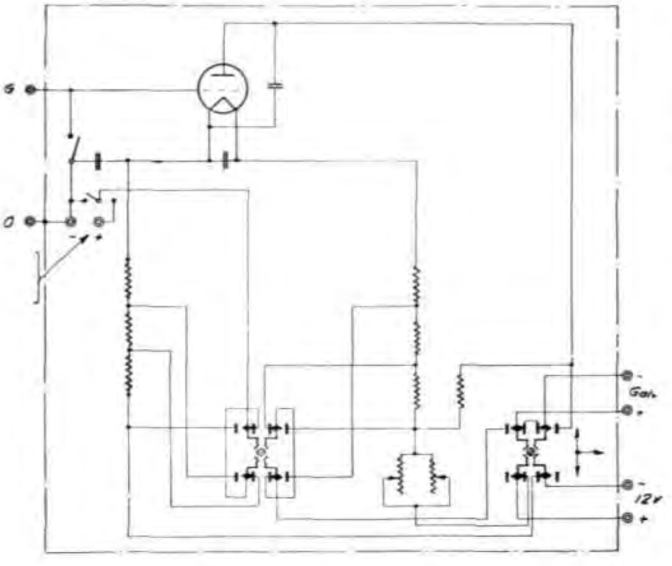


B 1957 Fig. 40. Valve voltmeter for A.C. voltages under 100 volts.

Valve volt-meters of various types are of great use in every laboratory and test room, and also in telephone exchanges — particularly for the maintenance of carrier equipments. Fig. 40 is a valve volt-meter for measuring A. C. up to 100 volt. The valves here function as pure rectifiers, and anode current will flow if the amplitude of the voltage measured be greater than the impressed negative bias. If, then, the bias is increased until it equals the amplitude of the voltage measured, the current through the valve will cease. This is indicated by the galvanometer connected to it. The connected voltmeter will, therefore, indicate the grid bias, and consequently also the amplitude of the measured voltage. Fig. 41 is a photograph of the instrument. Different ranges to be measured can be selected by plugging the voltmeter to different jacks.

Another volt-meter of interest is shown in Fig. 42. This is intended for measuring A. C. voltages of small amplitudes between 0 and 3 volt, and works with anode rectification at negative grid bias. There will, consequently, be no grid current when it is used for measuring voltages of amplitudes less than the grid bias. The constant anode current component, i. e. the anode circuit D. C. corresponding to the impressed grid bias, is so

B 1927 Fig. 41. Valve voltmeter, type RVS.



R 1958 Fig. 42. Valve Voltmeter for measuring small A.C. amplitudes.

compensated that the galvanometer receives no current if the valve filament current is correctly adjusted and no A. C. voltage is impressed. A sensitive galvanometer can therefore be used for measuring, and that galvanometer can be graduated directly in volts. Fig. 43 shows the valve voltmeter.

The valve volt-meter shown in Fig. 44 may be used with advantage as an indicator in bridge measurements. It can be used for a very wide range of frequencies, viz. between 50 and 50 000 cycles per second. The valve volt-meter is compensated so that the effect on the galvanometer from D. C. in the valve anode circuit is neutralized by means of adjustable current taken from the filament circuit. Its sensitivy is great, and the needle will deviate 20 degrees of the scale for a voltage of 0.1 mV at the input terminals

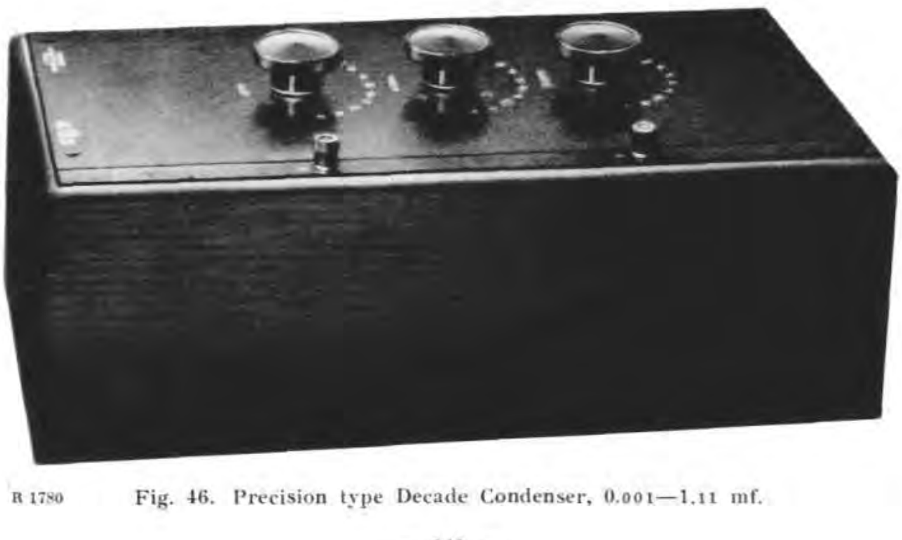
R 1944 Fig. 45. Valve voltmeter. type RVH.

R 1941 Fig. 43. Valve voltmeter, type RVA.

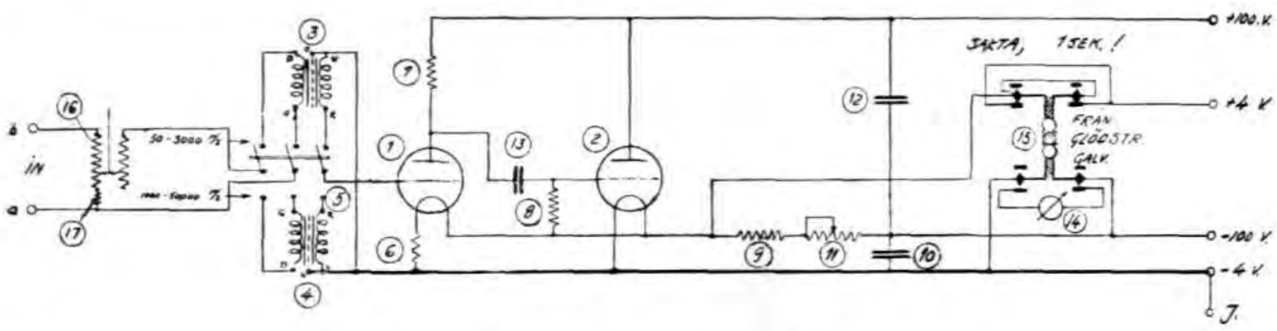
for a frequency range of 50 to 3 000 cycles. The corresponding figure for the higher frequencies is 2 mV. Fig. 45 shows this type of valve voltmeter.

Fig. 46 is a decade condenser with mica condensers of precision type, with a maximum capacity of 1.11

In this review of equipment and measuring instruments for long distance telephone systems it is, of course, impossible to give anything but a cursory account of the several types of apparatuses, and those interested are therefore referred to the literature published on the various instruments.



R 1780 Fig. 46. Precision type Decade Condenser, 0.001—1.11 mf.



R 1959

Fig. 44. Valve voltmeter for the 50—50 000-cycle frequency range.

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The factory of Svenska Radioaktiebolaget.
(Swedish Radio Corporation) at Stockholm.

The Stockholm Trunk Exchange.

Some general principles of interurban telephony, and their application.

By *A. Lignell*, Director of Telephones.

The areas of free traffic, i. e. traffic for which no charge is made beyond the annual subscription, are very extensive in Sweden, contrary to what is generally the case abroad. The subscriber is thus allowed free telephone communication not only within his own exchange area, but also within the immediate rural surroundings. Where these free areas are larger, as is sometimes the case, the subscriptions are higher, both for subscribers in the town and in the surrounding free areas, than the corresponding subscriptions in smaller free areas.

Calls between the town and the free area are dealt with as inter-group calls, or in the same manner as a call to another sub-exchange in the town, with the difference, however, that the calling party only asks for the exchange desired and, when this exchange replies, asks for the number of the called party. These calls are counted in the number of calls determining the annual subscription, in the same manner as the purely local calls, i. e. by automatic meters. The service cost of these calls in Stockholm is no larger than that of a call between two local exchanges in the town, while the same call, if put through in the same manner as in a trunk exchange, would be considerably more expensive not only as regards the requisite service staff, but also as regards service facilities, accomodation required, and administration.

The free junction call traffic offers considerable advantages to the subscribers, and also indirectly to the administration.

The subscriber is immediately connected without having to wait, which is important in these short-distance calls. The commercial district surrounding the town gets as rapid and cheap telephone communication as the town itself. The administration avoids the more complicated and costly trunk service and the costs of booking and collecting the short distance fees, which cannot reasonably be put high enough to leave any profit if trunk service were used. Even in so-called direct trunk traffic i. e. when the caller as a general rule is put through immediately when ordering the call, an operator can hardly effectuate more than an average of 35 calls an hour, while in outgoing inter-group traffic the daily average of an operator is 330 calls per hour.

The significance of this with regard to the cost of these calls when the line-costs of the call are slight is easily understood. The free traffic area round Stockholm, the radius of which averages 40 km., at present includes about 38 000 subscriber's stations connected to 203 exchanges, with 2 350 lines connecting these to Stockholm, and the traffic between the town and the other free-traffic-area exchanges amounts to c. 200 000 calls per week day, an average of c. 85 calls per connecting line. Corresponding calls abroad are generally charged for and considered trunk calls.

With respect to the cost of effectuating the call, trunk traffic may be divided into traffic where line-costs are low and staff costs predominate — short trunk calls — and traffic where staff-costs are insignificant in comparison to the high line-costs — long trunk calls.

To obtain the most economic results, it is therefor necessary to reduce staff-costs as much as possible for short trunk calls, while for long trunk calls efforts must be concentrated on obtaining the best possible utilization of the line for taxed call-periods.

The Exchange for Interurban Traffic.

In consideration of these circumstances, the inland trunk circuits in Stockholm are divided into two groups, housed in different parts of the Exchange. Foreign traffic is located in a separate room, with a new design of cordless service desks.


STOCKHOLM'S
FREE SERVICE ZONE
EXCHANGES WITH MORE THAN 1500 SUBSCRIBERS
" BETWEEN 1500 AND 1000 "
" " 1000 " 500 "
" " 500 " 100 "
" LESS THAN 100 "
BOUNDARY OF THE STOCKHOLM FREE SERVICE ZONE.
Södertälje
Upplands Åsby
Odensala
Sigtuna
Märsta
Vendelsö
Österhaninge
Södra Åsby

Booking of Calls.

No central record positions for trunk calls are used in Stockholm, but subscribers order their calls direct from the operators at the trunk positions for the route required. Orders to the heavily engaged routes, however, are not received by the switchboard operators, but by special order-clerks placed close to each board. The switchboard operators assist in this only in case of a rush of orders.

When ordering a trunk call, the subscriber need only tell the A-operator the name of the exchange required. The A-operator then calls a special distributing section—the "position distributor"—, the multiples of which hold the record lines to the various interurban positions—2 lines to each interurban positions—and asks for the exchange, when the subscriber is connected to the trunk operator direct.

This section is thus intermediate between on the one hand the local exchanges and on the other hand the trunk exchange, and directs the calls ordered to the traffic route desired. Subscribers to automatic exchanges are connected directly to an operator in this section by dialling the figure 9. and then only ask for the name of the exchange. An operator in the distributing section directs an average of 300 call-orders an hour.

This procedure avoids the frequently long delays caused in large trunk exchanges by the time required for sorting and dispatching the call-orders from a central order office to the trunk positions, frequently equal to, or even longer than, the time necessary to put the call through. The calling party is also in direct communication with the operator on the line he wants, which is useful for getting to know the approximate time he will have to wait for the call, and also for the correct reception of the order, this latter particularly for international calls, the operators on these routes being linguists. Enquiries and alterations of orders can also be made to the service boards direct, without the detour and loss of time involved by a central order office.

R 2044 Position Distributor.

Connecting a subscriber to the trunk exchange.

On account of their many advantages, manual B-positions for connecting subscribers to the interurban exchanges are retained in the conversion of the Stockholm net to automatic working.

Some of these advantages are:

The B-position multiple is connected before the automatic exchange, and a trunk call therefore does not have to pass the many contact points of the automatic equipment.

A subscriber's line may be blocked for other trunk calls, but still be open to local traffic, as, when the subscriber's line is taken in the B-multiple, the trunk operator can disconnect it or leave it open for local calls at will, and cut off any conversation in progress at the very instant when the trunk call is to be connected.

The subscriber is accessible to the traffic watch in case of faults in his automatic equipment. The supervisor and the traffic control being placed close to the B-board, certain information can be given to the subscribers, e. g. regarding a number engaged for a long time. If necessary, they many cut in on the line to hurry up such a conversation.

trunk traffic. Indicator plugs in its subscriber multiple enable the trunk operator to find out without waste of time

a) the new number, if number has been changed. Such changes are frequent, and often necessary when a subscriber has moved to another address in large telephone areas,
b) when trunk calls should be referred to another number during long or short periods,
c) if a subscription is cancelled, or a number vacant
d) if a number for one reason or another is cut off,
e) if a number is cut off only for trunk-calls.

B 2045 Trunk junction position.

If the switchboard for reliability control is placed near to the B-board, control of "number engaged" and "no reply" in the automatic system may be exercised from the B-board.

The trunk lines require the full attention of the operator, whose work will be simplified, while at the same time the connexion will be more quickly obtained by order wires than by using a dial.

If international calls are connected to the local net over a special trunk multiple, the B-operator, at the request of the international operator, can if necessary break an inland call in favour of a long distance, hard-to-establish foreign call.

The B-board supplies information regarding

The B-operator also informs the trunk operator if the number is engaged by another trunk-call, or by an international call.

All trunk service positions may of course be fitted with dials, in case it should be found expedient to have no B-operator on night duty in local exchanges with slight trunk night-traffic.

The Section for Short Distance Calls.

In one of the inland sections, lines of up to 90 km. in length are served. This distance includes our two lowest call-tolls — 20 öre for calls within 45 km. and 30 öre for calls at distances between 45 and 90 km.

According to what has been said above, the staff costs for the calls in this section should be as low as possible, while the intensive utilization of the lines, which always demands larger staff and therefore increases the cost, will be a secondary consideration.

Three ways of effecting this have been used, viz.:

1. The introduction of technical devices, mainly intended to utilize the staff to the utmost, and so cheapen the service,

tor in the section can take any call in that section. The calls are established over the trunk junction positions of the local exchanges by order wires.

This arrangement allows a flexible adjustment of the staff to the variations of the traffic curve at various hours of the day (see diagram 1). During busy hours, each operator serves 10—11 trunk circuits with good answering times (average time for answering, c. 5 sec.).

R 2046

Section for Short Distance Calls.

2. simplifications in traffic regulations (putting through the calls),
3. the employment of less highly paid staff than for the long distance traffic.

Where a line of communication contains several trunk circuits, these are always divided in outgoing and incoming circuits. For the full utilization of the staff, the following arrangements are made for incoming traffic:

100—120 trunk circuits are connected in sections of 9—12 service positions, the reply jacks and call lamps being multiplied so that any opera-

The average number of calls per circuit and day (8 a. m.—10 p. m.) is 66 (during the summer 77), which may be considered a good utilization of the circuits with regard to the short waiting times—average waiting time max. 10 min. for ordinary calls—required in the traffic on these short lines. The average number of calls per operator and period of duty (6.5 hours on week days) is 340, thus an average per operator and week-day-hour of 52.3.

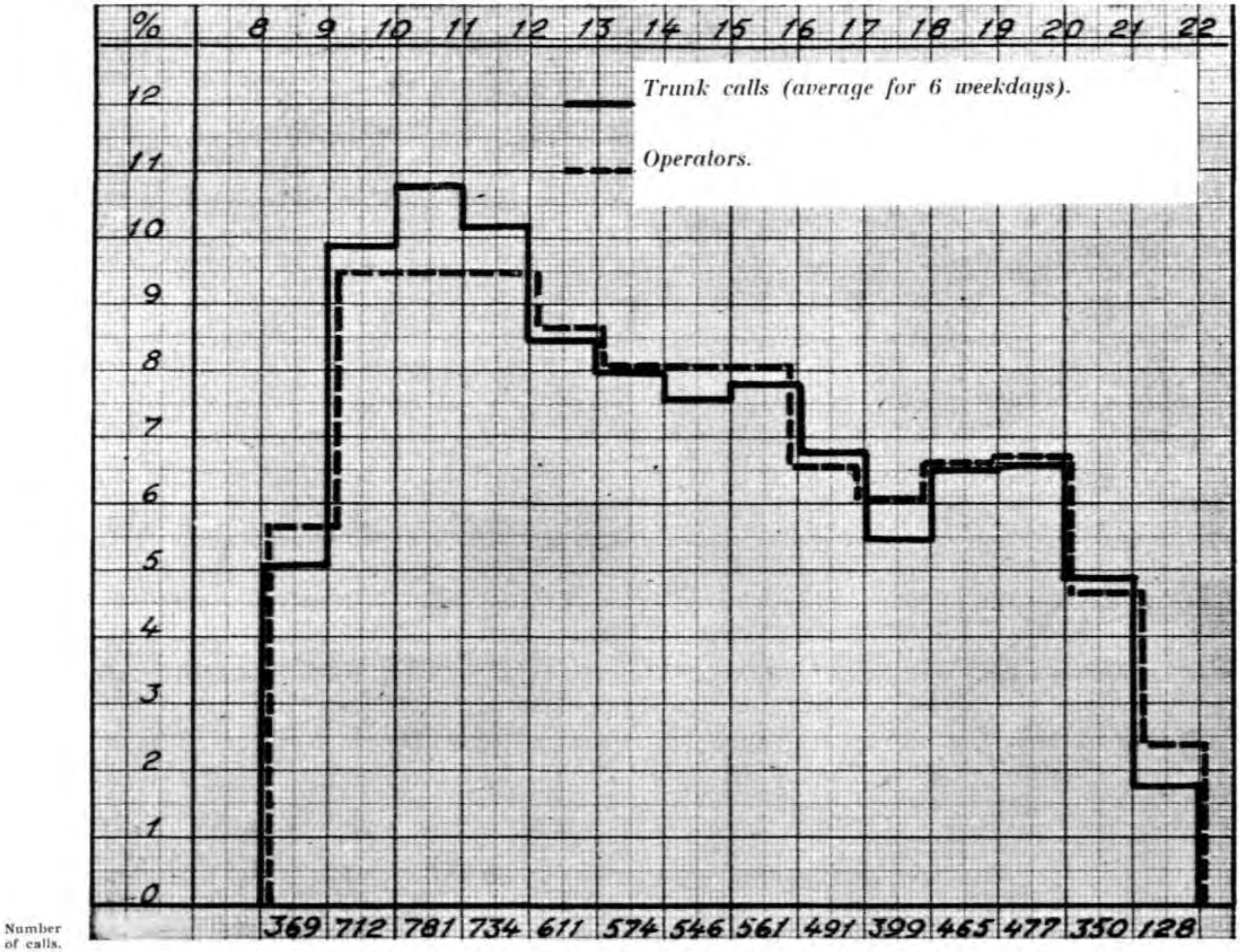
For routes where the number of personal calls is large, special service is detailed for the

DISTRIBUTION of Incoming Trunk Calls.

In per cent. of the number of calls and operators, during the hours 8—22.

137.5 Operator-hours, 7198 calls = 52.3 calls per operator-hour.

HOURS.



B 3016

DIAGRAM I.

circuits dealing with these calls, which of course demand specific attention in the exchange of destination.

These arrangements not only save operators but, as a consequence of this, also space and service positions in the exchanges, which represent considerable amounts.

The circuits for outgoing calls are placed in separate sections, each section comprising 9 service positions. The connecting devices in each position consist of double cords with a service switch for each double cord (for speech or signals), cut-off key and two supervisory lamps. To be able to speak or signal by one of the cords only, two interruption keys are provided, belonging to the front and back row of cords respectively. Finally, each position has a keystrip for automatic selection of order wire to a disengaged B-operator at the trunk junction positions of the local exchange, and 6 keys for reception of call-orders from the subscribers. The two middle ones belong to the two order lamps of the position, and the remaining 4 to the two order lamps of each of the neighbouring positions. This arrangement enables the operators to assist one another in taking the orders.

The service procedure in the department for short distance calls is the simplest possible. Advance calling is only needed for personal calls, as this department is most concerned with utilizing the staff, and the time the circuit is engaged is of secondary importance.

The section for incoming calls does not control the duration of the calls, which is thus left entirely to the originating exchange. The correct charging and booking of the calls are, however, checked by constant line and service control, the object of which is to keep up a high standard of service. This control is exercised in the originating exchange as well as in Stockholm, and checks that the charges are correct and that all calls are booked. The staff used in this department consists of group-centre operators ranking between local and trunk operators, with lower pay than the trunk operators proper and, unlike the latter, not permanent officials.

The department serves 262 trunk circuits to 58 exchanges, and out of the 66 positions 49 are at present filled in busy hours, 37 of which are outgoing (including 2 order positions) and 12 incoming.

In the outgoing section an average of 4 lines are served by each operator when all positions are occupied, and in the incoming department 10.

R 2047 Incoming Call Section.

The Section for Long Distance Calls.
(Lines more than 90 km. in length.)

In this department, the special concern is the full utilization of the circuits for taxed call-periods. The technical devices are therefore designed to enable a trunk circuit to be rapidly connected to a subscriber's line as soon as the preceding call is finished, and includes cut-off keys by which a local call in progress can be rapidly disconnected by the telephonist. Each position is equipped with 6 cord-groups, each consisting of a central cord and 2 subscriber cords (one right-hand and one left-hand cord). In front of the centre cord, there is a cord selector as well as a calling and supervisory lamp. The connexion of the long distance circuit to the group may either be permanent or obtained by the centre cord. When the cord selector is set to the left, the line is connected to the left-hand subscriber cord, if to the right, to the right-hand cord. If a call is proceeding on either of the subscriber cords, the call next in turn may be prepared on the other subscriber cord, and the connexion for this later call can be made by a simple manipulation of the switch. A cut-off key is provided for each subscriber cord. From the time when the subscriber is warned in advance of the call, until the final connexion is made, this is pulled up. During this time the subscriber, who is blocked for trunk calls, can use his line for both incoming and outgoing local calls.

266 circuits to 90 exchanges are served in this department from 131 positions, 128 of which, besides a requisite number of special booking positions, are at present engaged during busy hours.

The distribution of the long distance traffic, as well as of personal calls, is shown in diagram II. For comparison, a percentage curve for the local traffic in Stockholm is also plotted.

The average number of inland long distance circuits handled by each operator during the busiest hours is 2.1. The average number of calls per long distance circuit per normal weekday is 89.

The average number of calls per operator per period of duty (6.5 weekday hours) is 95.

of electric time recorders. As the desks have no multiples, they are also more easily supervised than the ordinary boards with high multiples. Each row of desks comprises 5 service positions, each position with 3—5 circuit groups. One of these groups is a reserve group, to which any circuit connected to one of the other groups in the position may be switched over by depressing a group switch.

Each service position is provided with:

R 2048 Section for Long Distance Calls.

The Section for International Traffic.

This section is equipped with cordless service desks with selector devices for finding a disengaged line to the trunk junction positions in the local exchange desired.

Special consideration has been given in the designing of these desks to making them roomy and convenient for journal writing and for accommodating the large number of directories required for international intercommunications. The desks are also equipped with a new design

Connecting switch, for connecting the operator's telephone set to that of the position to the right, (for assistance in linguistic difficulties etc.),

Listening-in key, allowing listening-in without disturbing the conversation,

Switch, for selecting an unamplified connexion in the through switching board (for transit traffic),

Switch, for selecting an amplified connexion in the through switching board (for transit traffic), Blocking lamp, which is lit as long as the trunk circuit of the group is served by another position for transit traffic.

Two concentration switches, for concentrating the circuits to the "night-service position", and for concentrating the circuits during slack hours of the day.

The switching devices otherwise provide the same service facilities as the corresponding devices in the department for long distance calls. The time recorders, driven by an electrical master clock, are equipped with observation lamps, which are lit 10 secs. before every full 3 min., 6 min., 9 min., etc., and burn for 20 secs. When the lamp is lit and at exactly 3 min., 6 min., 9 min., etc., a short buzzer signal is also heard.

The time recorders are also provided with a device for automatically sending out a tone on the circuit, to warn the subscribers 10 secs. before the end of every full 3 min. period.

Each service position also has a place for a motordriven miniature Morse apparatus with automatic starting and stopping devices. This apparatus is placed so as not to encroach on the writing accomodation, and the tape runs, at right angles to the length of the table, to the left of the operator. This device is used on routes where calls are ordered by telegraph on account of the additional advantages to the service of receiving on tape instead of by buzzer signals.

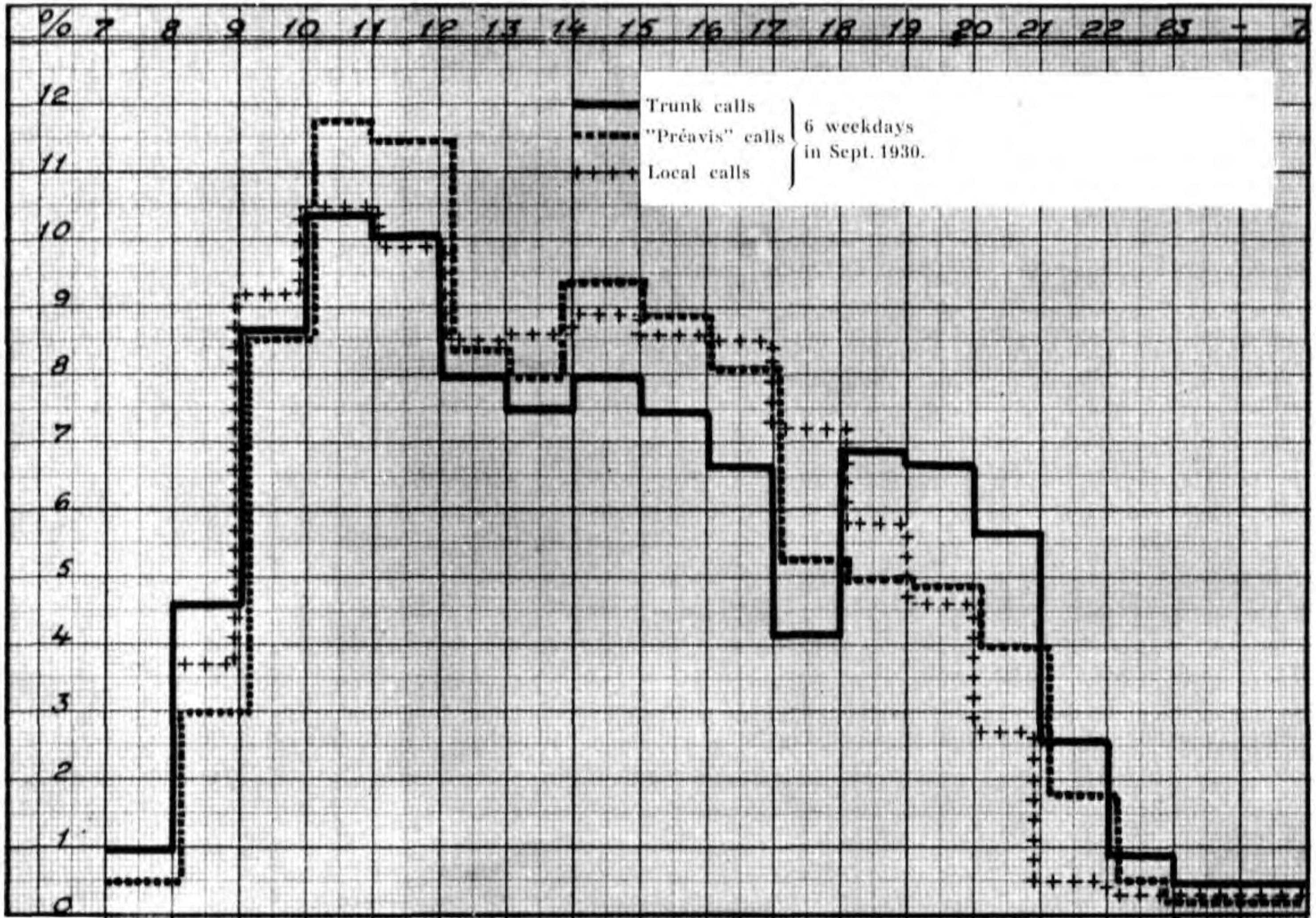
R 2049 Section for International Traffic.

Transit Traffic.

In this room a special board is arranged for transit conversations between 2 trunk circuits, which also serves for a night-service board. The transit call can be established with as well as without amplification, and all the trunk circuits in which amplification is wanted, as well as certain trunk circuits exclusively intended for transit traffic, are connected to the multiple of the transit board. All supervision and handling of the call is always done by the "Opératrice Directrice".

Distribution, in per cent., to the different hours of the day of inland trunk calls (out, in and transit), and of inland personal calls (out and in) in the Section for Long Distance Calls, and the distribution, in per cent., of the local telephone traffic.

Hours



Average per day:

	7–8	8–9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	17–18	18–19	19–20	20–21	21–22	22–23	23–7		Per weekday
No. of calls (trunk).	240	1086	2037	2440	2357	1866	1745	1873	1764	1569	982	1607	1569	1333	608	219	182	S:A	23 417
No. of "préavis" calls.	39	250	714	972	945	697	662	779	733	672	433	410	404	328	152	43	16	S:A	8 249

DIAGRAM II.

R 2054

Ericsson

In the department for inland long distance calls, there is no separate transit board, but in case of a transit call the long distance circuits are connected directly in the long distance multiple, and cord amplifiers are placed in the positions directing the traffic on those routes where amplification is needed for the inland traffic.

The size of international traffic and its distrubution throughout the day are shown in diagram III, which also shows the number and distribution of international personal calls.

B 2050 Row of desks in the Section for International Traffic.

Traffic Testing and Distributing Board.

In each of the 3 service rooms there is a testing and distribution board, to which all the trunk circuits of that room are connected, as well as all the record lines to the trunk positions.

Each line in this board is provided with 4 jacks, viz. one break jack to the line, one break jack towards the exchange, and, between these, 2 branching jacks.

Below the jack panel in the desk top are cords for distributing the lines (direct connexion or connexion with clearing-signal).

In these switch boards, which are used for tests, for temporary re-direction of the traffic, and when faults occur, the circuits for broadcasting and telephotography are also dealt with, though for the two latter the line connexions are made in the repeater station.

Beyond the sections mentioned, there is another section, common to the whole exchange, which is called the "Trunk Queue". When required, this section will allot to the service operators such subscriber lines as are much in request for long distance calls in their proper order of booking.

Control Department.

A control department, placed in a separate room, is provided as a check on the capacity of the telephonists, and of the utilization of the circuits for taxed call-periods.

Traffic.

Direct lines between all places with any considerable reciprocal traffic are essential for efficient service. Intermediate exchanges need not then take any part in putting through the calls, which would increase staff costs, impede the full utilization of the circuits considerably, and also delay the calls.

Stockholm is therefore joined by direct lines to all the 140 more important traffic centres of the country, and the traffic transmitted over these exchanges to other places is comparatively insignificant. The fact that only 2.8 per cent. of the Stockholm inland telephone traffic is transmitted by any intermediate exchange confirms this.

The unit-tolls for Swedish inland calls are shown in the table below.

	9 a. m.—6 p.m. or 11 p.m.—7 a. m. Öre	7—9 a. m. or 6—11 p. m. Öre
Distances up to 45 km.	20	20
Distances above 45 up to 90 km.	30	30
» » 90 » » 180 »	50	40
» » 180 » » 270 »	70	50
» » 270 » » 450 »	90	60
» » 450 » » 540 »	110	70
» » 540 » » 630 »	130	80
» » 630 » » 720 »	160	90
» » 720 » » 810 »	200	100
» » 810 km.	250	120

These charges are notably low, which is made possible by letting ordinary calls wait a reasonable time, while really urgent calls are put

R 2051 2 Trunk Positions.

through quickly at double tolls. By this method the line can be far better utilized—which improves the yield per line—than could be done by the "no delay" system.

Business men and subscribers in general undoubtedly find it more advantageous to pay a low toll for the bulk of the traffic, put through after a reasonably short time of waiting, and to pay a raised fee for really urgent calls, and get them practically immediately.

That the Swedish telephone system really keeps the times of waiting for ordinary calls within reasonable limits, is best shown by the very low percentage of urgent calls.

For the whole trunk net this was

in 1926	1.9	per cent
1927	1.7	" "
1928	1.7	" "
1929	1.7	" "
1930	1.3	" "

The distribution of outgoing trunk calls in Stockholm among the various months of the year, 1926—1920, is shown in diagram IV a. It will be noted that the summer months July and August show the heaviest traffic.

The average annual increase in 1926—1929 is 4.5 per cent. The larger increase in 1930—6.8 per cent. — is to a certain extent accounted for by the Exhibition during that summer.

The total trunk traffic of Stockholm 1930 was made up of

5.262.294 outgoing calls
5.788.523 incoming calls
391.328 transit calls.

A total of 11.442.145

In addition, about 200 000 free calls are put through daily between Stockholm and the free traffic area (c. 40 km. radius from Stockholm).

Diagram IV b gives the number of outgoing call-minutes to foreign countries from Stockholm during each mounth, 1928 — February 1931. In comparison to February 1928, February 1931 shows an increase of 108 per cent., and compared to the previous year the whole outgoing traffic has increased

during 1929 by 54 per cent.
" 1930 by 16 per cent.

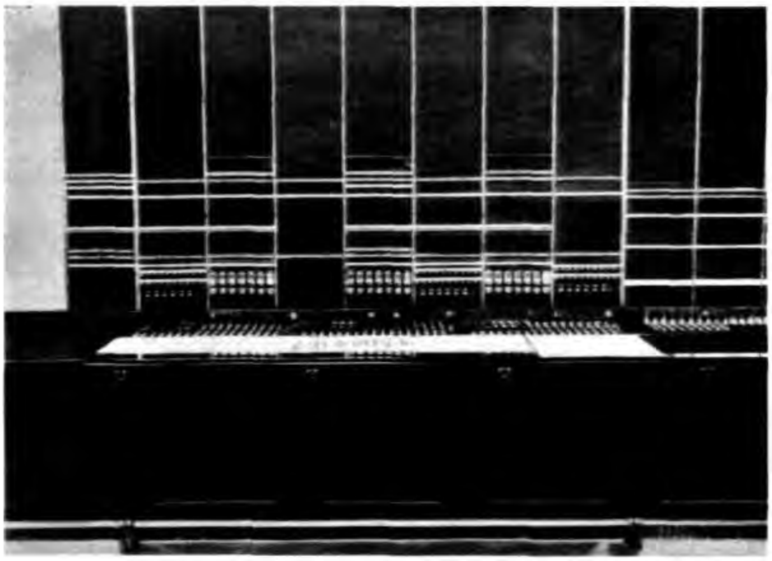
During 1924, 29 per cent. of all calls booked from Stockholm were personal calls.

In 1927,	this figure was increased to	39 per cent
1928,	" " " "	41 " "
1929,	" " " "	42.6 " "
1930,	" " " "	43.4 " "

which shows that the proportion of personal calls is steadily rising.

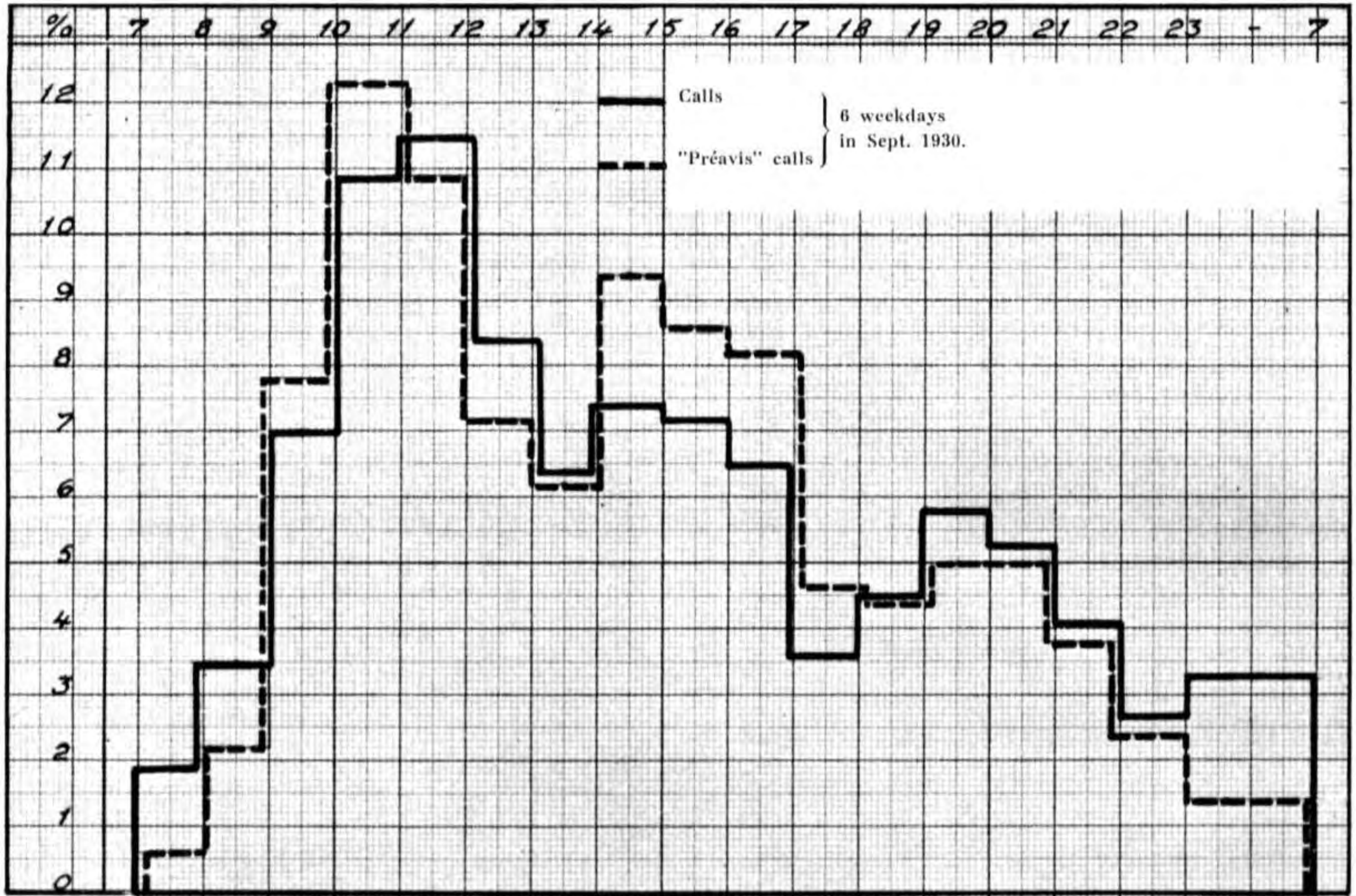
The number of calls per weekday during October 1930 between Stockholm and certain inland traffic centres is shown by the Table (on page 156), which also gives the number of inhabitants and distance from Stockholm of the respective traffic centres. These traffic areas are arranged in the Table according to distance from Stockholm as the crow flies, and the number of calls per 100 inhabitants and year is also given.

To enable our most convenient, rapid, and



R 2052 Transit- and Night-Service Board.

Distribution in per cent. over the hours of the day of the number of foreign calls (out, in and transit), and of the number of personal calls (out and in).



Average per day:																		Per weekday
No. of calls.	25	47	94	148	156	113	87	100	97	88	49	61	78	71	55	36	45	S:A 1350
No. of "préavis" calls.	3	11	39	61	54	36	31	47	43	41	23	22	25	25	19	12	7	S:A 499

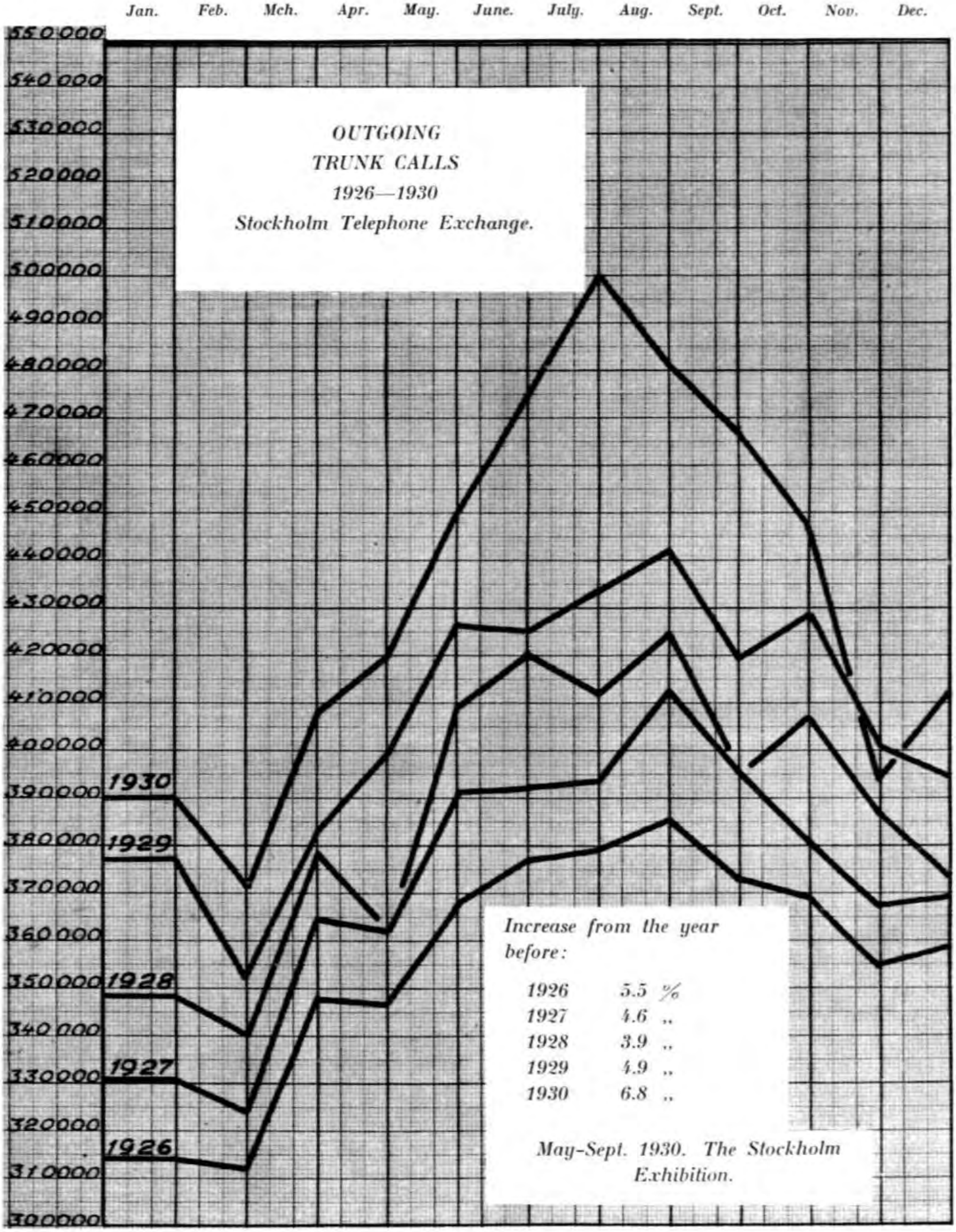
DIAGRAM III.

R 2055

R 2053 Traffic Testing and Distributing Board.

Calls between the Stockholm traffic area and subscribers in certain other traffic areas during October 1930. (In addition, the same lines carry a certain amount of transit traffic.)

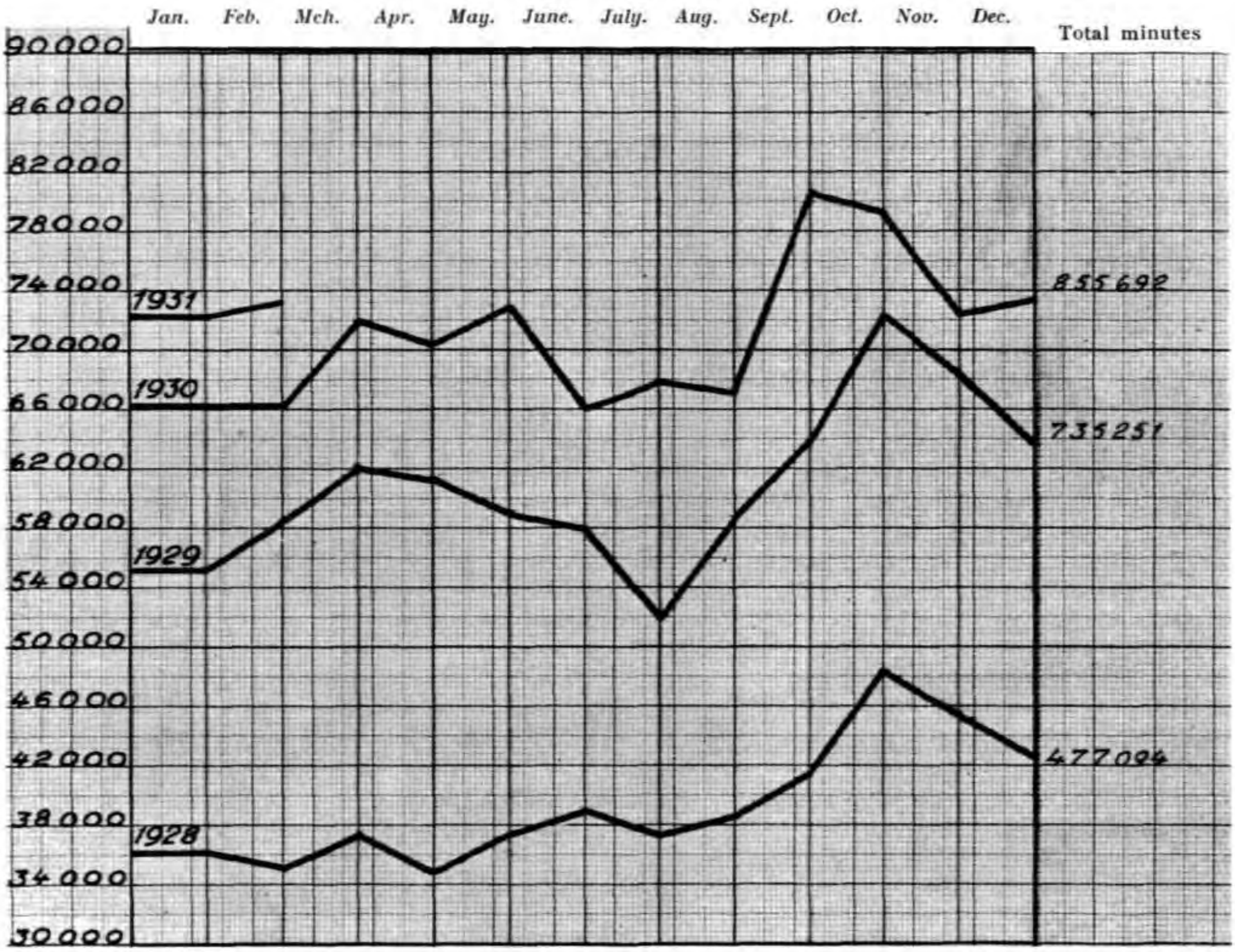
Traffic area (Subscribers generally have free calls within their traffic area)	Distance from Stockholm as the crow flies	Number of inhabitants in the traffic area	Number of calls interchanged with Stockholm	
			Per weekday	Per 100 inhabitants and year
Stockholm	—	666.732	—	—
Norrtälje	60	41.227	1.399	1.093
Uppsala	65	81.707	2.690	1.060
Eskilstuna	88	60.331	981	524
Västerås	92	44.503	929	672
Norrköping	136	99.314	1.230	399
Gävle	158	144.175	1.340	299
Örebro	162	121.947	1.003	265
Visby	188	57.380	331	186
Falun	196	92.387	638	222
Karlstad	258	68.023	398	188
Mora	270	60.231	204	109
Jönköping	284	77.230	381	159
Kalmar	224	72.187	313	140
Sundsvall	349	117.613	625	171
Borås	357	106.785	317	96
Karlskrona	389	91.752	233	82
Göteborg	403	360.274	2.357	211
Halmstad	426	101.957	219	69
Östersund	465	89.205	296	107
Hälsingborg	485	87.728	384	141
Malmö	514	172.795	1.166	217
Umeå	569	48.415	183	122
Luleå	780	31.610	119	121



R 8017

DIAGRAM IV a.

Number of Call-Minutes from Stockholm to abroad.
1928—Feb. 1931.



R 3018

DIAGRAM IV b.

effective means of communication — the telephone — to meet subscribers' demands for satisfactory call facilities, the development of traffic must be aided and stimulated by avoiding long waits for a call. The waiting times, which chiefly depend on the relation between the supply of circuits and the traffic intensity, are therefore subject to continuous, careful control on every traffic route. As soon as times of waiting show a definite tendency to increase, steps are taken to increase the number of circuits.

Practically all the important traffic routes originating in Stockholm being now fitted with cables, the average waiting times which have been found expedient can be kept almost constant. A subscriber, knowing the usual time of waiting, can adapt himself accordingly. If, at any time, he should require to be put through more quickly, he can use urgent or lightning calls instead. Experience has shown that the need of faster communication than is allowed by the ordinary call is not great in Sweden.

As we have already mentioned, the number of urgent calls in 1930 was 1.3 per cent. of the total number of calls, and the lightning calls in Stockholm the same year were only 52 amongst 5.2 millions of outgoing calls.

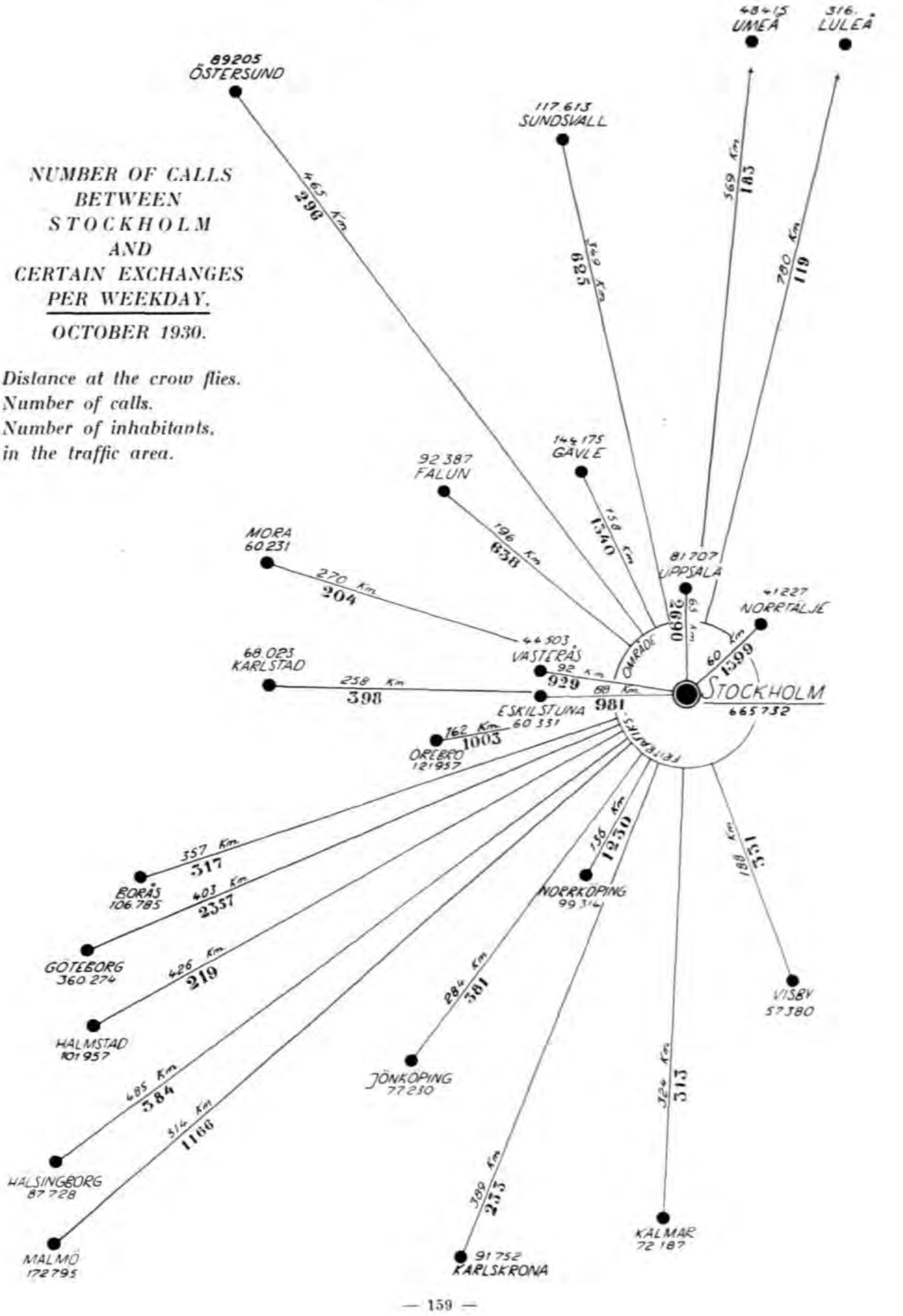
Diagram V shows the increase in the total number of trunk circuits and *outgoing* trunk calls from the end of 1926 up to and including 1930. The number of circuits has been increased by 29 per cent., while the traffic has increased by 21.7 per cent. in the same period.

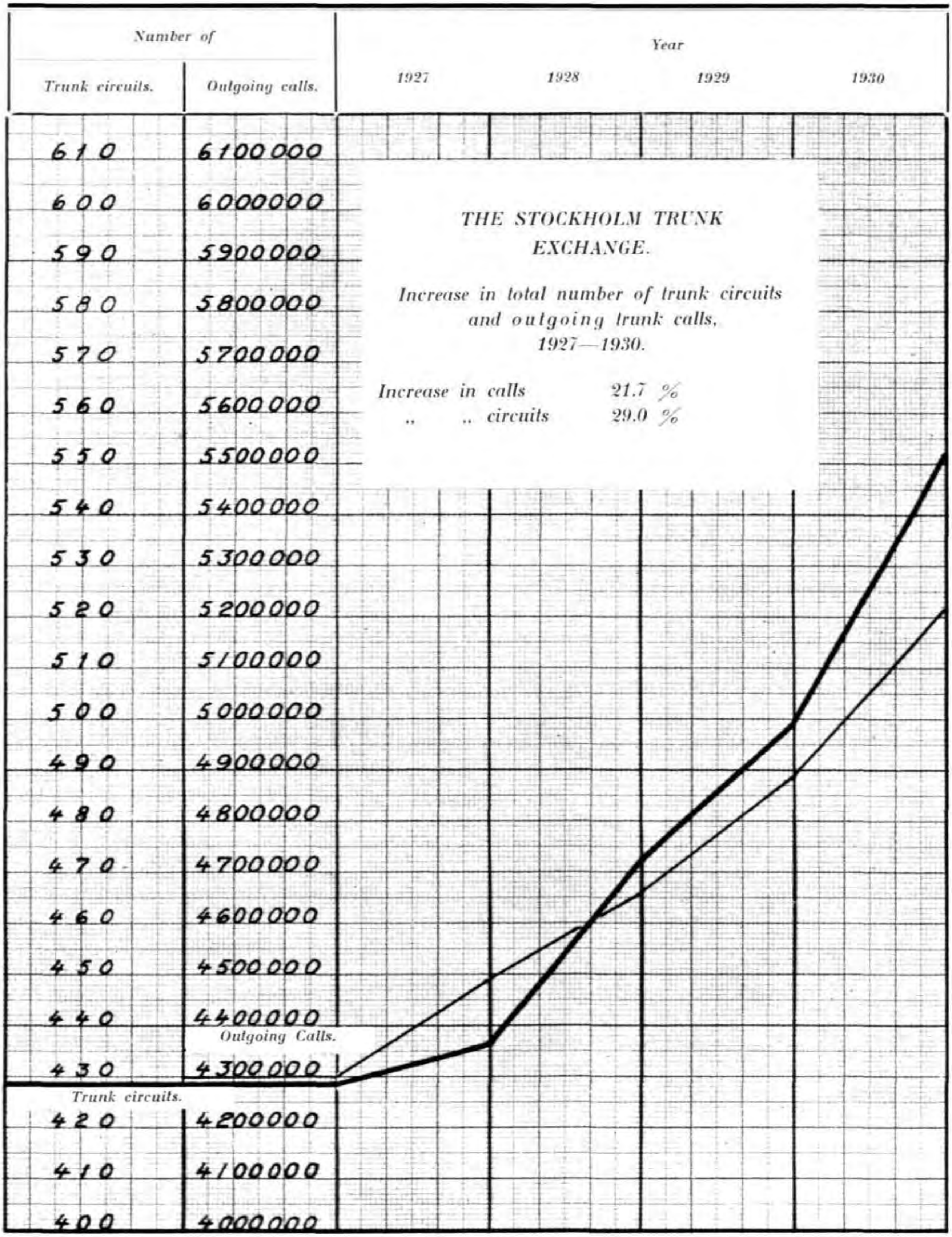
Diagram VI and VII show the increase in the number of circuits and the number of calls per weekday, as well as the number of calls per cir-

NUMBER OF CALLS BETWEEN STOCKHOLM AND CERTAIN EXCHANGES PER WEEKDAY.

OCTOBER 1930.

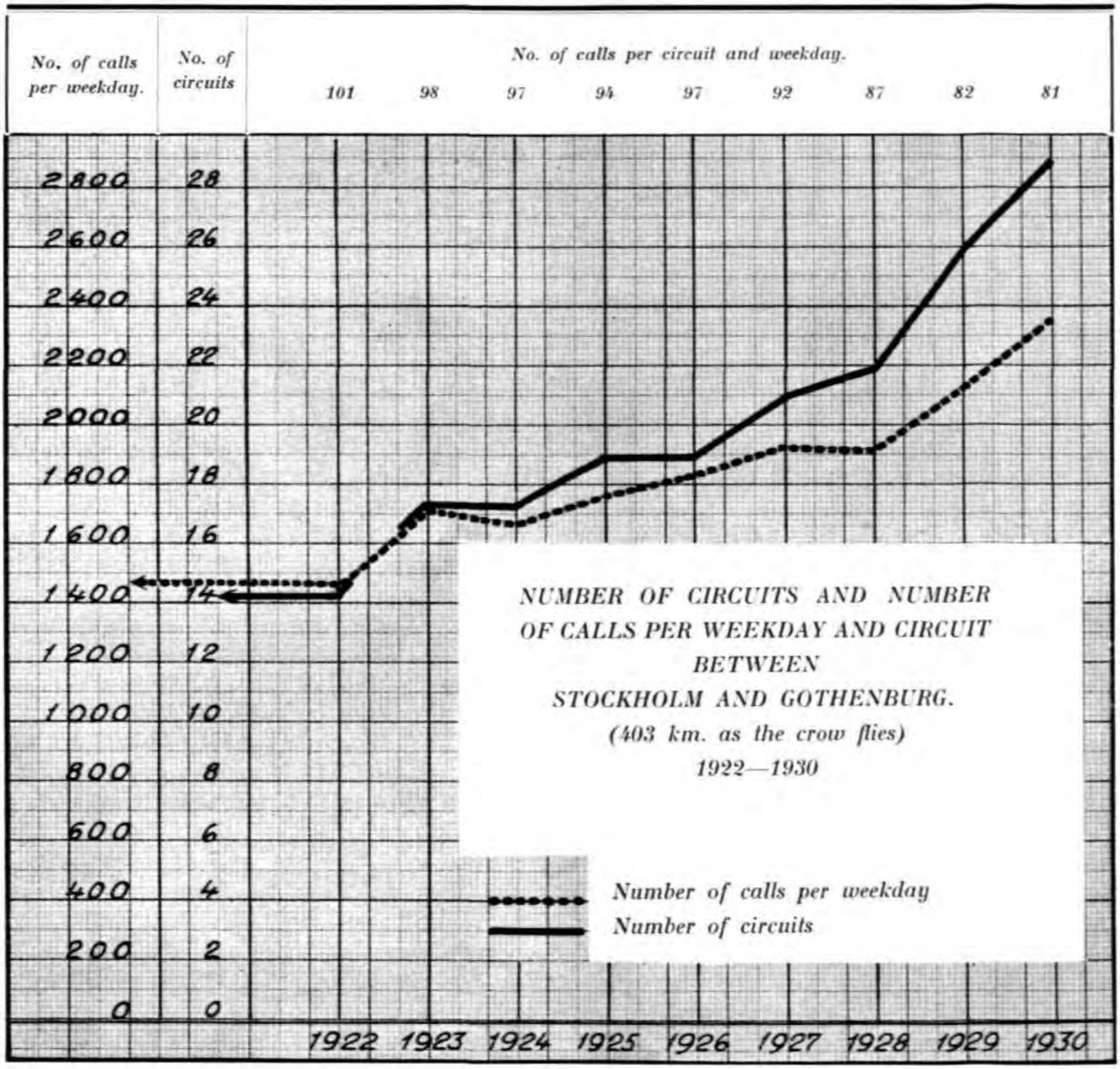
Distance at the crow flies.
Number of calls.
Number of inhabitants, in the traffic area.





R 3020

DIAGRAM V.



B 3021

DIAGRAM VI.

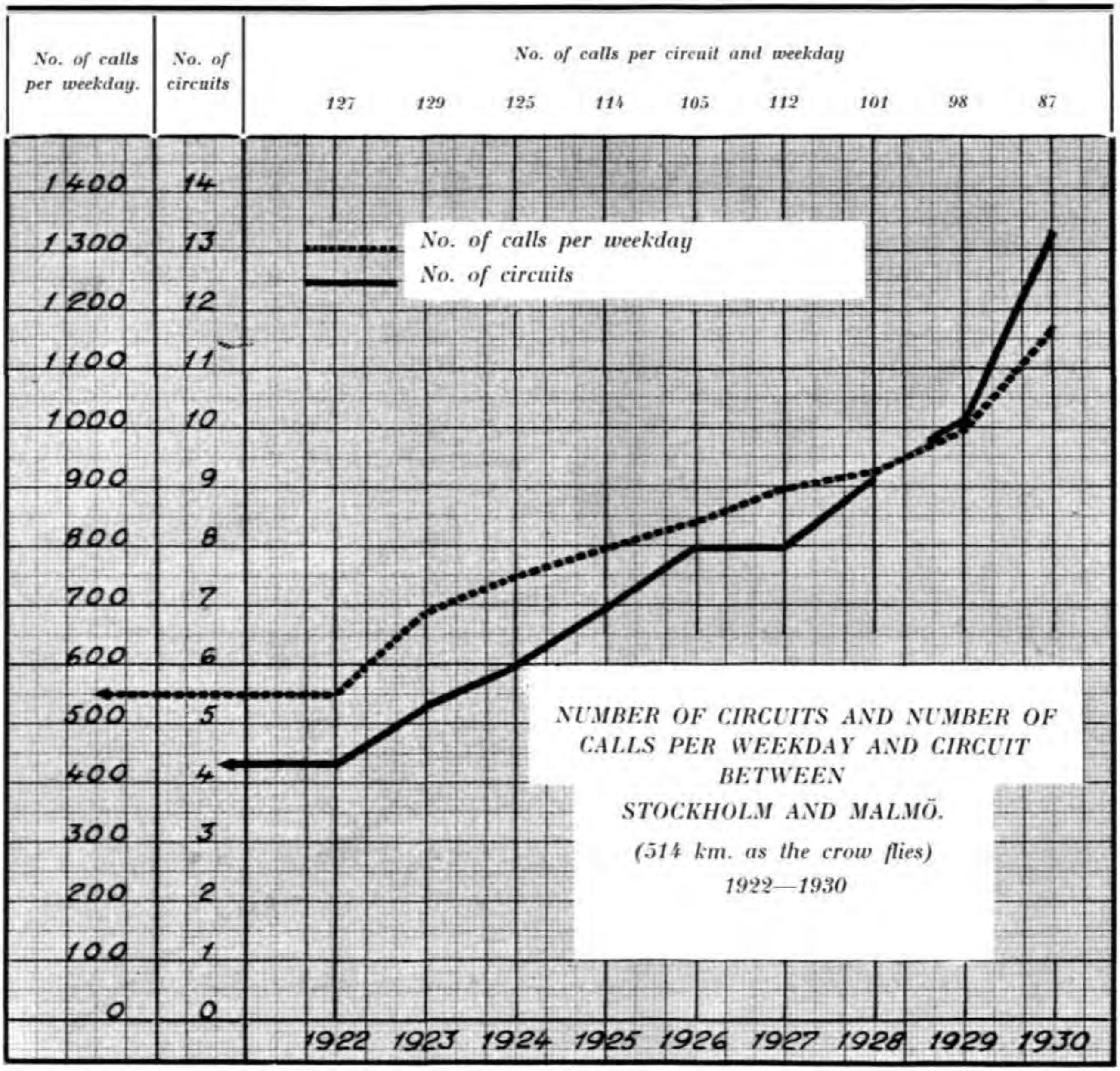
cuit and weekday during the years 1922—1930 on a couple of long distance routes.

In diagram VI—of the Stockholm-Gothenburg line, 403 km. (245 miles) as the crow flies — the number of lines has been increased by 107 per cent. from 1922 to the end of 1930, while the number of calls per weekday has increased by 62 per cent. The number of calls per line and day has at the same time been reduced from 101 to 81.

Diagram VII—the Stockholm-Malmö line, 514 km. (310 miles) as the crow flies — shows that the number of lines on this route has been increased by 208 per cent., and the number of calls per weekday by 113 per cent. The number of calls per line, which in 1922 was too high for satisfactory waiting times, has been reduced from 127 to 87 in connexion with the introduction of cable on this route.

These curves show that the number of circuits has been increased practically every year, and that the traffic has been growing rapidly.

The total number of trunk circuits in the Exchange was 552 on January 1st 1931, of which: for inland traffic:



R 3019

DIAGRAM VII.

outgoing	195	
incoming	223	
both ways	110	528

for foreign traffic:

outgoing	8		
incoming	8		
both ways	8	24	552

(The free traffic within the 40 km. area is catered for by 2 350 lines to Stockholm).

Staff.

The Trunk Exchange staff consists of one Chief Controller, second in command to the Director of Telephones.

1 First Assistant,
2 Assistants,
3 First Supervisors,
13 Supervisors for supervision, operator traiing, and line control,
336 Operators for day and night service,
20 Clerks for foreign control, statistics, card index, office, etc.

A total of 376 persons, of which 20 senior officials.

Members of the local and district staffs, specially trained for the purpose, act as reserves and substitutes in case of illness and leave, and are in their turn replaced by supernumerary local telephonists.

THE L. M. ERICSSON REVIEW

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CONTENTS:

No. 7—9 ENGLISH EDITION 1931

A method of computing the attenuation in a band pass filter arbitrarily composed of resistances, inductances, capacities and transformers.

By Professor *H. Pleijel.*

A filter circuit with no losses will let stationary alternating currents pass without attenuation within certain ranges or bands of frequencies. In practice, however, losses must always be allowed for in the coils, transformers, and capacities of the filter circuit, and a certain amount of attenuation will always occur. This attenuation is as a rule increased when the frequency approaches the cut-off frequencies, and sometimes the whole width of the band can therefore not be used. It is consequently of interest to determine the attenuation in the centre and at the edges of a band of frequencies in a filter circuit. It is of course always possible to use the generally applicable formulæ obtained from the filter element by applying the theory of what has somewhat inadequately been designated a "quadripole". This, however, is a troublesome way, and the formulæ deduced are not easily surveyable in a general discussion. H. F. Mayer*) has given a formula for the approximate computation of the attenuation in a filter. But this formula is not generic, and the author has therefore attempted to deduce generally applicable formulæ for the attenuation.

To attain this object, a filter consisting of an arbitrary, complex circuit connected between two line contacts and earth is chosen, built up of resistances, inductances, capacities, and transformers. The loss angles of all the appliances are assumed to be small.

In a complex circuit joining two line contacts and earth, the following relations exist between voltages and currents at the ends (line contacts):

$$v' = I \cdot i' - A \cdot i''$$
$$v'' = A \cdot i' - J \cdot i''$$

*) E. N. T. Vol. 2, 1925, p. 335.

I and J are the insulation impedances measured from the two ends of the circuit. The corresponding short-circuit impedances are designated R and K. The complex circuit can, we know, be regarded as a circuit with the characteristics Z' and Z'' from the two end points, and with a total attenuation complex $= \Theta$.

The relations of these quantities are given by the following equations:—

$$I = Z' \coth \Theta$$
$$R = Z' \tanh \Theta$$
$$J = Z'' \coth \Theta$$
$$K = Z'' \tanh \Theta$$
$$A = \frac{\sqrt{Z' Z''}}{\sinh \Theta}$$

By adding and substracting the two first equations we get:—

$$I + R = \frac{Z' \cosh 2\Theta}{\sinh \Theta \cosh \Theta}$$
$$I - R = \frac{Z'}{\sinh \Theta \cosh \Theta}$$

Consequently after division:

$$\frac{I+R}{I-R} = \cosh 2\Theta = \frac{J+K}{J-K}$$

If the circuit is symmetrical as regards its centre point ($I = J$; $R = K$), half the circuit may with advantage be used in the computation, which thus will give us $\cosh \Theta$ instead of $\cosh 2\Theta$.

From the equation obtained we get the attenuation and the phase angle of the device. We introduce the symbol

$$\Theta = b + ja,$$

where b thus is the attenuation and a the phase constant.

Any one of the circuits can now be expressed by the formula.

$$z' = r + j\omega l + \frac{1}{j\omega c}$$

where ω is the frequency, r the resistance, l the inductance, and c the capacity forming part of the circuit.

If a transformer forms part of the complex circuit, its primary and secondary impedances may be referred to the conductors to which they are attached, or else be regarded as independent conductors with resistance and inductance. The mutual inductance will appear in the equations as an independent conductor of the type $r + j\omega m$.

The various conductors forming part of the complex circuit are numbered and their impedances designated $z'_1,\ z'_2,\ z'_3 \ldots$ If the resistances be made nil, z' will change into purely imaginary quantities, here designated $z_1,\ z_2,\ z_3 \ldots\ldots$

Both I and R are now homogeneous polynomes of the same degree in $z'_1,\ z'_2 \ldots\ldots$ The same will be the case with $\frac{I+R}{I-R}$, and its numerator and denominator will be of the same degree after transformation also.

We temporarily introduce:—

$$\frac{I+R}{I-R} = \varphi\,(z'_1,\ z'_2,\ z'_3 \ldots\ldots)$$

The function φ is thus the quotient in z'_1, $z'_2 \ldots$ of two homogeneous polynomes, which are of the same degree.

We have now:

$$z'_1 = z_1 + r_1$$
$$z'_2 = z_2 + r_2$$

where $r_1,\ r_2$, etc. (except possibly for certain z-values) are assumed to be small in relation to $z_1,\ z_2 \ldots\ldots$ respectively.

We expand the function φ in a Taylor's series and get:

$$\varphi\,(z'_1\, z'_2 \ldots) = \varphi\,(z_1\, z_2 \ldots) + \frac{\delta\varphi}{\delta z_1} r_1 + \frac{\delta\varphi}{\delta z_2} r_2 + \ldots;$$

$z_1,\ z_2 \ldots\ldots$ are functions of ω. On the assumption that $r_1,\ r_2 \ldots\ldots$ are small, and that not all the derivates $\frac{\delta\varphi}{\delta z_1}, \frac{\delta\varphi}{\delta z_2} \ldots\ldots$ are nil, we may terminate the expansion as above. $\varphi\,(z_1,\ z_2, \ldots\ldots)$ being the quotient of two polynomes which are of the same degree and homogeneous, $\varphi\,(z_1,\ z_2, \ldots\ldots)$ must be real. But $\frac{\delta\varphi}{\delta z_1}, \frac{\delta\varphi}{\delta z_2}$ are also the quotients of two homogeneous polynomes, but the degree of the numerator is one unit lower than the degree of the denominator; these derivates must therefore be purely imaginary. If we therefore introduce

$$\cosh\, 2\,\Theta = \frac{I+R}{I-R} = A + jB,$$

where A and B are real, we thus get:

$$A = \varphi\,(z_1,\ z_2,\ z_3 \ldots\ldots)$$

$$jB = \frac{\delta\varphi}{\delta z_1}\cdot r_1 + \frac{\delta\varphi}{\delta z_2}\cdot r_2 + \ldots\ldots$$

or

$$jB = \frac{\delta A}{\delta z_1} r_1 + \frac{\delta A}{\delta z_2} r_2 + \ldots\ldots$$

A is thus obtained by introducing $z_1,\ z_2 \ldots\ldots\ldots$ respectively instead of $z'_1,\ z'_2$ in the expression $\frac{I+R}{I-R}$ or, in other words, by computing $\frac{I+R}{I-R}$ for the circuit on the assumption of the resistances everywhere being nil. The function A consequently also determines B, which as we have seen is obtained by deriving A with respect to its variables $z_1,\ z_2 \ldots$

If the losses are small, B will be small in relation to A. If solved, the equation:—

$$\cosh 2\,(b + ja) = A + jB$$

will give:

$$\begin{Bmatrix} \cosh 2b \cdot \cos 2a = A \\ \sinh 2b \cdot \sin 2a = B \end{Bmatrix}$$

If we here substitute

$$\sinh\, 2b = x$$
$$k^2 = A^2 + B^2$$

we get, by eliminating 2a, the formulæ:

$$\left\{\begin{aligned} x &= \sinh\, 2b = \frac{1}{\sqrt{2}}\left[-(1-k^2) + \sqrt{(1-k^2)^2 + 4B^2}\right]^{1/2} = \frac{\sqrt{2}\cdot B}{\left[1-k^2+\sqrt{(1-k^2)^2+4B^2}\right]^{1/2}} \\ \sin\, 2a &= \frac{\sqrt{2}\cdot B}{\left[-(1-k^2)+\sqrt{(1-k^2)^2+4B^2}\right]^{1/2}} = \frac{\left[1-k^2+\sqrt{(1-k^2)^2+4B^2}\right]^{1/2}}{\sqrt{2}} \\ \cos\, 2a &= \frac{\sqrt{2}\cdot A}{\left[1+k^2+\sqrt{(1-k^2)^2+4B^2}\right]^{1/2}} \end{aligned}\right\}$$

The first formula shows that x or $2b$ will be small if $k^2 < 1$ and large if $k^2 > 1$.

Hence the bands of frequencies which let a stationary alternating current pass with small attenuation will correspond to the values of ω tor which $A^2 + B^2 < 1$.

As we have assumed the losses to be small, B^2 must be small in relation to A^2, and hence the bands of frequencies will practically correspond to those frequencies for which

$$-1 < A < 1$$

The function A will consequently determine the bands of frequencies. By introducing $k^2 = A^2$, our formulæ may be abbreviated:—

Within the bands: $(A^2 < 1)$.

$$\left\{\begin{array}{l} x = \sinh 2b = \dfrac{B}{\sqrt{1-A^2}} \\ \sin\ 2a = \sqrt{1-A^2} \\ \cos\ 2a = A \end{array}\right\}$$

Outside the bands: $(A^2 > 1)$.

$$\left\{\begin{array}{l} \sinh\ 2b = \sqrt{A^2-1} \\ \sin\ 2a = 0 \\ \cos\ 2a = \pm 1 \end{array}\right\}$$

For $2\ b$ we may then write:—

$$2b = \log\left[A + \sqrt{A^2-1}\right]$$

$\cos 2\ a$ must be of the same sign as A, as $\cosh 2\ b$ always is positive.

At the edge of the band: $(k^2 = A^2 = 1)$

$$\left\{\begin{array}{l} \sinh\ 2b = \sqrt{B} \\ \sin\ 2a = \sqrt{B} \\ \cos\ 2a = \dfrac{A}{\sqrt{1+B}} = \dfrac{\sqrt{1-B^2}}{\sqrt{1+B}} = \sqrt{1-B} \end{array}\right\}$$

Above we have now found an expression for B, viz:

$$B = \left|\frac{\delta A}{\delta z_1} r_1 + \frac{\delta A}{\delta z_2} r_2 \ldots\right|.$$

For the attenuation *within* a band, the final formula will thus be:

$$2b = \sinh\ 2b = \frac{\left|\dfrac{\delta A}{\delta z_1} r_1 + \dfrac{\delta A}{\delta z_2} r_2 + \dfrac{\delta A}{\delta z_3} r_3 + \ldots\right|}{\sqrt{1-A^2}} \quad \ldots (1)$$

and at the edge of the band

$$\sinh\ 2b = \sqrt{\left|\frac{\delta A}{\delta z_1} r_1 + \frac{\delta A}{\delta z_2} r_2 + \frac{\delta A}{\delta z_3} r_3 + \right|} \quad \ldots\ldots (2)$$

In practice A will frequently take the form:—

$$A = 1 + U,$$

where U is the quotient of two homogeneous polynomes of the same degree:—

If U is substituted for A, we get the formulæ:—

$$2b = \frac{\left|\dfrac{\delta U}{\delta z_1} r_1 + \dfrac{\delta U}{\delta z_2} r_2 + \ldots\right|}{\left|\sqrt{2U}\right| \cdot \sqrt{1 + \dfrac{U}{2}}} \quad \ldots\ldots\ldots (3)$$

and at the edge:—

$$\sinh\ 2b = \sqrt{\left|\frac{\delta U}{\delta z_1} r_1 + \frac{\delta U}{\delta z_2} r_2 + \ldots\right|} \quad \ldots\ldots (4)$$

U usually occurs divided into certain factors, and it may be of interest to have an expression for the attenuation, taking this division into account.

The cut-off frequencies are obtained by making $U = 0$ and $U = -2$.

For the sake of simplicity we assume only two factors, thus

$$U = U_1\ U_2$$

If we substitute this expression for U, and introduse the abbreviation $r\nabla = r_1 \dfrac{\delta}{\delta z_1} + r_2 \dfrac{\delta}{\delta z_2} + r_3 \dfrac{\delta}{\delta z_3} + \ldots$, formula (3) will be changed into:—

$$2b = \frac{1}{\sqrt{2}} \frac{\sqrt{U_1 U_2}}{\sqrt{1 + \dfrac{U_1 U_2}{2}}} \cdot \left[\frac{1}{U_1} \cdot r\nabla \cdot U_1 + \frac{1}{U_2} \cdot r\nabla \cdot U_2\right] (5)$$

and formula (4) into:—

$$\sinh 2b = \left|\sqrt{U_1 U_2} \cdot \sqrt{\frac{1}{U_1} \cdot r\nabla \cdot U_1 + \frac{1}{U_2} \cdot r\nabla \cdot U_2}\right| (6)$$

Before passing to the application of the formulæ deduced to specific instances, we will examine what happens to the attenuation when a certain ω-value renders both $U_1 = 0$ and $U_2 = 0$. In that case two bands will meet in the point in question, and we get $\dfrac{\delta U}{\delta z_1} = \dfrac{\delta U}{\delta z_2} = \ldots\ldots = 0$. In formula (3) both denominator and numerator will then be nil, while formula (5) can be written:—

$$\left.\begin{array}{l} 2b = \dfrac{1}{\sqrt{2}} \dfrac{1}{\sqrt{1 + \dfrac{U_1 U_2}{2}}} \cdot \\ \left[\sqrt{\dfrac{U_2}{U_1}} \cdot r\nabla \cdot U_1 + \sqrt{\dfrac{U_1}{U_2}} \cdot r\nabla \cdot U_2\right] \end{array}\right\} \ldots (7)$$

Although both U_1 and U_2 are nil, $\frac{U_2}{U_1}$ will as a rule be finite.

(Above, we have assumed $A = 1$ as the limit, but the same argument is valid if the two bands meet in a point where $A = -1$).

Had U been composed of three factors, i. e.

$$U = U_1\, U_2\, U_3$$

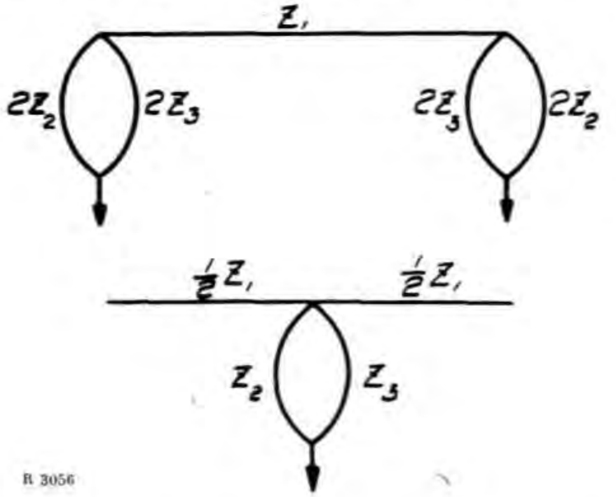
the formula for the attenuation would have been:—

$$2b = \frac{\sqrt{U_1 U_2 U_3}}{\sqrt{2}\cdot\sqrt{1 + \frac{U_1 U_2 U_3}{2}}}\cdot\left[\frac{1}{U_1}\cdot r\nabla\cdot U_1 + \frac{1}{U_2}\cdot r\nabla\cdot U_2 + \ldots\right]$$

Application.

We will apply the formulæ derived above to a specific example.

A great number of filters are made up of elements arranged as in the diagram:



For the sake of brevity we will introduce the symbols:—

$$z_1 = \sigma$$

$$\frac{z_1 z_2}{z_1 + z_2} = \varrho$$

σ is here the impedance in the longitudinal direction of the conductor and ϱ the impedance between the line and earth.

These two filters are symmetric with respect to their centre points, and it is therefore expedient to divide them into two equal halves, and use one of them for the calculations. We take the filter at the top of the figure.

The half circuit then gives us:

$$I = 2\varrho$$

$$R = \frac{\sigma\varrho}{\frac{\sigma}{2} + 2\varrho}$$

and therefore:

$$\cosh\,\Theta = \frac{I+R}{I-R} = 1 + \frac{\sigma}{2\varrho}$$

(The filter circuit at the bottom of the figure will give the same equation.)

Substituting the values of σ and ϱ, we get the following expression for A:—

$$A = 1 + \frac{z_1}{2}\left[\frac{1}{z_2} + \frac{1}{z_3}\right]$$

and

$$U = U_1 U_2 = \frac{z_1}{2}\left[\frac{1}{z_2} + \frac{1}{z_3}\right];\ U_1 = \frac{z_1}{2};\ U_2 = \frac{1}{z_2} + \frac{1}{z_3}$$

The cut-off frequencies are obtained by making $U = 0$ and $U = -2$.

The conditions of the cut-off frequencies will thus be:—

$$z_1 = 0;\ \frac{1}{z_2} + \frac{1}{z_3} = 0;\ \frac{1}{z_2} + \frac{1}{z_3} + \frac{4}{z_1} = 0$$

The number of bands obtained will depend on the composition of z_1, z_2, z_3.

We have:

$$r\nabla\cdot U_1 = \frac{r_1}{2}$$

$$r\nabla\cdot U_2 = -\frac{r_2}{z_2^{\,2}} - \frac{r_3}{z_3^{\,2}}$$

Formula (5) now gives the attenuation:

$$b = \frac{1}{2}\,\frac{\left| r_1\sqrt{\frac{1}{z_1}\left(\frac{1}{z_2} + \frac{1}{z_3}\right)} - \left(\frac{r_2}{z_2^{\,2}} + \frac{r_3}{z_3^{\,2}}\right)\sqrt{\frac{z_1}{\frac{1}{z_2} + \frac{1}{z_3}}}\right|}{\sqrt{1 + \frac{z_1}{4}\left(\frac{1}{z_2} + \frac{1}{z_3}\right)}} \qquad (8)$$

As a specific example we choose:

$$z_1 = j\omega L + \frac{1}{j\omega C} = \frac{1 - \omega^2 LC}{j\omega C}$$

$$z_2 = \frac{1}{j\omega K}$$

$$z_3 = j\omega M$$

consequently:

$$\frac{1}{z_2}+\frac{1}{z_3}=\frac{1-\omega^2 MK}{j\omega M}$$

$$\frac{1}{z_2}+\frac{1}{z_3}+\frac{4}{z_1}=\frac{1-\omega^2 MK}{j\omega M}+\frac{4j\omega C}{1-\omega^2 LC}$$

If we substitute:

$$\omega_1=\frac{1}{\sqrt{LC}};\ \omega_2=\frac{1}{\sqrt{MK}};\ \omega_3=\frac{1}{\sqrt{MC}}$$

we may write:

$$A=1-\frac{1}{2}\,\frac{\left(1-\frac{\omega^2}{\omega_1^2}\right)\left(1-\frac{\omega^2}{\omega_2^2}\right)}{\frac{\omega^2}{\omega_3^2}}$$

This expression shows that when ω is intermediate between ω_1 and ω_2, A will be positive and larger than 1. The bands will therefore lie on both sides of the range bounded by ω_1 and ω_2. For $\omega=0$ and $\omega=\infty$, A will be negative and infinitely large. In the equation $A=-1$ there will thus be two real roots ω^2, and consequently we obtain two bands.

If we introduce the values of z_1, z_2, z_3 in formula (**8**), we get the attenuation within the bands according to the formula:

$$b=\frac{1}{2}\,\frac{r_1\sqrt{\frac{C}{M}}\cdot\sqrt{\frac{1-\omega^2 MK}{1-\omega^2 LC}}+\left(r_2\omega^2K^2+\frac{r_3}{\omega^2M^2}\right)\sqrt{\frac{M}{C}}\cdot\sqrt{\frac{1-\omega^2 LC}{1-\omega^2 MK}}}{\sqrt{1-\frac{1}{4}\frac{(1-\omega^2 LC)\,(1-\omega^2 MK)}{\omega^2 MC}}}$$

If $MK=LC$, ω_1 and ω_2 will coincide and the two bands will be contiguous. The formula for b will then be simplified to:

$$b=\frac{1}{2}\,\frac{r_1\sqrt{\frac{C}{M}}+\left(r_2\omega^2K^2+\frac{r_3}{\omega^2M^2}\right)\sqrt{\frac{M}{C}}}{\sqrt{1-\frac{1}{4}\frac{(1-\omega^2 LC)^2}{\omega^2 MC}}}$$

At the edges of the bands the attenuation formula will be:

$$\sinh b=\left|\sqrt{\frac{1-\omega^2 MK}{\omega M}\frac{r_1}{2}+\frac{1-\omega^2 LC}{\omega C}\left(\frac{r_2}{2}\omega^2K^2+\frac{r_3}{2}\frac{1}{\omega^2M^2}\right)}\right|$$

We see here that, at the points corresponding to the cut-off frequencies ω_1 and ω_2, the second and first term respectively under the root mark will disappear. In case the bands meet, the formulæ are not applicable to the point of meeting, as B would be nil at that point. The expansion of z'_1 z'_2 z'_3 must then include terms of a higher degree. This and related questions will be dealt with in a subsequent paper.

Above, the loss in the condensers has been regarded as represented by resistances. Frequently, however, it may be more expedient to substitute the leakage of the condenser. A condenser may then be introduced as a conductor, the z' value of which is $g+j\omega c$, where g is the leakage of the condenser. The corresponding z will then be $j\omega c$. Although the function A thus obtained will no longer be a homogeneous function of the z-values, j will appear in it in exactly the same way as before, and hence the formulæ given above for A and B will be valid.

To illustrate this method, we will apply it to the simple instance of a Kennelly π-device, the line impedance of which consists of an inductance L connected in series with the condenser C, and where the impedance to earth corresponds to a condenser of the capacity K. We assume L to have a resistance r_1, C a leakage g_2, and K a leakage g_3.

We have here:

$$z_1=j\omega L$$
$$z_2=j\omega C$$
$$z_3=j\omega K$$
$$\sigma=j\omega L+\frac{1}{j\omega C}=z_1+\frac{1}{z_2}$$
$$\frac{1}{\varrho}=z_3$$

The expression for A will consequently be:

$$A=1+\frac{1}{2}\left(z_1+\frac{1}{z_2}\right)z_3 \text{ and}$$

$$U=\frac{1}{2}\left(z_1+\frac{1}{z_2}\right)z_3=\frac{1}{2}\frac{K}{C}[1-\omega^2 LC]$$

The cut-off frequencies are obtained when $U=0$ and $U=-2$. They will be:

$$\omega_1=\frac{1}{\sqrt{LC}}$$

$$\omega_2=\frac{1}{\sqrt{LC}}\cdot\sqrt{1+\frac{4C}{K}}$$

U changes from 0 to -2 as ω changes from ω_1 to ω_2. The transmission band will thus lie between ω_1 and ω_2.

Formula (3) now gives the attenuation. We write this formula as follows:

$$b = \frac{\left| \frac{1}{U}\frac{\delta U}{\delta z_1} r_1 + \frac{1}{U}\frac{\delta U}{\delta z_2} g_2 + \frac{1}{U}\frac{\delta U}{\delta z_3} g_3 \right|}{\sqrt{1 + \frac{2}{U}}}$$

We know that

$$\frac{\delta U}{\delta z_1} = \frac{1}{2} z_3$$

$$\frac{\delta U}{\delta z_2} = -\frac{1}{2}\frac{z_3}{z_2^2}$$

$$\frac{\delta U}{\delta z_3} = \frac{1}{2}\left(z_1 + \frac{1}{z_2}\right)$$

Substituting these values, a slight transformation gives us:

$$b = \left| \frac{r_1}{z_1} \cdot \frac{1}{1 + \frac{1}{z_1 z_2}} - \frac{g_2}{z_2} \cdot \frac{1}{z_1 z_2 + 1} + \frac{g_3}{z_3} \right| \cdot \frac{1}{\sqrt{1 + \frac{4 z_2}{z_3 (z_1 z_2 + 1)}}}$$

or

$$b = \left\{ \frac{r_1}{\omega L} \cdot \frac{\omega^2}{\omega^2 - \omega_1^2} + \frac{g_2}{\omega C} \cdot \frac{\omega_1^2}{\omega^2 - \omega_1^2} + \frac{g_3}{\omega K} \right\} \cdot \frac{1}{\sqrt{1 - \frac{4C}{K}\frac{\omega_1^2}{\omega^2 - \omega_1^2}}}$$

In his paper, Mayer has assumed the loss factors of all the inductances in the system to be equal and that this is also the case with the capacities forming part of the lines, which assumptions have enabled him to deduce the following simple formula for the attenuation:

$$b = \frac{1}{2}\,\omega \frac{\delta a}{\delta \omega} [f + h],$$

where a is the phase constant in Θ, f the loss factor of one of the inductances, and h the same factor for one of the condensers. Dr. M. Vos, in computing filters under similar conditions, has used the following instead of the Mayer formula:

$$b = \frac{1}{2} \cdot \frac{\omega \frac{\delta A}{\delta \omega}}{\sqrt{1 - A^2}} [f + h]$$

This last formula has the advantage over Mayer's that only loss factors and the function A, which determines the cut-off frequencies, enter on the right hand side.

We will now see how it is possible to deduce from the general formula this special formula, valid for any network linking two line contacts and earth. For a conductor with inductance and capacity in series, we introduce the symbol

$$z_n = z_n' + \frac{1}{z_n''}$$

where

$$z_n' = j\omega L_n$$

$$z_n'' = j\omega C_n.$$

(z' has previously been used to signify something else, but this will hardly cause confusion). The function A is now homogeneous in all its z_1, z_2 ......, and its degree is zero, as denominator and numerator are of the same degree. A well known theorem then allows us to write:

$$z_1 \frac{\delta A}{\delta z_1} + z_2 \frac{\delta A}{\delta z_2} \ldots . = 0.$$

If we substitute the above subdivision for z_1 and z_2, we get the equation:

$$\left. \begin{aligned} & z_1' \frac{\delta A}{\delta z_1} + z_2' \frac{\delta A}{\delta z_2} + \ldots . = - \\ & -\frac{1}{z_1''}\frac{\delta A}{\delta z_1} - \frac{1}{z_2''}\frac{\delta A}{\delta z_2} - \ldots . \end{aligned} \right\} \ldots\ldots \quad (10)$$

We pass to the formula for b. We have found:

$$2b = \frac{\left| \frac{\delta A}{\delta z_1} r_1 - \frac{\delta A}{\delta z_1}\frac{1}{z_1''^2} g_1 + \frac{\delta A}{\delta z_2} r_2 - \frac{\delta A}{\delta z_2}\frac{1}{z_2''^2} \cdot g_2 + \ldots \right|}{\sqrt{1 - A^2}}$$

This formula can be written:

$$2b = \frac{\left| z_1' \frac{\delta A}{\delta z_1}\frac{r_1}{z_1'} + z_2' \frac{\delta A}{\delta z_2}\frac{r_2}{z_2'} + \ldots . - \frac{1}{z_1''}\frac{\delta A}{\delta z_1}\frac{g_1}{z_1''} - \ldots \right|}{\sqrt{1 - A^2}}$$

or, if we substitute the loss factors f_n and h_n of the inductances and capacities:

$$2b = \frac{\left| z_1' \frac{\delta A}{\delta z_1} f_1 + z_2' \frac{\delta A}{\delta z_2} f_2 - \frac{1}{z_1''}\frac{\delta A}{\delta z_1} h_1 - \ldots . \right|}{\sqrt{1 - A^2}}$$

If all f and all h are alike, equation (10) gives us:

$$2b = \frac{\left| z_1' \frac{\delta A}{\delta z_2} + z_2' \frac{\delta A}{\delta z_2} + \ldots . \right| (f + h)}{\sqrt{1 - A^2}}$$

But we have

$$\omega \frac{\delta A}{\delta \omega} = \frac{\delta A}{\delta z_1}\left[z_1' - \frac{1}{z_1''}\right] + \frac{\delta A}{\delta z_2}\left[z_2' - \frac{1}{z_2''}\right] + \ldots .$$

or, according to (10),

$$\omega \frac{\delta A}{\delta \omega} = 2\left[z_1' \frac{\delta A}{\delta z_1} + z_2' \frac{\delta A}{\delta z_2} + \ldots \right]$$

The attenuation may therefore be written:

$$2b = \frac{1}{2} \cdot \frac{\omega \left|\frac{\delta A}{\delta \omega}\right|}{\sqrt{1 - A^2}} (f + h)$$

This formula is thus valid for any network, provided all inductances as well as all capacities have the same loss factor.

We will now examine the attenuation in a band at the cut-off points.

We have found that at the cut-off points, which are determined by the condition $k^2 = 1$ (or practically $A^2 = 1$), the attenuation will be $\sqrt{B}$, where B is obtained from the equation:

$$B = \left| \frac{\delta A}{\delta z_1} r_1 + \frac{\delta A}{\delta z_2} r_2 + \dots \right|$$

To begin with, we assume that the derivates $\frac{\delta A}{\delta z_1}, \frac{\delta A}{\delta z_2}$ are not all zero at the cut-off point. A has thus no maximum or minimum value at this point, but is rising or falling, and B has a finite value. We call the cut-off frequency ω_o, and will examine the attenuation in points corresponding to the frequency $\omega_o + d\omega$, where $d\omega$ may be either positive or negative. At the cut-off point we may write

$$k^2 = 1 + \frac{\delta k^2}{\delta \omega} \delta \omega,$$

as $k^2 = 1$ when $\omega = \omega_o$.

But $k^2 = A^2 + B^2$, and B^2 is now small in relation to A^2, and $\frac{\delta A}{\delta \omega}$ is not zero at the cut-off point. With some approximation, we may therefore write:

$$\frac{\delta k^2}{\delta \omega} = \frac{\delta A^2}{\delta \omega} = 2A \frac{\delta A}{\delta \omega} = \pm 2 \frac{\delta A}{\delta \omega}$$

We may thus write:

$$1 - k^2 = \pm 2 \frac{\delta A}{\delta \omega} \delta \omega$$

The general attenuation formula may be written (see p. 2).

$$2b = \frac{\sqrt{2B}}{[\sqrt{(1 - k^2)^2 + 4B^2} + 1 - k^2]^{1/2}} =$$

$$= \frac{\sqrt{B}}{\left[\sqrt{1 + \left(\frac{1 - k^2}{2B}\right)^2} + \frac{1 - k^2}{2B}\right]^{1/2}} =$$

$$= \frac{B}{\sqrt{1 - k^2}} \cdot \frac{\sqrt{2}}{\left[1 + \sqrt{1 + \left(\frac{2B}{1 - k^2}\right)^2}\right]^{1/2}} \text{ (if } k^2 < 1)$$

$$= \sqrt{k^2 - 1} \cdot \frac{1}{\sqrt{2}} \left[1 + \sqrt{1 + \left(\frac{2B}{k^2 - 1}\right)^2}\right]^{1/2} \text{ (if } k^2 > 1)$$

We now have

$$\frac{1 - k^2}{2B} = \pm \frac{\omega_o \frac{\delta A}{\delta \omega} \frac{\delta \omega}{\omega_o}}{\left[\frac{\delta A}{\delta z_1} r_1 + \frac{\delta A}{\delta z_2} r_2 + \dots\right]}$$

If, for the sake of simplicity in studying the attenuation in the neighbourhood of the cut-off point, we assume that all coils have the same loss factor and that the same is the case for all capacities, we may, according to the above, write:

$$B = \frac{1}{2} \omega_o \left| \frac{\delta A}{\delta \omega} \right| (f + h)$$

Using this expression, we get:

$$\frac{1 - k^2}{2B} = \pm \frac{\frac{\delta \omega}{\omega_o}}{\frac{f + h}{2}}$$

The attenuation can thus be written:

$$2b = \frac{\sqrt{B}}{\left[\sqrt{1 + \left(\frac{2}{f + h} \frac{\delta \omega}{\omega_0}\right)^2} \pm \frac{2}{f + h} \frac{\delta \omega}{\omega_0}\right]^{1/2}}$$

or

$$2b = \frac{B}{\sqrt{1 - k^2}} \cdot \frac{\sqrt{2}}{\left[1 + \sqrt{1 + \left(\frac{f + h}{2} \frac{\omega_0}{\delta \omega}\right)^2}\right]^{1/2}} \; (k^2 < 1)$$

$$2b = \sqrt{k^2 - 1} \cdot \frac{1}{\sqrt{2}} \left[1 + \sqrt{1 + \left(\frac{f + h}{2} \frac{\omega_0}{\delta \omega}\right)^2}\right]^{1/2} (k^2 > 1)$$

The first formula is used when we are so near the cut-off point that $\frac{2}{f + h} \cdot \frac{\delta \omega}{\omega_o} < 1$, the second when $\delta \omega$ is large enough to make this expression larger than 1. The above formulæ can now approximately be written:

$$2b = \sqrt{B} \left[1 \pm \frac{1}{f + h} \frac{\delta \omega}{\omega_0}\right]$$

and

$$2b = \frac{B}{\sqrt{1 - k^2}} \cdot \left[1 - \frac{1}{8} \left(\frac{f + h}{2} \frac{\omega_0}{\delta \omega}\right)^2\right] (k^2 < 1)$$

or

$$2b = \sqrt{k^2-1}\cdot\left[1+\frac{1}{8}\left(\frac{f+h}{2}\,\frac{\omega_0}{\delta\omega}\right)^2\right]\;(k^2>1)$$

The formulæ derived show that the slope of the attenuation curve is determined by the expression:

$$\frac{2}{f+h}\,\frac{\delta\omega}{\omega_0},$$

where f and h are the loss factors of an inductance and a capacity respectively.

The first of the three formulæ shows the attenuation in the immediate neighbourhood of the cut-off point, and the two latter the transition of the attenuation to the values within and outside the band. The cut-off range may suitably be defined as that range in which $\frac{2}{f+h}\cdot\frac{\delta\omega}{\omega_0}$ is less than 1, or a width half of which is on each side of the cut-off point and equal to

$$\omega_0\,(f+h)$$

Outside this range the original formulæ may be used.

Constant Current Instead of Constant Voltage at the Track Transformer in an A.C. Track Circuit.

By *Ture Hård.*

The usual arrangement of an A. C.-fed track circuit is shown in fig. 1. The supply voltage is stepped down in the track transformer to a constant secondary voltage, which is imposed on the track circuit over a series resistance of suitable size. This resistance may be inductive or purely ohmic, and its object is in either case to cause a heavy voltage drop between the track transformer and the rails when a carriage enters the track. The shunt created by the wheel axles causes more current to be fed to the rails, thus producing an increased voltage drop in the series resistance. The secondary voltage of the track transformer being all the time constant, the potential between the rails will at the same time be reduced. The track relay is released when the voltage has dropped so much that it is no longer sufficient to maintain the minimum energizing

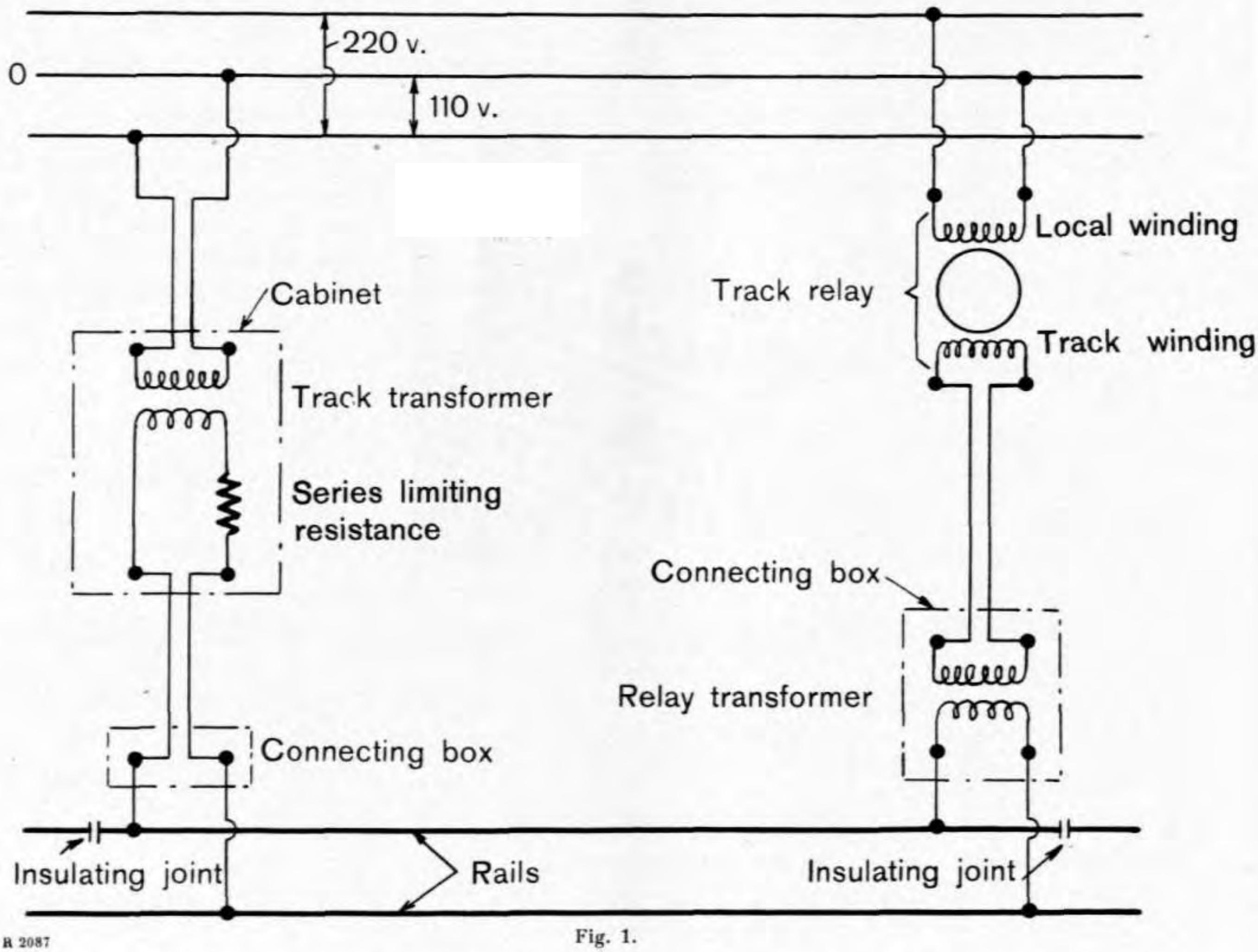


Fig. 1.

current required for the relay. The current in the relay is then reduced to or below a value, characteristic of the relay, which is called the "drop away" value.

Again considering fig. 1, we find that a wheel axle placed between the rails is connected in parallel with the relay transformer primary and the ballast. The current from the track transformer is distributed between the wheel axle, the ballast, and the relay transformer, in inverse proportion to their resistances. The current in each branch increases as the total current is increased. To attain the necessary traffic security, the relay must be released even if the wheel axle offers a certain resistance to the current. The increase of the total current is therefore in itself a drawback, as a more complete shunting through the wheel axle, i. e. a lower resistance, is required to lead away the increase of current also from the relay. If the current from the track transformer could be retained unchanged, release might be obtained with higher resistance, i. e. with greater margin of safety than is possible with any arrangement based on increasing current and series resistance.

We now introduce the following symbols:

u = the normal current output of the track transformer when the track is clear.

u_o = the current taken by the relay and ballast together when the current through the relay is reduced to the "drop away" value.

p_o = the voltage at the track, corresponding to u_o.

d_1 = the wheel axle resistance between the rails, necessary for obtaining p_o.

o = the increase of current in the track transformer caused by shunting with d_1.

We then get:

$$P_o = (u + o - \omega_o)\, d_1;$$

Assuming that the increase of current o may be eliminated and u remain unchanged after the shunting, and denoting the shunt then required d_2, we get

$$p_o = (u - u_o)\, d_1;$$

and hence $\frac{d_2}{d_1} = \frac{u + o - u_o}{u - u_o} = 1 + \frac{o}{u - u_o}$

This expression indicates that the resistance d_2 will always be higher than d_1.

We will now assume that in a track circuit according to fig. 1 a two-phase frequency-selective vane relay, Westinghouse type L with 6 front- and 2 back-contacts, of the following data is to be used:

Local winding: 0.66 amp. at 110 volts.

$$\cos \varphi_L = 0.78,\ \varphi_L = 39°.$$

Track winding: Working current = 0.63 amp. at 7.5 volts.
"Drop away" current = 0.21 amp. at 2.5 volts.

$$\cos \varphi_S = 0.50,\ \varphi_S = 60°.$$

Consequently the relay will not be released until the current has dropped to $^1/_3$ of the value required for full attraction.

The relay is to be connected to the track over a relay transformer of the ratio 1:3, mounted close to the track. The resistance of the leads between the relay transformer and the relay is assumed to be 12 ohms.

By means of the vector diagram shown in fig. 2, the magnitudes and phases of the voltage e and current i required at the primary of the relay transformer in order to obtain 0.63 amp. in the relay track winding are ascertained.

The diagram gives us:

$i = 2.0\,\underline{|0°}$

$e = 5.2\,\underline{|30°}$

The current i is made the reference-axis.

The following are the data of the track circuit:

Length of the track circuit, km. $l = 1$.

Rail impedance, ohm per km, $z = 0.45\,\underline{|45°}$

Ballast resistance, ohm per km, $r = 2$.

To calculate the track circuit, the auxiliary constants a, b and c, defined in an article with the heading "Some hints on track circuit calculation" printed in the L. M. Ericsson Review No. 4—6, 1928, are now obtained as follows:

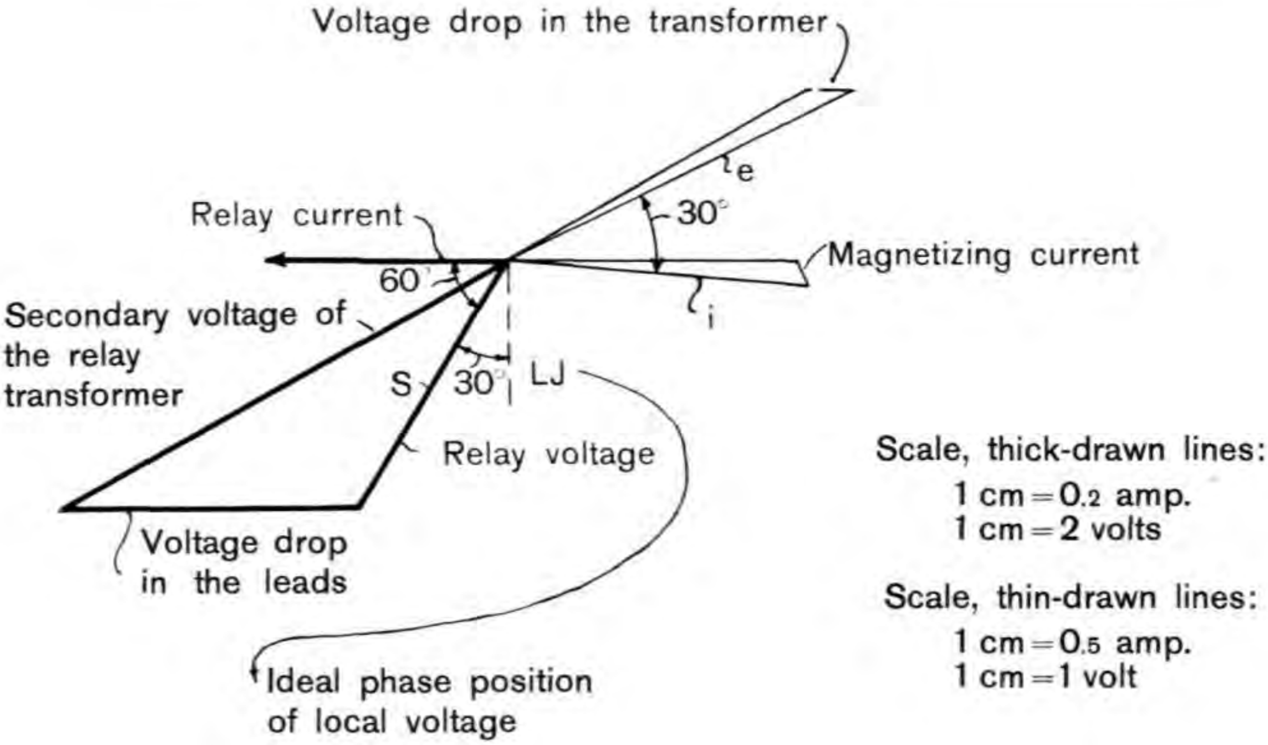
$$a = \sqrt{rz} = 1.23\,\underline{|22.5°}$$

We have: $l\sqrt{\frac{z}{r}} = 0.62;\ Z = 45°.$

By the aid of the curves shown in the article, we get:

$$b = 0.6\,\underline{|18°}$$

$$c = 1.15\,\underline{|7.5°}$$



R 2088

Fig. 2.

Hence:

$$e\frac{b}{a} = 5.2\underline{|30^\circ} \times \frac{0.6\underline{|18^\circ}}{1.23\underline{|22.5^\circ}} = 2.6\underline{|25.5^\circ}$$

$$i\,a\,b = 2\underline{|0^\circ} \times 1.23\underline{|22.5^\circ} \times 0.6\underline{|18^\circ} = 1.5\underline{|40.5^\circ}$$

If u and p denote current and voltage at the transformer end of the track circuit, formulæ (1) and (2) in the article mentioned give us:

$$u = \left(i + e\frac{b}{a}\right)c = (2.0\underline{|0^\circ} + 2.6\underline{|25.5^\circ}) \times 1.15\underline{|7.5^\circ} =$$
$$= 2.3\underline{|7.5^\circ} + 3.0\underline{|33^\circ}.$$

$$p = (e + i\,a\,b)\,c = (5.2\underline{|30^\circ} + 1.5\underline{|40.5^\circ}) \times$$
$$\times\, 1.15\underline{|7.5^\circ} = 6.0\underline{|37.5^\circ} + 1.75\underline{|45^\circ}$$

To determine the magnitudes and phases of u and p, we plot the vector diagram shown in fig. 3, which gives us:

$$u = 5.2\underline{|22^\circ}$$
$$p = 7.7\underline{|40^\circ}$$

The phase angles refer all the time to the current i as the reference axis:

In fig. 4 the two vectors $OA = u$ and $OB = p$ are drawn with the reference axis i in the direction of the ordinate.

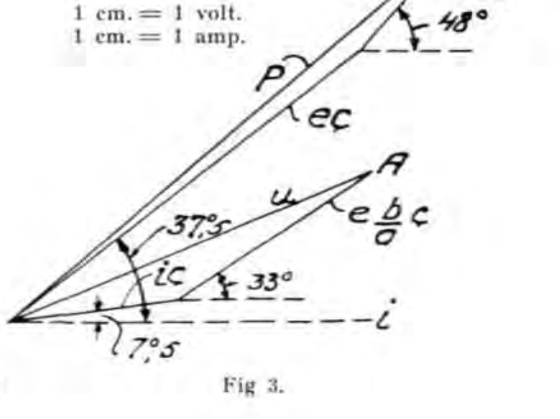
Assuming an ohmic series resistance, and a voltage on the secondary winding of the track transformer of 16 volts, the voltage drop BC in the series resistance can be determined by plotting BC parallel to OA, and making $OC = 16$ volts.

From the vector diagram we get

$$BC = 8.5 \text{ volts.}$$

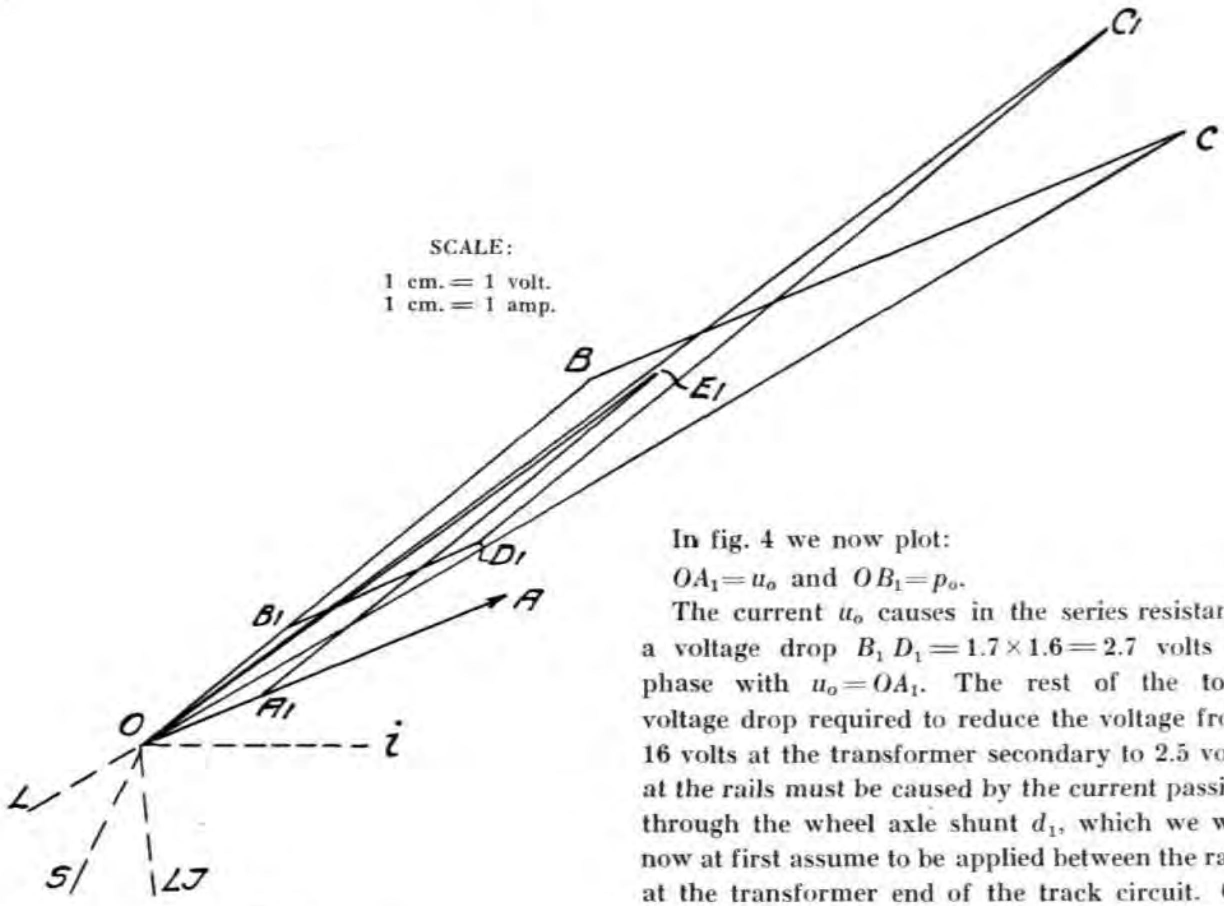
Consequently a series resistance of $= \frac{8.5}{5.2} = 1.6$ ohms may be used for this track circuit.

We will now calculate the value of the wheel axle resistance d_1 required for the release of the



R 2089

Fig 3.



B 2090 Fig. 4.

relay. To de-energize the relay, the voltage at the relay must drop to $^1/_3$ of the value required for full attraction. Assuming d_1 to be applied opposite the track-transformer, the voltage impressed on the rails must be reduced to $^1/_3$ of p, which obviously will reduce the current in the track circuit in the same proportion, i. e. to $^1/_3$ of u.

If e_o and i_o denote the voltage and current in the rails at the relay end, and p_o and u_o the corresponding current and voltage in the rails at the transformer end, the release of the relay will occur with:

$$e_o \leqq \frac{1}{3} \times 5.2; \quad i_o \leqq \frac{1}{3} \times 2.0$$

$$p_o \leqq \frac{1}{3} \times 7.7; \quad u_o \leqq \frac{1}{3} \times 5.2$$

Consequently we may assume:

$e_o = 1.7$ volts	30°
$i_o = 0.65$ amp.	0°
$p_o = 2.5$ volts	40°
$u_o = 1.7$ amps.	22°

In fig. 4 we now plot:

$OA_1 = u_o$ and $OB_1 = p_o$.

The current u_o causes in the series resistance a voltage drop $B_1 D_1 = 1.7 \times 1.6 = 2.7$ volts in phase with $u_o = OA_1$. The rest of the total voltage drop required to reduce the voltage from 16 volts at the transformer secondary to 2.5 volts at the rails must be caused by the current passing through the wheel axle shunt d_1, which we will now at first assume to be applied between the rails at the transformer end of the track circuit. On account of the nature of this shunt, the shunt current may be assumed to be in phase with the impressed voltage $p_o = OB_1$. The vector of the voltage drop $D_1 C_1$ caused by the shunt current may therefore be plotted in parallel with OB, its length being determined by OC_1 having to be 16 volts.

The diagram gives us $D_1 C_1 = 10.7$ volts.

As the series resistance was 1.6 ohms, the shunt current will be $\frac{10.7}{1.6} = 6.7$ amps.

A wheel axle resistance $d_1 = \frac{2.5}{6.7} = 0.37$ ohm will thus be required for release.

Completing now also the current diagram in fig. 4 by plotting the vector of the shunt current $A_1 E_1 = 6.7$ amps. in phase with the voltage OB, we get the total current $= OE_1 = 8.3$ amps.

Thus the increase of current

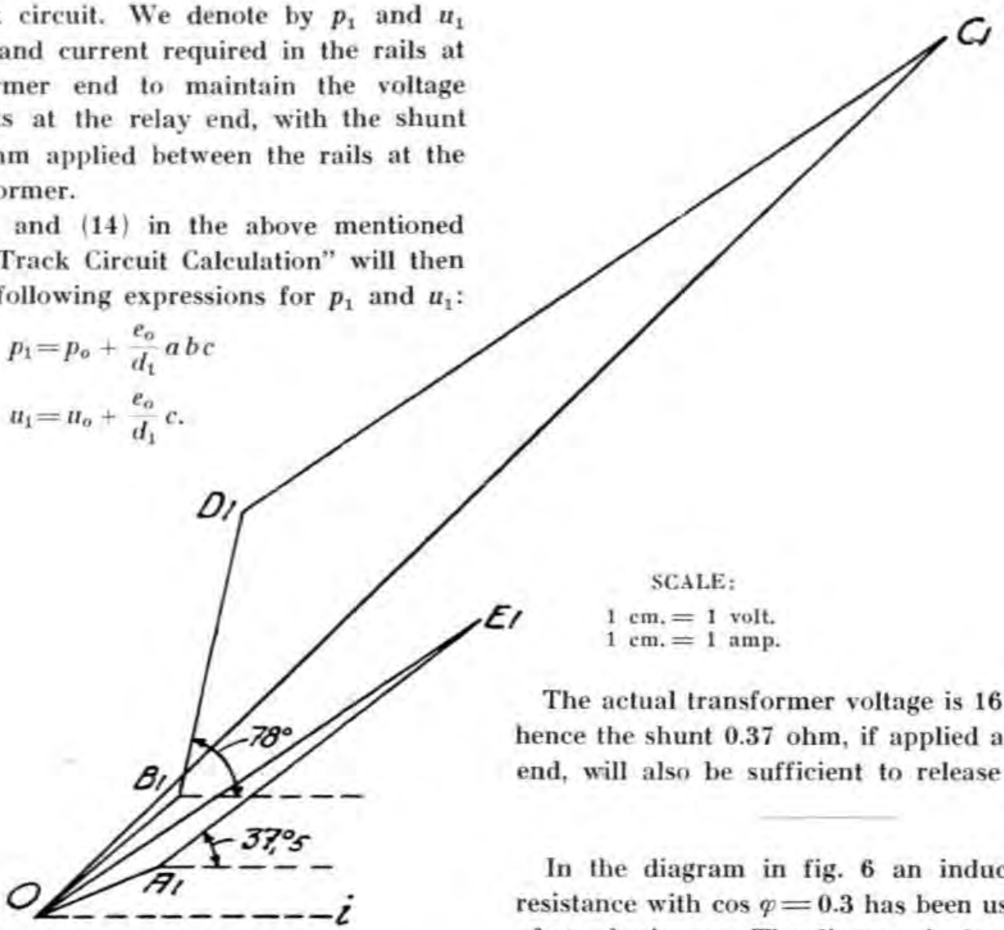
$$o = 8.3 - 5.2 = 3.1 \text{ amps.}$$

The object of the diagram drawn in fig. 5 is to show the effect of the same shunt $d_1 = 0.37$ ohm, applied between the rails at the relay end of the track circuit. We denote by p_1 and u_1 the voltage and current required in the rails at the transformer end to maintain the voltage $e_o = 1.7$ volts at the relay end, with the shunt $d_1 = 0.37$ ohm applied between the rails at the relay transformer.

Equ. (13) and (14) in the above mentioned article "On Track Circuit Calculation" will then give us the following expressions for p_1 and u_1:

$$p_1 = p_o + \frac{e_o}{d_1}\, a\, b\, c$$

$$u_1 = u_o + \frac{e_o}{d_1}\, c.$$



SCALE:
1 cm. = 1 volt.
1 cm. = 1 amp.

R 2091 Fig. 5.

Thus, with the current i as reference axis:

$$p_1 = p_o + \frac{1.7}{0.37}\,\underline{|30^\circ} \times 1.23\,\underline{|22.5^\circ} \times 0.6\,\underline{|18^\circ} \times$$
$$\times\, 1.15\,\underline{|7.5^\circ} = p_o + 3.8\,\underline{|78^\circ}$$

$$u_1 = u_o + \frac{1.7}{0.37}\,\underline{|30^\circ} \times 1.15\,\underline{|7.5^\circ} = u_o + 5.3\,\underline{|37.5^\circ}$$

As before, the vectors $OA_1 = u_o$ and $OB_1 = p_o$ are plotted.

To OA_1 we add the vector $A_1 E_1 = 5.3$, its phase being 37.5° in advance of the reference axis i.

From the diagram we get:

$u_1 = OE_1 = 7.0$ amps.

To OB_1 we add the vector $B_1 D_1 = 3.8$, its phase being 78° in advance of the reference axis i.

The voltage drop in the series resistance is now plotted as the vector $D_1 C_1 = 7 \times 1.6 = 11.2$ volts, in phase with the current vector OE_1.

The vector OC_1 will then be the voltage required at the track transformer. From the diagram we get $OC_1 = 16.7$ volts.

The actual transformer voltage is 16 volts, and hence the shunt 0.37 ohm, if applied at the relay end, will also be sufficient to release the relay.

In the diagram in fig. 6 an inductive series resistance with $\cos\varphi = 0.3$ has been used instead of an ohmic one. The diagram is drawn in analogy with fig. 4, except that the voltage drop in the series resistance is always drawn at an angle of 72° in advance of the current causing the voltage drop.

The diagram first gives us $BC = 10.2$ volts, from which we get the series resistance $= \frac{10.2}{5.2} = 1.9$ ohms.

As the final result we get $D_1 C_1 = 11.8$ volts, and the shunt current $\frac{11.8}{1.9} = 6.2$ amps.

Heuce the wheel axle resistance required for releasing the relay:

$$d_1 < \frac{2.5}{6.2} = 0.40 \text{ ohms.}$$

The total current $OE_1 = 7.7$ amps.

Consequently the increase of the current $o = 7.7 - 5.2 = 2.5$ amps.

Fig. 7 is showing the diagram when the shunt $d_1 = 0.40$ ohm is applied at the relay end.

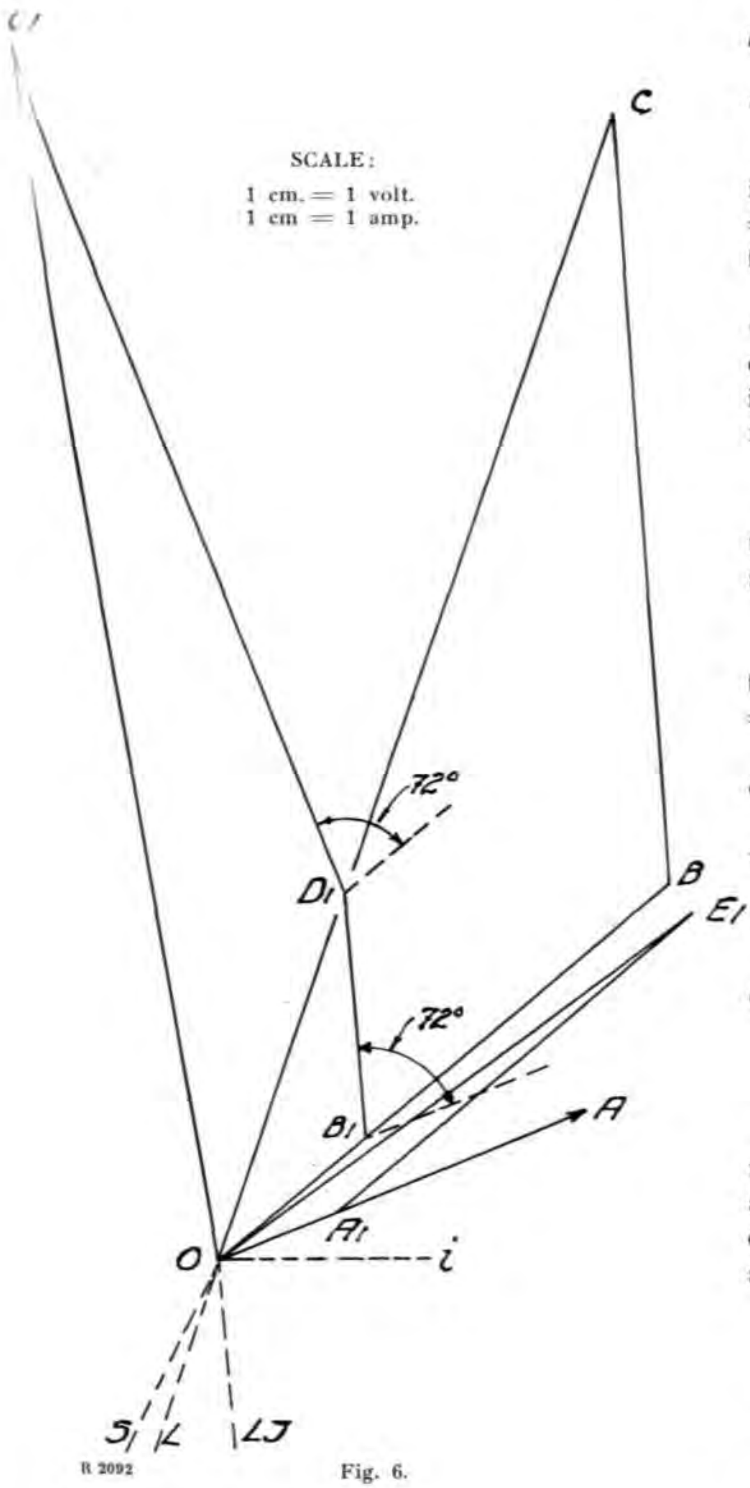


Fig. 6.

We have, as in fig. 5:

$$p_1 = p_o + \frac{e_o}{d_1} abc$$

$$u_1 = u_o + \frac{e_o}{d_1} c$$

Hence:

$$p_1 = p_o + \frac{1.7 \times 1.23 \times 0.6 \times 1.15}{0.40} \underline{|78^\circ} = p_o + 3.6 \underline{|78^\circ}$$

$$u_1 = u_o + \frac{1.7 \times 1.15}{0.40} \underline{|37.5^\circ} = u_o + 4.9 \underline{|37.5^\circ}$$

The diagram is obtained in the same way as in fig. 5, except that the voltage $D_1 C_1 = 6.5 \times 1.9 = 12.4$ volts is now drawn 72° in advance of the current $OE_1 = 6.5$ amps.

In this case also we find the sought voltage $OC_1 > 16$ volts and consequently a shunt of 0.4 ohm will be sufficient to release the relay even if applied at the relay end instead of the transformer end of the track circuit.

We will now assume that the total current from the track transformer can be kept constant in spite of the shunting of the track, i. e. at 5.2 amps.

Fig. 8 again shows the vector $OA_1 = u_o$.

The vector $A_1 E_1$ of the shunt current is plotted in phase with the voltage p_o, making $OE_1 = 5.2$.

From the vector diagram we then get the shunt current $A_1 E_1 = 3.6$ amps.

The shunt resistance d_2 required for release will thus be

$$d_2 \leqq \frac{2.5}{3.5} = 0.71 \text{ ohm.}$$

Assuming instead the shunt applied at the relay end, we have as before

$$u_1 = u_o + \frac{e_o}{d_2} c.$$

The current $\frac{e_o}{d_2} c$ is in the diagram, fig. 8, represented by the vector $A_1 E_2$ being 37.5° in advance of the reference vector i. The length of AE_2 is determined by $u_1 = OE_2$ being 5.2 amps.

From the diagram we get:

$$AE_2 = \frac{e_o}{d_2} c = 3.5.$$

Consequently $d_2 = \frac{1.7 \times 1.15}{3.5} = 0.56$ ohm.

With constant current, the wheel axle resistance required for release will thus, even in the most unfavourable circumstances, be considerably higher than the one required when using a track transformer with constant voltage.

Some methods of obtaining constant current by a combination of inductive and condensive reactances in series are discussed in Steinmetz: "Theory and Calculation of Alternating Current Phenomena."

In fig. 9 a) and b), two devices taken from Steinmetz book are shown, by means of which a constant A. C. voltage t impressed between 1 and 2, can be transformed into a constant current y_1 between 3 and 4, irrespective of the impedance of the current consumer, provided that the condenser and the inductive resistance of the device are selected so that $\omega L = \frac{1}{\omega C}$, i. e. that current resonance obtains between the inductive and condensive reactances L and C.

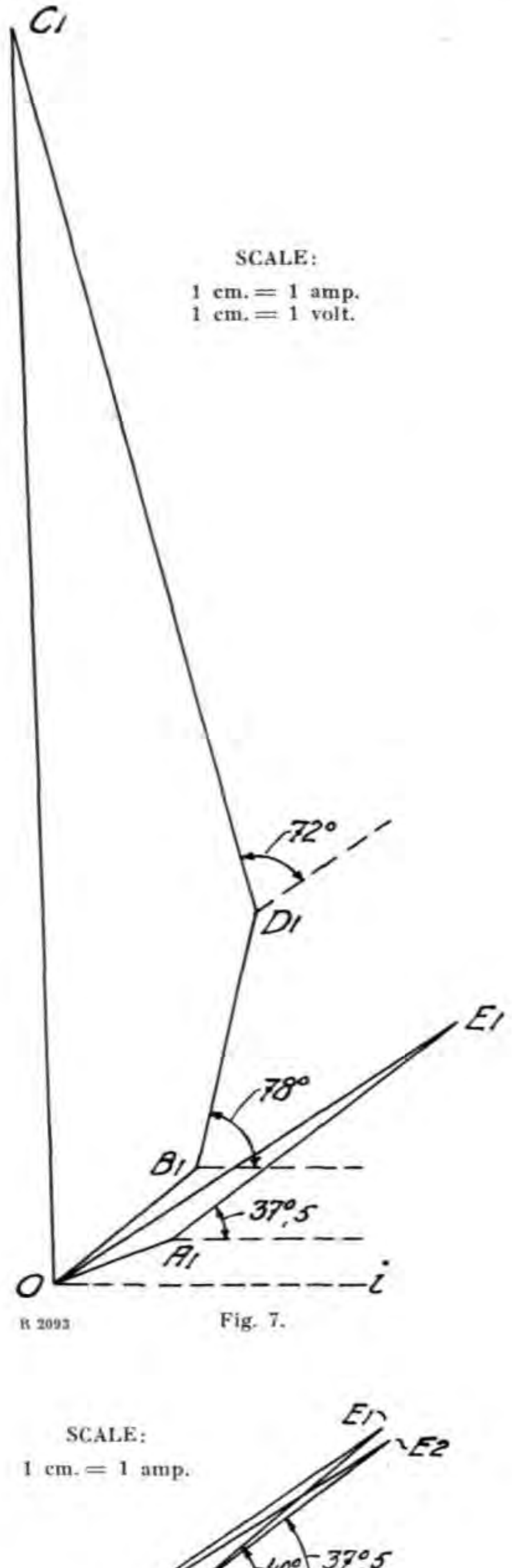
The value of the constant current y_1 depends on the voltage t and the magnitude of the reactances, according to the formula

$$y_1 = \frac{t}{\omega L} = t \omega C.$$

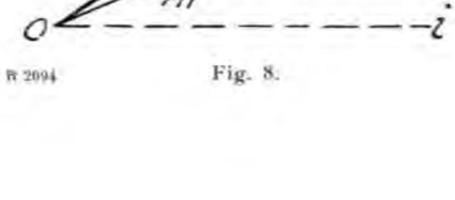
With an impressed voltage $t = 110$ volts, 50 cycles, a capacity $C = \frac{5.2}{110 \times 2 \times 3.14 \times 50} = 0.000150$ farad would thus be necessary for obtaining the constant current $y_1 = 5.2$ amps. Consequently the condenser will be of a magnitude which makes the arrangement according to fig. 9 rather unsuitable for direct practical use in connexion with track circuits.

By *inserting a current transformer* between 3 and 4, as shown in fig. 10 a) and b), the size of the condenser can be reduced in proportion to the ratio of the current transformer. A considerable portion of the constant current in the primary of the current transformer, however, is now consumed for magnetizing the transformer. This magnetizing current varies, on account of the variations in the primary voltage of the current transformer, and the current y_1, transformed to the track circuit, can therefore no longer be constant.

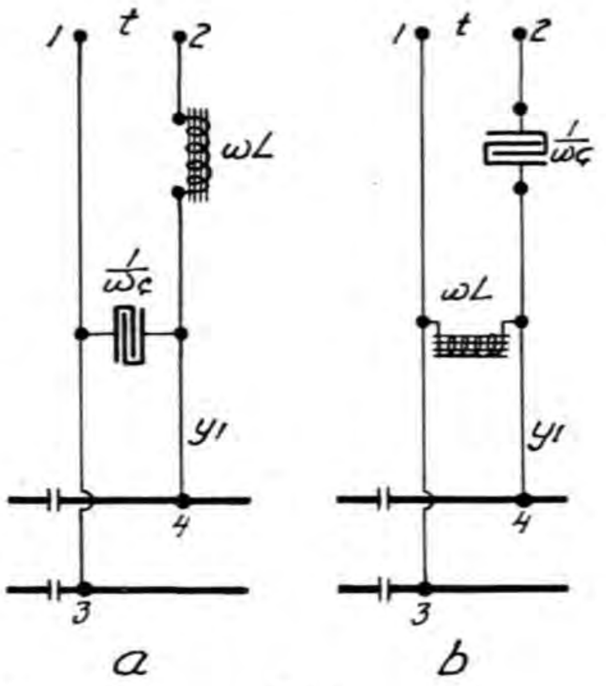
A method more fitted for practical purposes is obtained by the modification of the fig. 10 b) arrangement shown in fig. 11, utilizing the primary winding of the track transformer as inductive reactance. The current which according to fig. 10 b) passes through the reactance ωL is according to fig. 11 utilized for the magnetization of the iron core of the transformer. If the selfinduction of the transformer is chosen to make current resonance with the capacity reac-



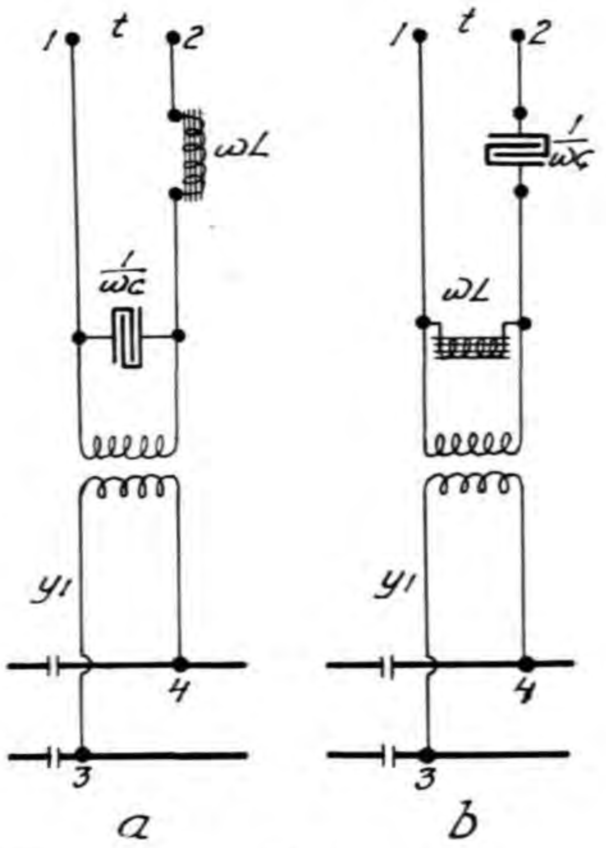
R 2093 Fig. 7.



R 2094 Fig. 8.

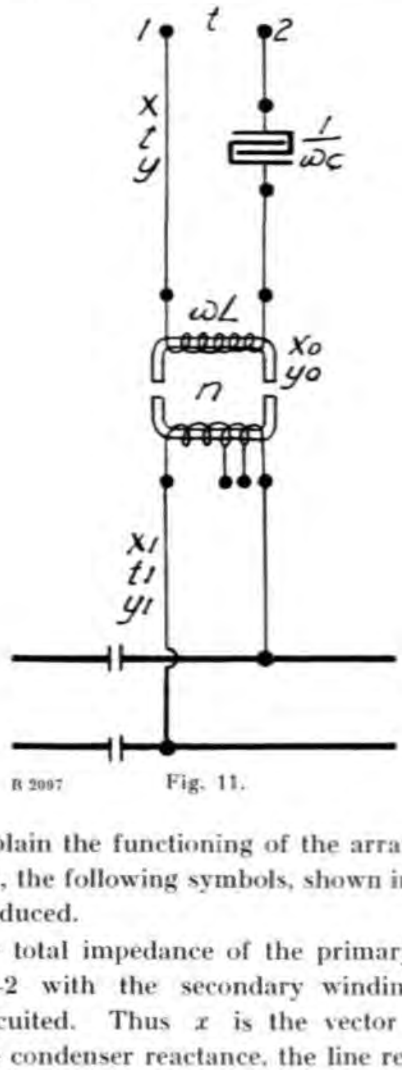


R 2095 Fig. 9.



R 2096 Fig. 10.

tance connected in series, it should be possible to obtain a constant current from the secondary winding of the current transformer. The amount of this current is determined by the voltage impressed between 1 and 2, as well as the ratio of the transformer, and can without changing any other part of the arrangements be regulated by using different taps on the secondary winding. The current is decreased by connecting more windings and increased by utilizing a smaller number of windings in the secondary of the transformer.



R 2097 Fig. 11.

To explain the functioning of the arrangement in fig. 11, the following symbols, shown in fig. 11, are introduced.

x = the total impedance of the primary circuit 1—2 with the secondary winding short-circuited. Thus x is the vector sum of the condenser reactance, the line resistance, and the short-circuit impedance of the transformer.

x_0 = the reactance of the track transformer with the secondary winding open.

x_1 = the total impedance of the secondary circuit.

n = ratio between the number of the primary turns to the number of secondary turns.

t = the voltage impressed between 1 and 2.

t_1 = the secondary current.

y = the primary current.

y_o = the magnetizing current.

y_1 = the secondary voltage of track transformer.

The following relations apply:

$$y_1 = \frac{t_1}{x_1}$$

$$y_o = \frac{nt_1}{x_o}$$

$$y = \frac{y_1}{n} + y_o = nt_1\left(\frac{1}{n^2 x_1} + \frac{1}{x_o}\right)$$

$$t = nt_1 + xy = nt_1\left(1 + \frac{x}{n^2 x_1} + \frac{x}{x_o}\right)$$

$$t_1 = \frac{t}{n\left(1 + \frac{x}{n^2 x_1} + \frac{x}{x_o}\right)}$$

$$y_1 = \frac{t_1}{x_1} = \frac{nt}{x + n^2 x_1\left(1 + \frac{x}{x_o}\right)}$$

If the ohmic and inductive components of the impedance x are assumed to be small compared to the condensive reactance, we may put $x = \frac{1}{j\omega C}$, where C = the capacity, ω = the frequency of the alternating current, and $j = \sqrt{-1}$.

For the track transformer, we may also put $x_o = j\omega L$, where L = the self-inductance of the primary winding.

Hence:

$$\frac{x}{x_o} = \frac{1}{j\omega C \times j\omega L} = \frac{1}{\omega^2 CL}$$

$$y_1 = \frac{nt}{x + n^2 x_1\left(1 - \frac{1}{\omega^2 CL}\right)}$$

If $\omega^2 CL = 1$, i. e. with series resonance between the condensive and inductive reactances, we get $y_1 = \frac{nt}{x}$. Therefore y_1 is constant for a given voltage t, condenser reactance x and ratio n. x being a condensive reactance, the phase angle of y_1 is rotated 90° in relation to the impressed voltage.

In figs. 12 a), b) and c) the functioning of an arrangement for constant current transformation according to fig. 11 is illustrated by means of vector diagrams. The diagrams a), b) and c) are plotted for the same values of n, t, and $x = x_o$, but for different, arbitrary values of x_1. The diagram will be of the shape indicated in fig. 12 a), b) and c) respectively, according to whether x_1 is an inductive, condensive, or a purely ohmic impedance. The current y_1 obtained in the secondary circuit is in all three cases of the same magnitude, and its phase is 90° behind the voltage t.

In plotting the diagrams, the given voltage t has first been drawn, and afterwards the vector xy, representing the voltage drop in the condenser, has been plotted at an arbitrary angle to t. The vector nt_1, representing the voltage drop in the primary winding of the transformer, is then obtained by combining the vectors xy and t.

x_o being given, the magnetizing current $y_o = \frac{nt_1}{x_o}$ can be plotted at an angle of 90° to nt_1. The current vector y is further plotted 90° in advance of the voltage xy, and its size is determined by dividing the magnitude of the arbitrarily chosen vector xy by the given x.

By combining the vectors y and y_o, the vector $\frac{y_1}{n}$ is obtained and, n being given, also the vector y_1 which is n times larger than $\frac{y_1}{n}$ and of opposite direction.

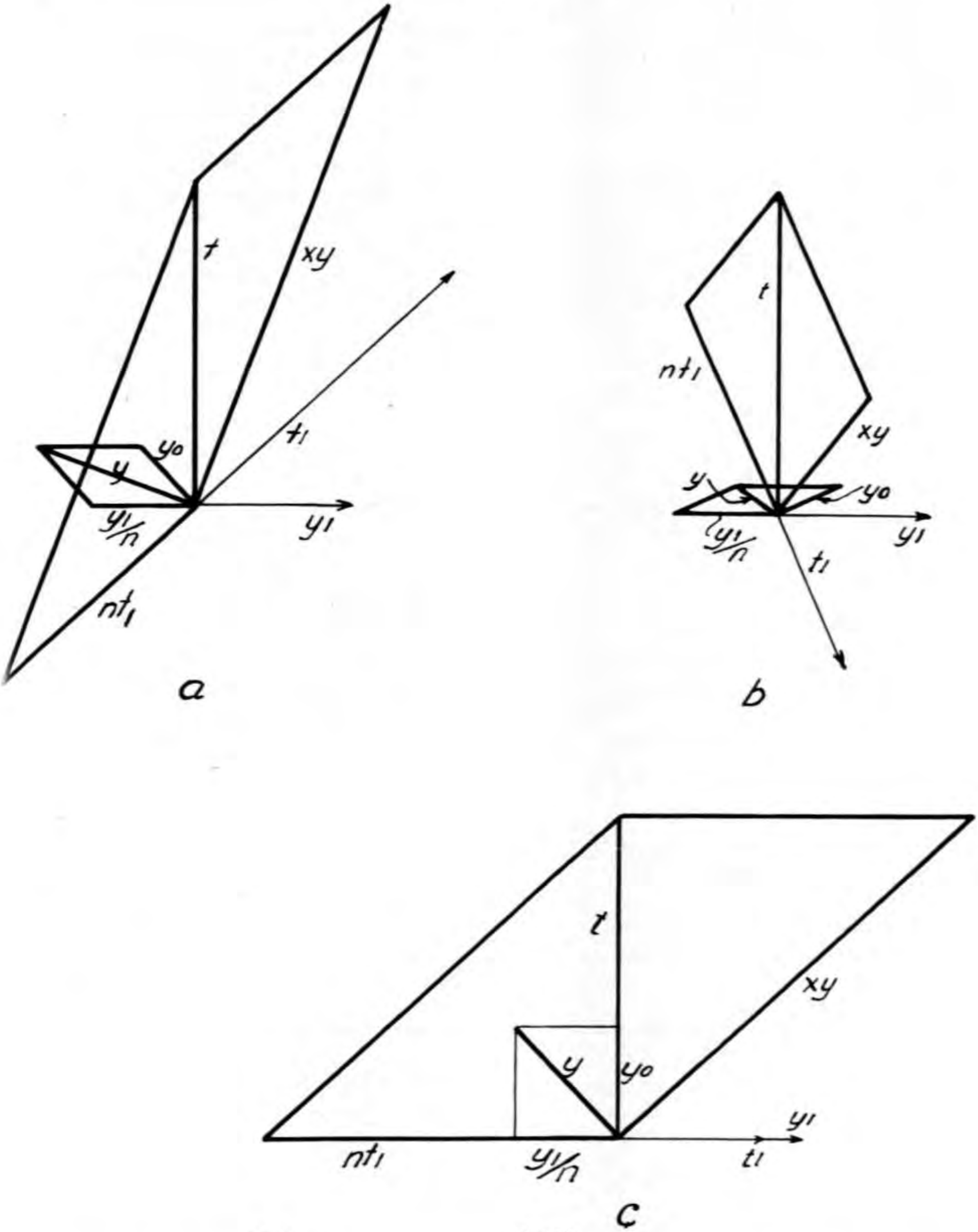
As $\frac{xy}{y} = \frac{nt}{y_o} = x$, and the vectors y and y_o respectively are at right angles to xy and nt_1 respectively, the vector $\frac{y}{n}$, composed of y and y_o, must form an angle of 90° with t, and its magnitude bear the same relation to the magnitude of t as y to xy.

Hence
$$\frac{y_1}{nt} = \frac{y}{xy}$$

$$y_1 = \frac{nt}{x}$$

The magnitude and phase of y_1 are thus constant for given values of the impressed voltage, the condenser reactance, and the ratio of transformation.

On account of unavoidable losses by the ohmic resistance in leads and transformer windings,



R 2098

Fig. 12.

magnetic leakage in the transformer, etc., absolutely constant current y_1 cannot be obtained in practice. The calculations, however, indicate how the device should be arranged to attain the best possible result.

The condenser should have a high reactance in order to neutralize the influence of the ohmic resistances on x. A high impressed voltage t is therefore an advantage, as a smaller condenser may then be used.

The iron core of the transformer should be provided with an air gap, so that the reactance will be constant, and the magnetizing current thus proportional to the voltage of the primary winding within sufficiently wide limits.

The air gap also retains the sinusoidal wave form of the current, which is of importance for the functioning of the device, in view of the demand for series resonance. For this purpose the iron losses should also be kept low, and when the primary voltage reaches such values that constant current will no longer be required. After the iron in the notched section has become saturated, the section will function as an additional air gap, and the reactance of the transformer is rapidly altered. The resonance with the condenser will therefore cease, and the rise in the voltage is automatically limited.

The curve marked *A* in fig. 13 illustrates the values at various voltages of the magnetizing cur-

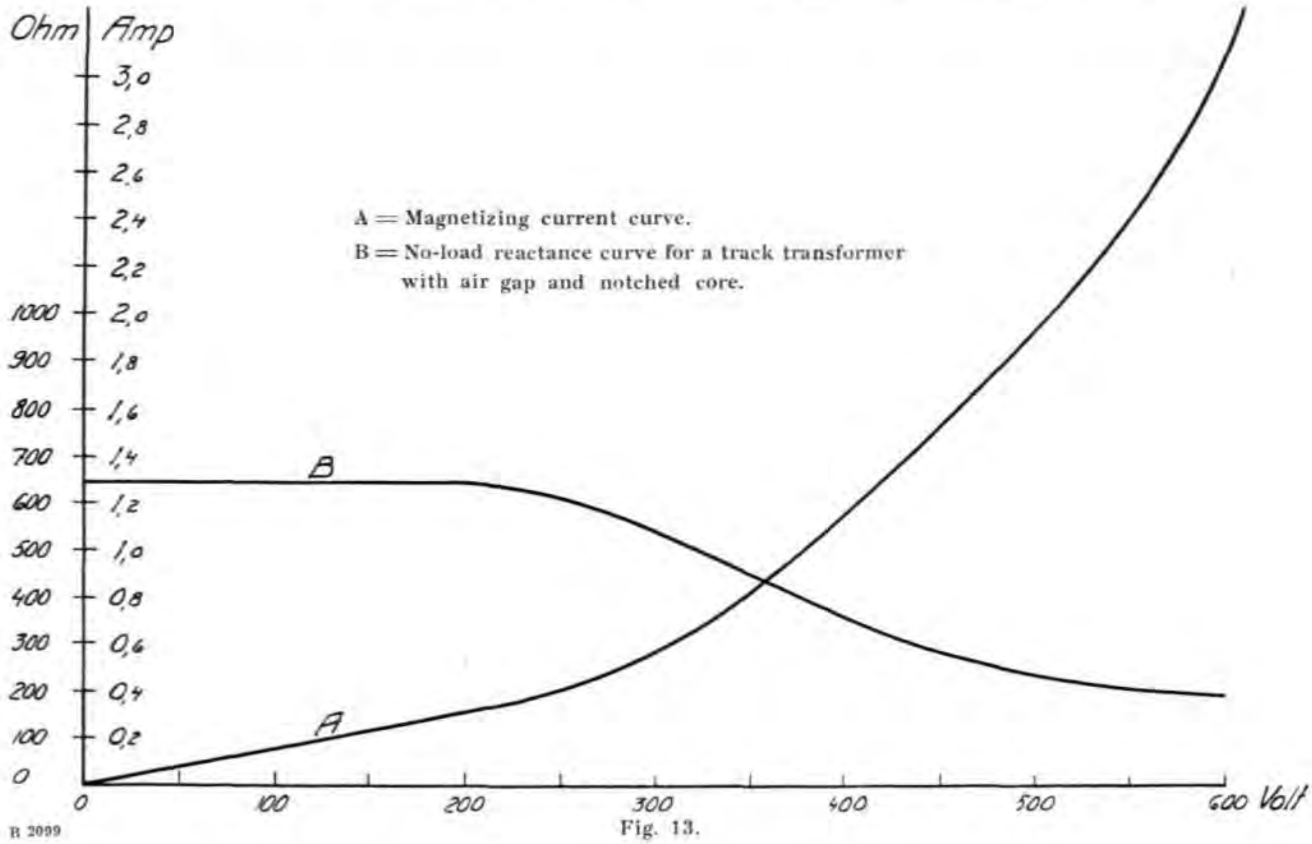


Fig. 13.

magnetic saturation be avoided within the voltage limits for which constant current is desired.

Due to the resonance between the capacity of the condenser and the inductance of the primary winding, however, high voltages will be produced at the condenser and the transformer when the secondary circuit is open. This rise of the voltage is limited by the transformer not being capable of retaining its reactance when the voltage becomes too high. In order to limit the rise of the voltage more exactly, the iron cores of the transformers designed for this purpose are equipped with a notch, so arranged that the iron in the notched section becomes saturated

rent in a transformer designed on the above mentioned principle. The curve marked *B* shows the alterations of the no-load reactance at various voltages. The diagram indicates that a rapid increase of the magnetizing current and a reduction of the reactance starts at about 250 volts in the primary winding.

Fig. 14 shows the same track circuit as fig. 1, provided with constant current feed.

A condenser of 5 microfarad is used. At 50 cycles we then get:

$$x = \frac{1}{2 \times 3.14 \times 50 \times 5} \times 10^6 = 640 \text{ ohms.}$$

An impressed voltage $t = 220$ volts gives

$$\frac{y_1}{n} = \frac{220}{640} = 0.35 \text{ amp.}$$

To obtain the necessary amount of current $y_1 = u = 5.2$ amps., a transformer ratio of

$$n = \frac{y_1}{0.35} = \frac{5.2}{0.35} \sim 15.$$

is required.

The diagram gives us the vector

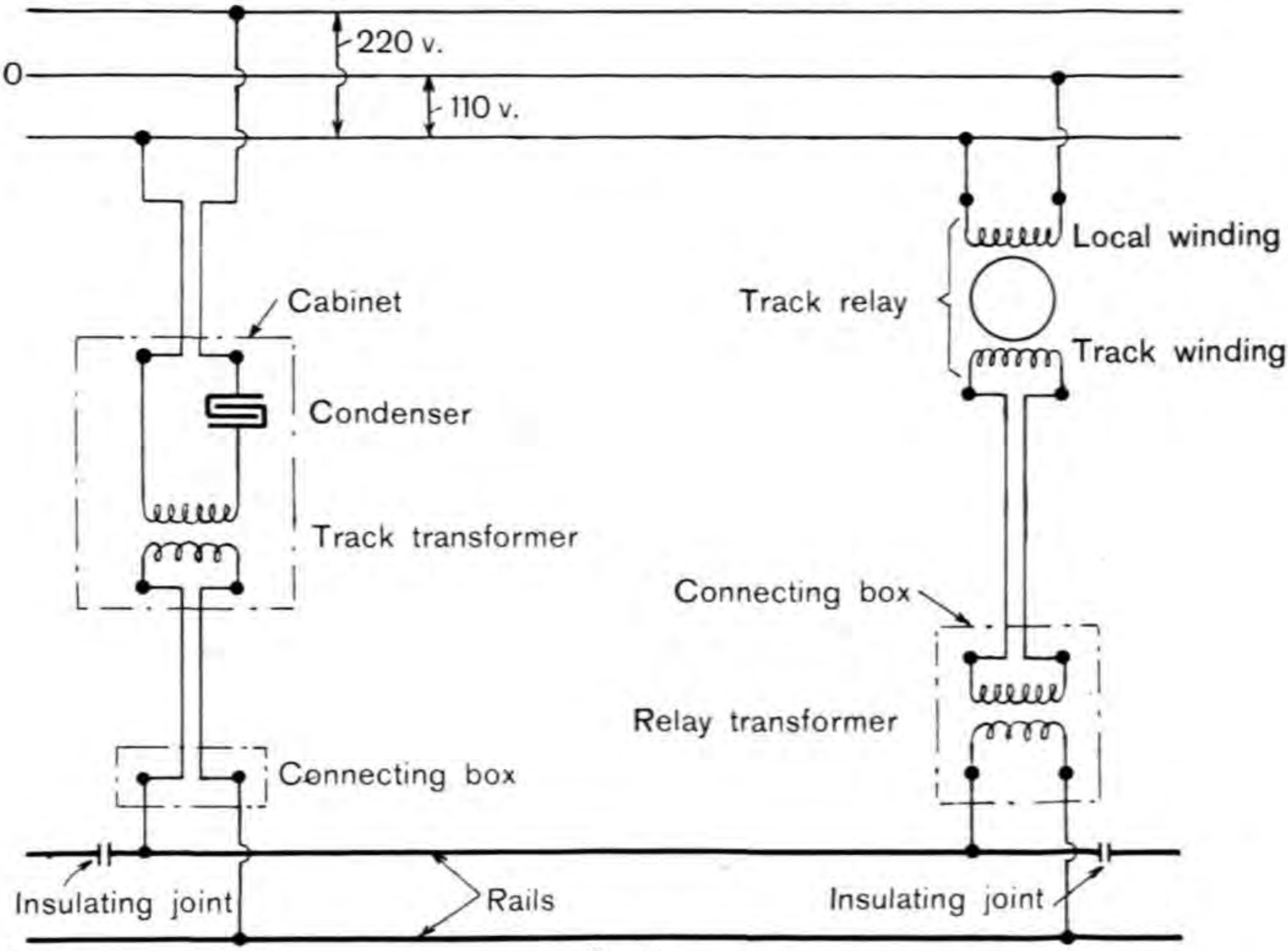
$$OC = t_1 = 12.7 \text{ volts.}$$

The vector

$$nt_1 = 15 \times 12.7 = 190 \text{ volts}$$

is marked off in the opposite direction to OC.

$$\frac{y_1}{n} = \frac{5.2}{15} = 0.35 \text{ amp.}$$



B 3000

Fig. 14.

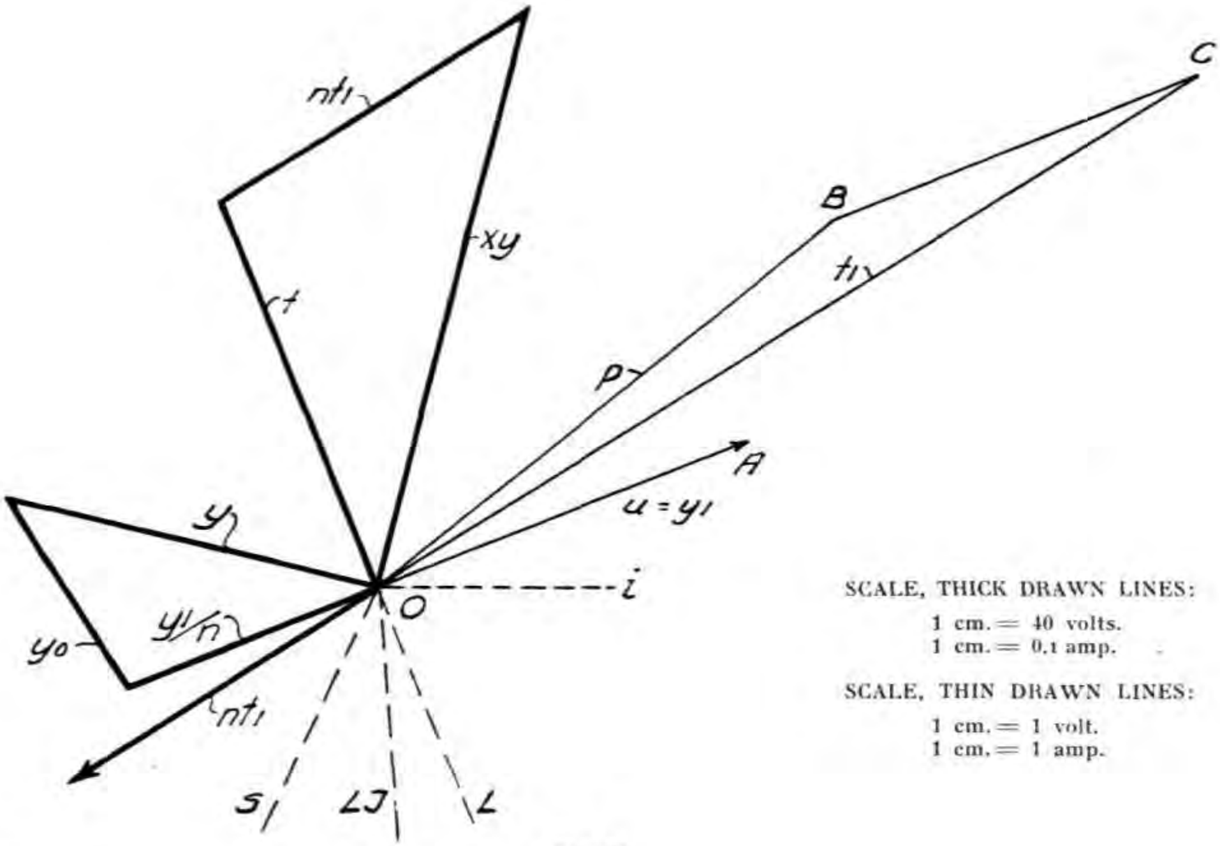
Fig. 15 shows the vector diagram of the track circuit, using the values of u and p already calculated for fig. 2. OA and BA are representing the vectors of u and p, with the relay transformer current i as a reference axis. BC is the voltage drop in the secondary of the track transformer including the leads to the rails, and is therefore plotted in phase with the current. If the resistance in the winding and the leads is assumed to be 1 ohm, we get:

$$BC = 1 \times 5.2 = 5.2 \text{ volts.}$$

The vector of the magnetizing current, $y_0 = \frac{n\,t_1}{640} = \frac{190}{640} = 0.30$ amp., is then plotted 90° behind the voltage vector nt_1.

The diagram now gives us $y = 0.5$ amp., and the voltage drop $xy = 640 \times 0.5 = 320$ volts is marked off 90° behind the current y.

By combining the vector of the condenser voltage xy with the vector of the transformer voltage nt_1, the vector for the input voltage t is obtained. As expected, this last vector will be

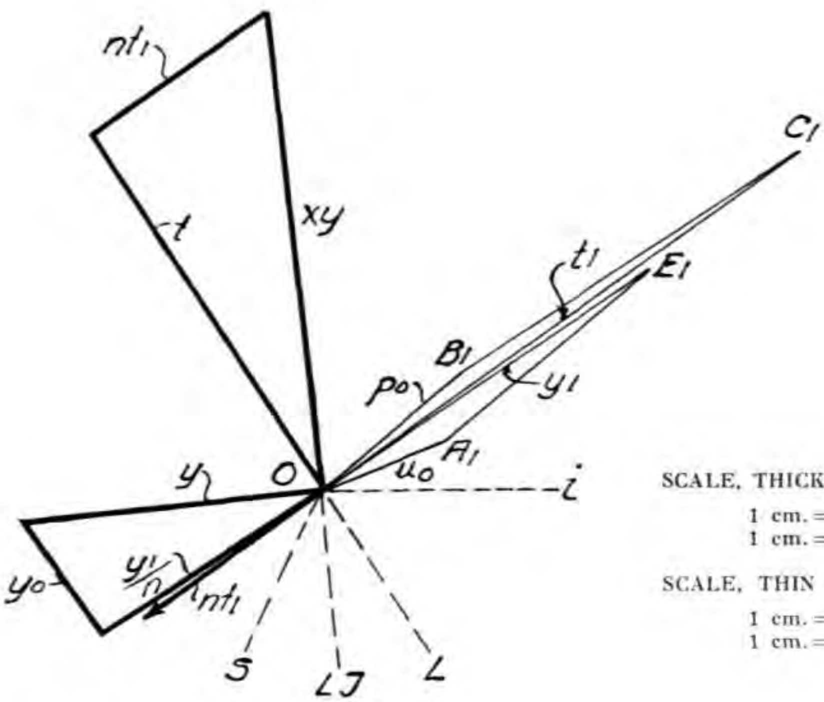


SCALE, THICK DRAWN LINES:
1 cm. = 40 volts.
1 cm. = 0,1 amp.

SCALE, THIN DRAWN LINES:
1 cm. = 1 volt.
1 cm. = 1 amp.

R 3001

Fig. 15.



SCALE, THICK DRAWN LINES:
1 cm. = 40 volts.
1 cm. = 0,1 amp.

SCALE, THIN DRAWN LINES:
1 cm. = 1 volt.
1 cm. = 1 amp.

R 3002

Fig. 16.

220 volt, its phase being 90° in advance of the current y_1.

Fig. 16 shows the appearance of the vector diagram when the track is shunted at the transformer end so that the track relay is released, i. e.

$$p_o = 2.5 \text{ volts. } \lfloor 40^\circ.$$
$$u_o = 1.7 \text{ amps. } \lfloor 22^\circ.$$

We draw the vectors $OA_1 = u_o = 1.7$, and $OB = p_o = 2.5$, with the current i as reference axis. The shunt current $A_1 E_1$ is then plotted in phase with p_o, and so that $OE_1 = y_1 = 5.2$.

The voltage drop in the leads and in the track transformer secondary, $B_1 C_1 = 1 \times 5.2 = 5.2$ volt, is plotted in phase with OE_1.

The diagram gives $OC_1 = t_1 = 7.7$ volts.

We now draw the vectors of

$$nt_1 = 15 \times 7.7 = 115 \text{ volts.}$$
$$y_1 = \frac{5.2}{15} = 0.35 \text{ amp., and}$$
$$y_o = \frac{115}{640} = 0.18 \text{ amp.}$$

The diagram gives us the vector $y = 0.40$ amp., and $xy = 640 \times 0.40 = 256$ volts is now plotted at right angles to y.

t is now obtained by combining nt_1 and xy. As expected, we get $t = 220$ volts and its phase is 90° in advance of y_1.

A two element relay receiving power in two separate windings being used, it is important that a proper phase angle is obtained between the currents in the two relay windings, designated "local" and "track" in figs. 1 and 14. For the type of relay used in the previous examples, the most suitable phase deflection between the currents is obtained when the track voltage is about 30° behind the local voltage. The efficiency of the relay is then highest. When the phase deflection is altered, this deflection from the most efficient angle must be compensated by increasing the supply of power.

With the aid of the diagram in fig. 2, we have indicated in the vector diagrams of figs. 4, 6, 15, and 16 the phase position of the relay track voltage S, as well as the ideal phase position LI of the relay local voltage. The difference in phase between S and LI is 30°.

If we now assume that the track transformer and the local relay winding are fed from the same power mains, as is the case when a single phase A. C. supply is used, the voltage vector of the local winding will have a direction opposite to that of the vector OC in figs. 4 and 6 and to the vector t in figs. 15 and 16. From fig. 4 we find that the phase angle between L and the ideal phase position LI is 60° à 70°. A more suitable phase deflection can of course be obtained by connecting the track circuit and the local winding to different phases, e. g. two different feed lines of a 3-phase power supply.

From the diagrams of figs. 6 and 15, it is evident that a suitable phase deflection between the voltages of the local and the track windings of the relay is also obtained when a single phase supply is connected.

The vector diagram of fig. 15 shows that the reference axis i is leading the local voltage. If the condenser is short-circuited, the voltage of the track winding of the relay rotates forward about 90°. This will cause a reversal of the torques acting in the relay, and will consequently release the track relay. Defective insulation causing a short-circuit in the condenser can thus not cause an improper attraction of the track relay, but is immediately announced by the release of the relay.

We are now going to compare the power consumption of a track circuit using a constant voltage transformer with the power consumption of the same circuit when fed from a current transformer.

According to fig. 4, $5.2 \times \frac{16}{110} = 0.76$ amp. at 110 volts, $\cos \varphi_S = 0.99$, is used for the track feed.

The relay local winding takes 0.6 amp. at $\cos \varphi_L = 0.78$.

Consequently the total current from the mains

$$\sqrt{(0.6 \cos \varphi_L + 0.76 \cos \varphi_S)^2 + (0.6 \sin \varphi_L + 0.76 \sin \varphi_S)^2} = \sqrt{1.49 + 0.23} = 1.31 \text{ amps.}$$
$$\cos \varphi_N = \frac{1.22}{1.31} = 0.93.$$

Volt-amps. consumed $= 1.31 \times 110 = 145$.

Watts consumed $= 0.93 \times 145 = 135$.

According to fig. 6, $5.2 \times \frac{16}{110} = 0.76$ amp. at 110 volts, $\cos \varphi_S = 0.64$, is used for feeding the track.

Thus the total consumption from the mains

$$= \sqrt{(0.6 \cos \varphi_L + 0.76 \cos \varphi_S)^2 + (0.6 \sin \varphi_L + 0.76 \sin \varphi_S)^2} = \sqrt{0.92 + 0.90} = \sqrt{1.82} = 1.35$$

$$\cos \varphi_N = \frac{0.96}{1.35} = 0.71.$$

Volt-amps. consumed $= 1.35 \times 110 = 149$.
Watts consumed $= 0.71 \times 149 = 106$.

According to fig. 15, 2×0.5 amps. $= 1.0$ amp. at 110 volts, $\cos \varphi_S = 0.57$, is used.

The total consumption from the mains

$$= \sqrt{(0.6 \cos \varphi_L + 1.0 \cos \varphi_S)^2 + (0.6 \sin \varphi_L - 1.0 \sin \varphi_S)^2}$$

$$= \sqrt{1.08 + 0.20} = \sqrt{1.28} = 1.13 \text{ amps.}$$

$\cos \varphi_N = \frac{1.04}{1.13} = 0.92$ (the current is leading the voltage).

Volt-amps. consumed $= 1.13 \times 110 = 124$.
Watts consumed $= 0.92 \cdot 124 = 114$.

The above examples indicate that it is possible by employing constant current to attain considerable reduction in the consumption of volt-amps., obviously because of the interaction between the condensive load in the track transformer and the inductive load in the local winding of the track relay. Should the condensive current, as in the above example, be predominant, this is as a rule no drawback, as the excess is absorbed by other inductive loads connected to the same mains, such as relays, choke coils, etc., the result being an improved power factor for the whole supply system.

An example of the advantages of using constant current was obtained from the plant at the Stockholm South Station, where 14 track circuits with frequency-selective track relays type L were provided with devices for constant current feed. The track circuits were previously provided with inductive series resistances according to fig. 1. The alteration was made in order to raise the release values of the track circuits with the object of increasing the margin of safety.

To obtain fully comparable measurements before and after the alteration, the release value for one of the longest track circuits was measured immediately before and after the change-over, with only about a 10 minute interval between the two measurements, so that the ballast leakage and the line voltage should be exactly the same on both occasions. Before the change, i. e. with a constant voltage transformer and inductive series resistance, the voltage at the track winding of the track relay was measured to be 7.6 volts, and at the local winding 107 volts. The front contacts of the relay opened 1.5 à 2 mm when the rails were shunted with 0.30 ohm. After the change over to current feed, the relay voltages were 8.1 and 107 volts respectively, but the release of the relay now occurred when the rails were shunted with 0.65 ohm.

By the alteration, the power consumption of the whole plant, including daylight signals as well as point indication relays and other relays, was reduced from 2 450 volt-amps., $\cos \varphi = 0.76$, to 2 020 volt-amps., $\cos \varphi = 0.90$. The difference would have been larger if the track relays had not previously been adjusted to receive the least possible power from the track. After the change-over to constant current, the power in the track windings could be increased by about 10 per cent without inconvenience to the shunting qualities, whereby a desirable increase of the attraction and contact pressure of the relay armatures was obtained.

Track circuits with constant current input had

Fig. 17. Track relay, relay transformer, track transformer, and condenser.

Fig. 18. Cabinet with track transformers and condensers.

earlier been put in use at the Gothenburg Central with 70 track circuits, at Hallsberg with 45, at Abisko with 8, and at Kiruna with 7 track circuits. The total number of such track circuits is consequently today 139, including the Stockholm South, the circuits varying in length from a few tens of metres up to about 500 metres. Frequency-selective relays type L with 6 front and 2 back contacts are used in all cases. Only one rail of the track circuit is insulated, as the other rail of the track must be continuous, to serve as return for the electric traction which uses alternating current of a frequency of 15 or $16^{2}/_{3}$ cycles.

The shunt values are found to vary between 0.65 and 1.1 ohm, which result would not have been possible to obtain with these relays with the former supply system using constant voltage and series limiting resistance.

The power factor of the Gothenburg plant has proved to be practically 1 and for Hallsberg 0.98, in both cases for the whole plant, i. e. including daylight signals, point-indication relays, etc. For comparison may be mentioned that the power factor in other similar plants, but with the track feed according to fig. 1, has proved to be 0.70—0.80.

The majority of the track circuits in use are short, and do not require as much current as has been assumed in the examples above. For the convenient supply of the proper amount of current to the track circuit, the transformers have been provided with several taps on the secondary side, so that the ratios 15, 11, 9, and 7.7 can be obtained. A tap for fine adjustments has also been arranged, so that these ratios can be altered to 12.5, 10, 8.5, and 7.2. When an impressed voltage of 220 volts and a 5 microfarad condenser is used, the current can thus be varied from $\frac{15 \times 220}{640} = 5.2$ amps. at a ratio of 15, to $\frac{7.2 \times 220}{640} = 2.25$ amps. at the lowest ratio.

The track transformers and their condensers are mounted in ordinary wooden cabinets placed

Fig. 19. Cast iron box with relay transformer and leads, fibre parts for an insulating joint, rail bond for welding, and cable connecting box with leads.

in the open air. For a number of adjacent track circuits a common cabinet is used, in which the supply mains are available. A 2-wire armoured underground cable for each track circuit is laid down from this cabinet to a connecting box placed close to the track, where the cable ends and the cable wires are connected each to its rail by a bare copper wire welded or soldered to the rail. The relay transformers are fitted in cast iron boxes close to the track. The primary winding is connected directly to the rails by bare copper wires. From the secondary winding two wires are then first led to a cable distribution box common to several track circuits, from which a joint multicore cable leads to the signal cabin.

The length of the feed wires from the track transformers to the cabinet can without inconvenience vary considerably when constant current is used, as the current required in each case can be regulated within wide limits, both by selecting a suitable tap on the track transformer secondary and by using different impressed voltages. It has therefore met with no difficulty to assemble all the track relays in the signal cabin, which makes the whole arrangement simpler and more easily surveyed, and gives a higher efficiency and a quicker functioning of the track circuits than is possible with the track relays mounted in detached cabinets near the track and repeated by separate relays in the signal cabin.

Investigations regarding mutual induction in parallel conductors earthed at the ends.

By *G. Swedenborg.*

The problem of the mutual induction in parallel conductors earthed at the ends is of great theoretical and practical interest. It is not an infrequent occurrence that induced voltages of considerable magnitude may be caused in communication lines by earthing faults in power lines. As an example we may mention that a case recently occurred in Sweden where tensions of 2 000 à 3 000 volt were repeatedly generated from a power line in a bunch of parallel telephone lines. The cause was flash-overs to earth in the power line. The risk of such voltages occurring in lines of communication is obvious. The consequences in this case were fortunately limited to the blowing of some safety fuses and more or less protracted interruptions of communications. In any case it is of course important to be able to determine fairly accurately the effect of a certain inducing current, so that the risk can be ascertained and suitable steps taken. The mathematical treatment of the problem is rather complex, as the earth enters as part of the electromagnetically connected circuits. The secondary current phenomena appearing in the earth have thus a considerable effect, and are in their turn dependent on the electrical properties of the earth, of which little is known, at least at the depths here in question. To arrive at approximate formulæ of practical use for the computations, it is therefore necessary to have recourse to simplifying hypotheses.

Earlier, the return currents in the earth used to be considered concentrated to a line underneath the inducing line. If the depth of this line was chosen equal to the heigth of the power line above the earth's surface, far too small values of the mutual induction were obtained. When the return currents were assumed to be concentrated to a greater depth, however, it was established that this was not independent of the distance between the inducing conductor and the line in which the induction arose.

The results obtained from measurements in various parts of Sweden have indicated that an equivalent depth of several km. must be selected for the return current to obtain agreement between the measured and the computed values. We see thus that the electrical properties of the earth's crust at considerable depths should be of importance.

The formula given by Breisig in his wellknown work "Theoretische Telegraphie"

$$m = 2\ (\log \frac{2\,l}{a} - q) \cdot 10^{-4}\ H/\text{km},$$

where l = the parallel length
a = the distance between the conductors
q = a constant > 1,

was at one time used as a standard for the computations. The constant q was intended to replace the figure 1 in the expression for the mutual induction between two parallel single conductors without return conductor:

$$m = 2\ (\log \frac{2\,l}{a} - 1) \cdot 10^{-4}\ H/\text{km};$$ (l is supposed to be large in relation to a)

The object of introducing q was thus to make allowance for the effect of the return currents in the earth.

In practice, however, it was found that a very different q had to be selected in different cases in order to obtain agreement with the measured results. In Sweden the best agreement was generally obtained with $q = 2.5$ to 3.5.

In Germany it was found that very varying q-values had to be chosen in different places. In some instances a value as large as 7 had to be used. But the size of q affects the result of the calculation considerably as subtraction has to be made from a logarithmic term, the numerical value of which is fairly small. The formula could therefore hardly be considered practical for the pre-determination of the induced effect.

When the International Committee for long distance telephony (CCI) was formed in 1924, the problem of disturbances in communication lines from power lines was made a special group among the questions to be dealt with. For computing the induction from a conductor earthed at its end, the formula

$$m = \frac{0.004}{\sqrt{a}} \ H/\mathrm{km}$$

was suggested, where a = the distance between the conductors in metres (the maximum value of the distance at which the formula should be valid was fixed to 1 000 metres).

The measuring results in Sweden as a rule indicated 3 to 4 times larger induction than that given by this formula. The method could therefore not be considered reliable. As regards the dependence on the distance between the conductors, the formula further gave an incorrect picture of the actual conditions, as, when the conductors are close together, the mutual induction is not in reality reduced as rapidly with the distance between the lines as indicated by the root expression, while at great distances conditions are reversed.

In the measuring method so far described, no consideration has been given to the dependence on the frequency. According to recent researches, however, the mutual induction is a function of the frequency also. A better basis for computations had to be found by other means. In some investigations published by Breisig in 1925, the induction effect from a conductor of finite length was computed on the assumption that the conductor was totally surrounded by a homogeneous medium of a certain electrical conductivity. The case presents a certain analogy with that of a conductor, surrounded by a metal cover, for which it is desired to compute the compensating effect of the current in the cover in case of induction effects from the outside. The problem of the compensating effect of cable-cover currents is as a matter of fact supposed to have suggested Breisig's new method of computation. Pleijel has also discussed the problem of compensation in cables in the September number of "Teknisk Tidskrift" 1923 and in a separate detailed treatise printed in 1925.

An investigation of the subject by Rüdenberg was published at about the same time as Breisig's paper. The inducing conductor is here assumed to be of infinite length and lying in the plane of the earth surface surrounded by a ditch of semicircular section, the radius of which is supposed to imitate the height above ground of the conductor. This arrangement is assumed in order to simplify the calculations relatively to the case of the inducing conductor being at a certain height above the ground. Assuming the magnetic field to be concentric to the conductor, Rüdenberg computes the earth currents, and from those the EMF:s arising at various distances from the inducing conductor.

The results obtained by Breisig and Rüdenberg indicate that the mutual induction ought to be highly dependent on the frequency. The formulæ show that the induction can be expressed as a function of a parameter $a\sqrt{\sigma\nu}$, where a is the distance between the conductors, σ the earth's conductivity, and ν the frequency.

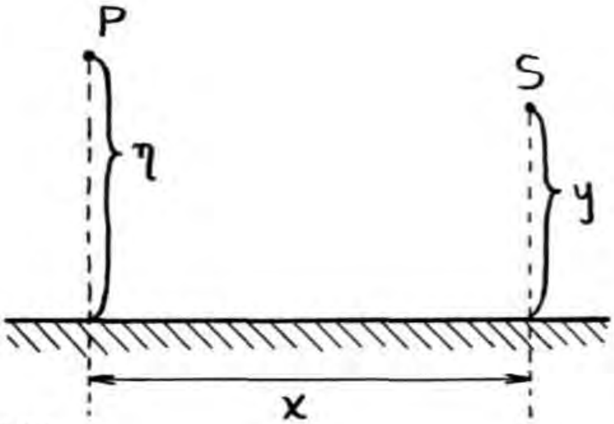
The mutual induction obviously decreases with increasing distance between the conductors. The nature of the parameter immediately shows that an increase of either conductivity or frequency should also have a reducing effect on the induction.

That the induction coefficient actually is highly dependent on the frequency was experimentally proved by a series of systematic measurements undertaken in 1925 by Siemens & Halske at Döberitz, the military training ground in the neighbourhood of Berlin. A number of test lines, 5 km. long and various distances apart (maximum 1 km.) were built here, and the induction was determined at frequencies varying from $16^2/_3$ to 2 000.

The calculations of Rüdenberg give a slightly higher induction effect than Breisig's. Both methods, particularly Breisig's, give a too rapidly diminishing induction when the distances between the conductors are increased, and have in recent years been superseded in the CCI by calculations proposed in two papers by Pollaczek, published in 1926 and 1927.

In these calculations, the inducing conductor is assumed to be of infinite length, and the attenuation in the line is disregarded. In a recently published paper, Pollaczek has shown that to disregard the changes of amplitude and phase angle along the line has no practical effect on the result at low and speech frequencies.

The respective media above and below ground are assumed to be homogeneous. The magnetic field generated by the current in the inducing conductor will cause eddy currents in the earth, originating secondary magnetic fields. Pollaczek



R 2074

Symbols: $0, \eta$ = coordinates of the primary line (P).
x, y = coordinates of the secondary line (S).

$k = e^{\frac{3j\pi}{4}} \sqrt{4\pi\sigma\omega}$; σ = conductivity of the earth; $\gamma = 1{,}7811$ (The Bessel constant).

a) for small distances:

$$m = \left\{2 \log \frac{2}{\gamma |k| \sqrt{x^2 + (y - \eta)^2}} + 1 - j\frac{\pi}{2} - \frac{4jk(y+\eta)}{3}\right\} 10^{-9} H/\text{cm}; \text{ Conditions: } |k| \sqrt{x^2 + (y+\eta)^2} < 0{,}5;$$

b) for medium distances:

$$m = \left\{-\frac{4}{k^2 x^2} + 2j\pi \frac{H_1^{(1)}(|kx|)}{|kx|}\right\} \cdot 10^{-9} = \left\{-\frac{4}{k^2 x^2} + 4\frac{kei^1(|kx|) - j \cdot ker^1(|kx|)}{|kx|}\right\} 10^{-9} H/\text{cm}; \text{ Conditions: } \begin{cases} |kx| < 3; \\ \frac{y+\eta}{x} < 0{,}05; \end{cases}$$

c) for large distances:

$$m = \left\{2 \log \sqrt{\frac{x^2 + (y+\eta)^2}{x^2 + (y-\eta)^2}} - \frac{4}{k^2} \cdot \frac{x^2 - (y+\eta)^2}{[x^2 + (y+\eta)^2]^2} + 4jk(y+\eta)\left(\frac{1}{k^2(x^2 + (y+\eta)^2)} + \frac{3x^2 - (y+\eta)^2}{k^4(x^2 + (y+\eta)^2)^3}\right)\right\} 10^{-9} H/\text{cm};$$

$$\text{Conditions: } |k| \sqrt{x^2 + (y+\eta)^2} > 3{,}5;$$

Fig. 1. Computation, according to Pollaczek, of the mutual coefficient in two parallel single conductors earthed at the ends.

gives differential equations for the electric and magnetic fields and, making certain simplified assumptions, finds by the solution of these equations an expression for the inducing EMF as a function of various influencing quantities. From this the mutual induction coefficient is computed, which is a complex quantity dependent on the frequency, the distance between the conductors, and the conductivity of the earth. In fig. 1, we give some approximate formulæ deduced by Pollaczek for the mutual induction in two parallel air lines.

The expression kx thus proves to be an essentially determinant parameter (analogous to the conclusions of Breisig and Rüdenberg). To facilitate computation, m might therefore conveniently be graphically given as a function of the distance, multiplied by the square root of the product of conductivity and frequency.

At large distances the induction will diminish, according to the Pollaczek computations, in inverse ratio to the square of the distance. When the inducing line is closer, however, the induction will diminish considerably more slowly with the distance.

At about the same time as Pollaczek, Carson also dealt with this problem with similar results. The theory is therefore frequently called the Pollaczek-Carson method.

Computations have since been made by other investigators, some of whom (e. g. Mayr) have assumed that only a certain layer of the earth's crust is conducting.

A practical verification of the Pollaczek computations was considered of great interest. Two extensive series of measurements were carried out in Germany in 1928, one in an Oldenburg fen district, the other in a limestone district at Münsingen near Ulm in Würtenberg. In both places, 5 km. long test lines were built at different distances apart (up to 3 km.). As at Döberitz, measurements were taken at frequencies varying from

$16^2/_3$ to 2 000. Both amplitude and phase angle of the mutual induction were measured by means of excellent instruments and apparatuses fitted in special measuring cars. The measuring equipment had been arranged by the German Telephone Administration in conjunction with Siemens & Halske. The same appliances were later used for the Swedish Skillingaryd tests and are described in detail below.

The results obtained in Germany showed that if, to verify the Pollaczek formulæ, the conductivity according to the observed induction values were computed, constant values were not obtained. Although the conductivity proved to be approximately the same for a given measuring frequency and varying distances between the lines, the conductivity was considerably reduced with rising frequency when varying frequencies and constant distance between the lines were used. The explanation was thought to be that at higher frequencies the earth currents are forced to go nearer the surface, where the conductivity may conceivably be worse than at greater depths. To allow for this, it was suggested that the conductivity should be assumed to be a function of the frequency, and the best agreement was then obtained by assuming inverse proportionality to the square root of the frequency:

$$\sigma = \frac{c}{\sqrt{\nu}}$$

The CCI has recently choosen the function

$$\sigma = 1{,}5 \cdot 10^{-12} \cdot \frac{1}{\sqrt{\nu}} \text{ c. g. s.}$$

for the conductivity, and has thus arrived at the standard curves for mutual induction given in fig. 17 (the fulldrawn curves). The coefficient in this expression has been determined on the basis of the results of the German measurements.

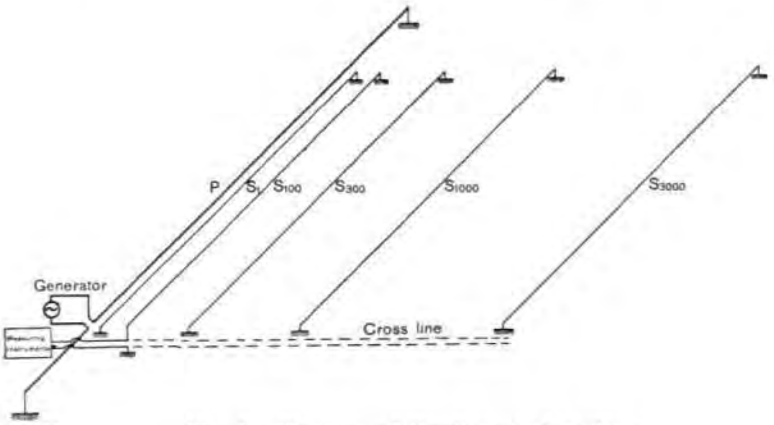
When checking the results of measurements in Sweden by the Pollaczek formulas, the computed conductivity has proved notably low. The mutual induction in this country has in most cases proved to be several times larger than that computed by the CCI curves. The differences are so apparent that a closer systematic investigation was considered justified. It is supposed that the general rocky nature of this country causes a particularly high induction effect. In the spring of 1930 it was decided to make systematic measurements in some convenient place in Sweden under the auspices of CMI, and with test lines and measuring appliances identical with those used in the German measurements in 1928.

A locality had then to be found where test lines might conveniently be put up at such a distance from any power lines that no disturbing influences sufficient to interfere with the measurements need be feared. Attention was directed to the shooting range at Skillingaryd, a place situated 40 km. south of the town of Jönköping. The Skillingaryd range at first proved to be exposed to strong influence from a 3-phase net, although there was only a local 3-kV direct generator-fed power line in the neighbourhood, the strength of which was only a few hundred kW. Fortunately it proved possible practically to eliminate the disturbances by such simple means as breaking the earthing resistance of the generators' zero point in the power station. An example of the significance of the zero-point connexion in the power lines for the disturbing effects on parallel telephone lines was thus provided.

Fig. 2. The lay-out of the test lines at Skillingaryd.

The test lines were put up across the field as shown in fig. 2. The five parallel rows of poles were made perfectly straight. The primary inducing line was put up furthest to the west on ordinary telephone poles. The line consisted of two 3 mm. copper wires placed close together and attached to insulators on hooks. The object


NORGE
SVERIGE
FINLAND
OSLO
JÖSSEFORS
ARVIKA
SÄFFLE
GÄVLE
UNTRA
VÄSTERÅS
ENKÖPING
ÖREBRO
STOCKHOLM
MOHOLM
TROLLHÄTTAN
GÖTEBORG
JÖNKÖPING
SKILLINGARYD
VISBY
MAJENFORS
LANDSKRONA
KØBENHAVN
MALMÖ
TRÄLLEBORG
DANMARK
Power lines
Telephone lines
Border between Sweden and neighbouring countries
0
50
100
150
200 KM.



R 2076 Fig. 3. Diagram of the lines and earths.

of selecting two parallel-connected wires was to reduce the resistance. One metre below this line the first secondary line of 1.5 mm. bronze wire was put up. At various distances (100, 300, 1 000 and 3 000 metres respectively) from the primary line, four 1.5 mm. bronze wires were put up on pole material, kindly supplied by the Swedish Field Telegraph Corps. The primary line was 7 km. and all the secondary lines 5 km. in length. This was done in order to avoid, if possible, the voltage drop of the earth return current of the primary line influencing the measurements of the induced voltages in the secondary line. The two extra lengths of line (1 km. at each end), however, subsequently proved too short for this purpose. The return currents in the earth caused potential differences between the earths of the secondary lines, which were particularly noticeable in the results at low frequencies. The only way to avoid this would have been to make the primary line considerably longer which, however, would have involved considerable expenditure, particularly as very heavily wooded ground beyond the shooting range would then have been entered. When judging the measuring results, it now became necessary to make allowances for the effect of the earth potentials caused by the return currents at low measuring frequencies.

A cross line was put up at right angles to both the primary and secondary lines, as shown in fig. 2. The place for the measurements was situated at the point where this cross line reached the primary line. The cross line, and ordinary twisted 2-wire telephone line of 1.5 mm. bronze wire, served as an auxiliary line between the measuring place and the secondary circuits. A diagram of the connexions used for this purpose is given in fig. 3.

The appearance of the primary pole line is seen in fig. 4. Fig. 5 shows the southern end of the secondary line 100 m. away from the primary line. The picture also shows one of the poles of the cross line. Special wires were arranged

R 2077 Fig. 4. The primary pole line.

R 2078 Fig. 5. The southern end of the 100 m. line. On the cross-line pole seen in the foreground, taps and leads were arranged to facilitate connexions.

on such poles in order to facilitate the different connexions desired.

A resistance of less than 25 ohms was from the outset considered desirable in each of the primary line earths, and of 50 ohms in each secondary line earth. All the earths consisted of star-shaped buried hoop iron (6-rayed star). For a 25 ohm earth about 600 m. of hoop iron were needed, for a 50-ohm earth about half that quantity. A depth of 25 or 50 cm. proved to give approximately the same result, and they were therefore buried only 25 cm. deep. As an experiment, two lengths of hoop iron were placed some distance apart in the same trench, to reduce if possible the length of the star rays to half, but this method did not have the desired effect on account of the diminished area occupied by the star, and was therefore abandoned.

Hoop iron was also used for earths in the earlier German measurements. This was placed in a circular ring with radiating arms. For a given earth resistance, only about $^1/_{10}$ of the length of hoop iron needed at Skillingaryd was required. This may be regarded as an indirect sign of the difference in earth conductivity.

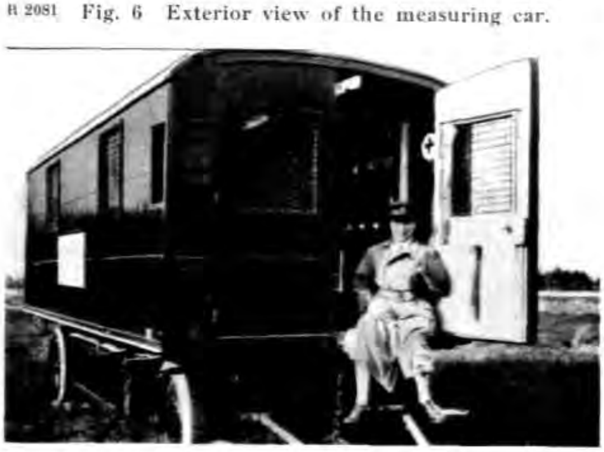
Fig. 5 shows the hoop iron earth at the southern end of the 100 m. line projecting from the ground.

Limitation of the earth resistance was necessary on account of the exactitude required in the measurements.

In connexion with the earth resistances, we might mention that the surface soil at Skillingaryd consists chiefly of sand. Its depth is not known, but is probably comparatively small, as the rocky ground is visible here and there on the range. The rock is gneiss. Skillingaryd lies a few miles west on the boundary line between the granite of eastern Sweden and the gneiss of western Sweden. The geological conditions are of course important, as according to the theories the conductivity of the ground plays an important role in the mutual induction.

As mentioned above, the measuring equipment was the same that was used for the 1928 measurements in Germany. The instruments were mounted in two cars specially adapted for this purpose, and exterior views of these are shown in figs. 6, 7 and 8. In one car (the measuring car), the actual measuring instruments were mounted, and

R 2081 Fig. 6 Exterior view of the measuring car.

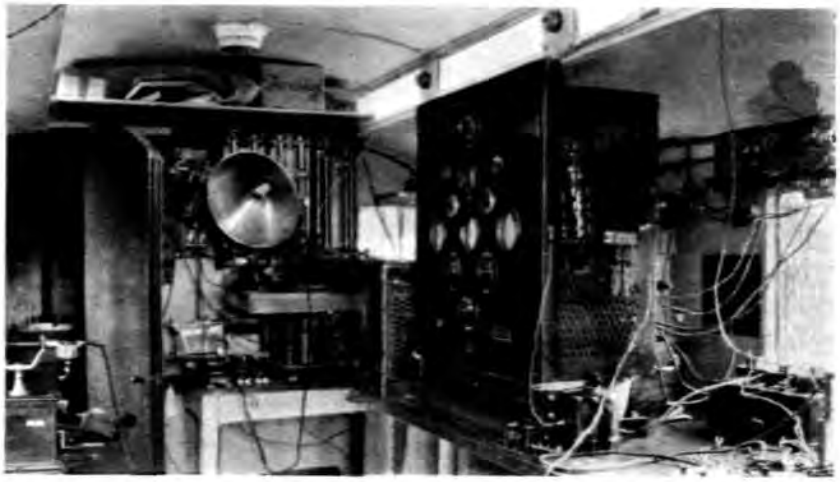


R 2080 Fig. 7. Exterior view of the machine car. Mr. Sterner, who had charge of the building of the test lines, is sitting on the step.

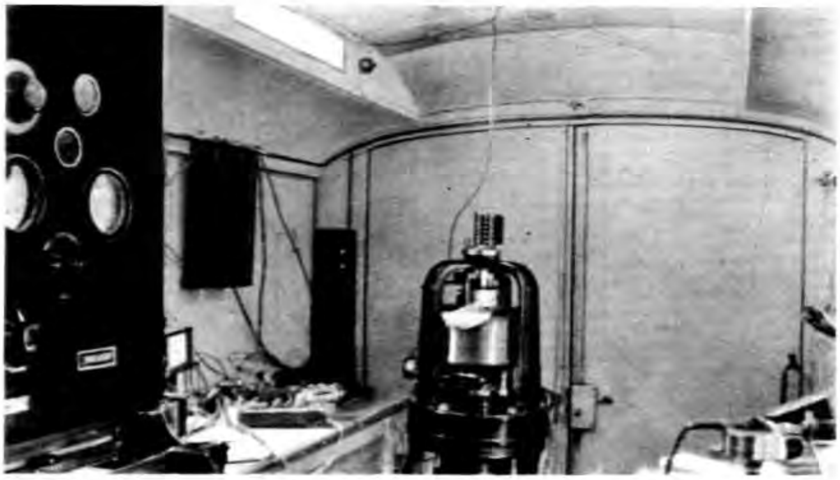
R 2079 Fig. 8. Transport of a car from the railway station to the place for the measurements.

a powerful amplifier was also fitted here to give great amplitude to the inducing voice-frequent currents. The amplifier, with a push-pull coupling, could give a maximum output of c. 200 watt. Figs. 9 and 10 show the interior of this car.

In fig. 10 a Franke-machine, used for measurements at frequencies in the 150—2 000 range, is seen in the centre in front of the door.



R 2082 Fig. 9. Interior view of the measuring car. To the left is the entrance to the dark room, and in the centre the 200 watt amplifier. The oscillograph is placed just behind the electrical radiator.



R 2083 Fig. 10. Interior of the measuring car. The Franke-machine is standing in front of the doors.

R 2084 Fig. 11. Interior of the machine car. In the background the charging set for the 230 volt battery can be seen.

The various sources of current and the instrument board of the amplifier were mounted in the second car (the machine car). The primary current supply consisted of a 220 volt battery of c. 100 amp. hours' capacity, placed in two large boxes underneath the car. The battery was charged by a set comprising a generator coupled to an internal combustion motor. This set is seen in fig. 11. The amplifier instrument board is visible on the left of fig. 12. The amplifier filament current consumption was c. 30 amp., and the anode voltage 1 500 volt. Filament current and anode voltage were obtained from two special motor generators fed by the storage battery.

The inducing alternating currents within the $16\,^2/_3$—300 frequency range were taken from a pair of generators, coupled to motor generator to obtain a convenient regulation of the speed. The one A. C. generator was used for the $16\,^2/_3$—100 cycle range, the other for the 100—300 cycle range.

No external electrical power supply was thus required, which was an obvious advantage considering the risk of disturbing influences.

The two cars were placed 50 m. apart so that the noise and vibration from the machine car should not disturb the observations in the measuring car.

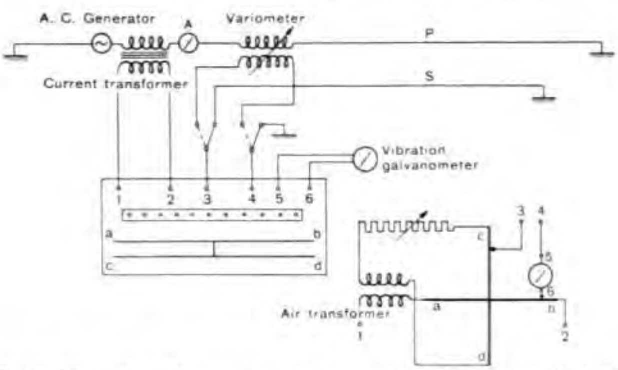
All measurements were made as compensation measurements. For the lower frequencies (up to 300 cycles) two different methods were used. In the one Geyger's compensator (fig. 13) was used. Two vibration galvanometers were alternatively used as zero instruments, one of which was a

R 2085 Fig. 12. Interior of the machine car. To the left is the instrument board of the two motor generators belonging to the amplifier equipment.

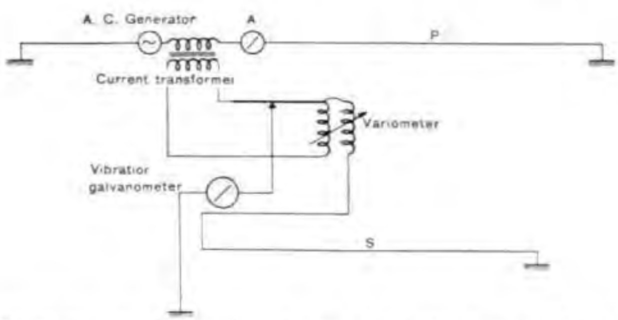
needle galvanometer, electromagnetically tuned according to Schering and Schmidt (for the lowest frequencies up to and including 140 cycles), the other a string galvanometer, mechanically tuned according to Moll (for the remaining frequencies up to and including 300 cycles).

The diagram shows how by means of an air transformer, the secondary circuit of which contained an ohmic resistance of such magnitude that the transformer will act with practically no load, two currents are obtained in the two bridge-wires, the phases of which are mutually deflected 90°. The constants are such that at a current of 0.5 amp. in the primary winding of the air transformer a voltage drop of 1 mV per cm. is obtained in each of the two bridge wires, which are united in the centre. In compensation measurements this arrangement may thus be regarded as a kind of voltmeter by which the voltage sought is conveniently obtained, divided into its components. Each bridge wire is 40 cm. long, and the amplitude of the voltage which can be compensated will obviously be rather limited. The various secondary lines were therefore connected to a potentiometer, by which only a portion of the voltage sought was taken out for compensation. The ratio of the current transformer was selected so that half an ampere was obtained in the secondary circuit from one ampere in the primary line. On account of the low impedance of the compensator arrangements, the transformer is practically shortcircuited, and the phase angle between the currents will therefore be almost 180°. To check this, the voltage from a variometer connected as shown in fig. 13 was also compensated.

In the second method, the Larsen compensation appliance was used, fig. 14. The voltage, adjustable as to amplitude and phase angle, opposing which the voltage sought is connected, is here obtained by means of a bridge wire and a variometer. The same galvanometers as before were used as zero instruments. The use of two



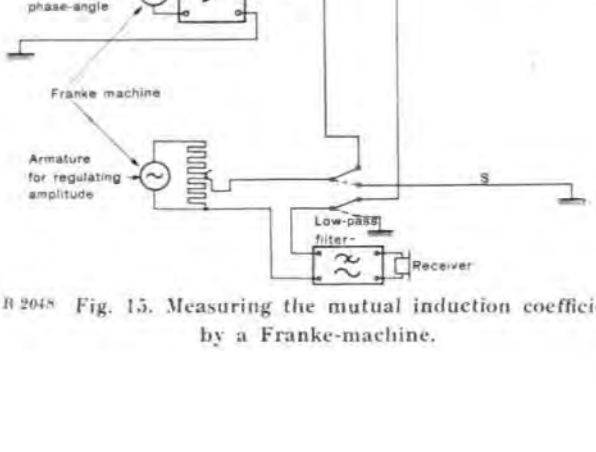
R 2086 Fig. 13. Measuring the mutual induction coefficient by a Geyger Compensator.



R 2087 Fig. 14. Measuring the mutual induction coefficient by a Larsen compensator.

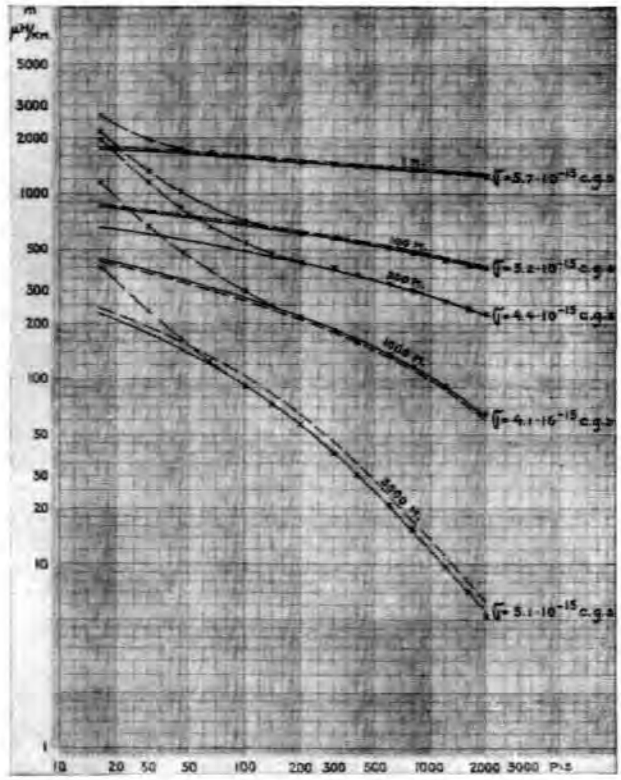
measuring methods for one and the same frequency range gave good control of the results.

For audio-frequencies, when an ordinary telephone receiver could be used as zero instrument, the connexions shown in fig. 15 were used. A Franke-machine supplies the current here. This machine has two mutually alike armatures, the "amplitude" armature and the "phase" armature, driven by a D. C. motor and revolving at an adjustable speed in a multi-polar field. By means of a graduated dial, the "phase" armature can be adjusted relatively to the "amplitude" armature, so that any arbitrary phase angle between the generated voltages can be obtained. The amplitude armature may be raised out of or lowered into the magnetic field, by which means the voltage amplitude can be regulated. An arrangement of this description should obviously be particularly suitable for these measurements. The primary line was fed from the phase armature during the test and the amplifier — indicated in the diagram on fig. 15 — was connected for measurements on the 1000-m. and 3000-m. lines (a powerful inducing current being essential in this case for the exactitude of the measurements). The compensating voltage was taken out from the potentiometer connected to the amplitude armature. In front of the telephone receiver, which was used as a zero indicator, a low-pass filter was introduced to remove the machine harmonics, which would otherwise have disturbed the listening. The phase angle of the induced voltages relatively to the inducing current could not be determined from that angle alone to which the two armatures were mutually adjusted, as the angle of the primary line current relatively to the voltage generated in the phase armature is not exactly known. For this reason a standard



R 2048 Fig. 15. Measuring the mutual induction coefficient by a Franke-machine.

The mutual induction coefficient in parallel conductors at Skillingaryd.



R 3014 Fig. 16. Results of the Skillingaryd measurements, compared with the values computed according to the Pollaczek formulæ.

× Measured values

——— Values computed on the Pollaczek formulæ, with earth conductivity selected to give best agreement with the mesured values.

— — — Values computed acc. to the Pollaczek formulæ, with earth conductivity fixed at 4.4.10—15c. g. s.

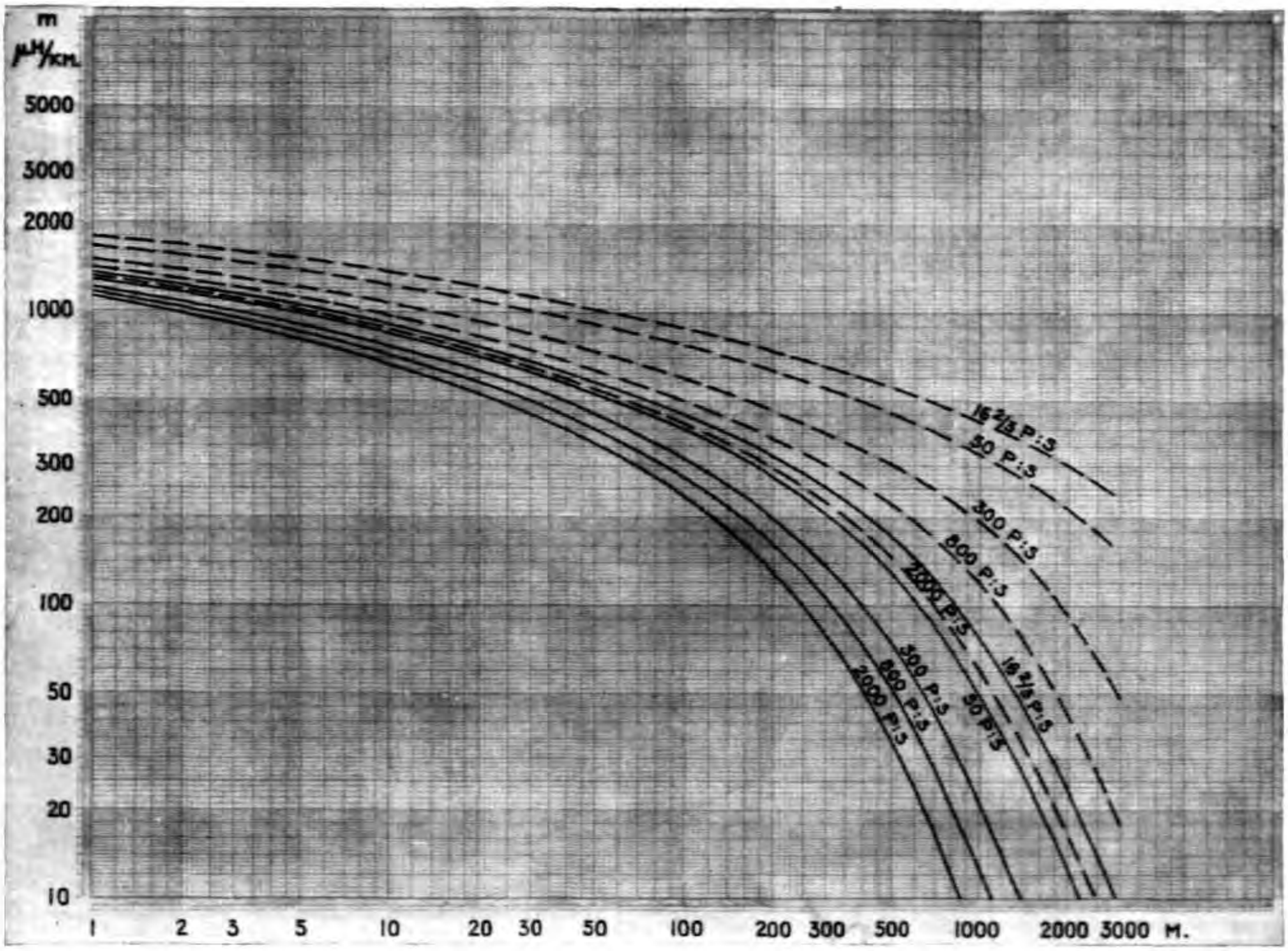
The distance between the lines is given at each curve.

Table 1.

Measured mutual induction values, in μ H/km at various line distances and pequencies.

Frequencies	Mutual inductance at the distance				
	1 m	100 m	300 m	1000 m	3000 m
$16^2/_3$	2617	2147	1959	1186	396
30	1950	1317	1160	692,5	231
45	1740	1007	850	495,5	166
65	1643	842	671	382,5	125
100	1583	728	549	300,0	92,5
140	1554	674	487	253,8	74,0
200	1514	626	439	219,8	58,2
300	1483	581	395	185,0	41,0
400	1453	556	366,4	162,6	30,4
600	1418	519	331	136,6	20,5
800	1382	487	299,7	117,6	15,4
1200	1348	447	261,7	92,8	9,73
1600	1327	423	237,9	77,2	7,06
2000	1316	407	218,2	65,3	5,24

Comparison between the results of the Skillingaryd measurements and the C. C. I's values.



R 3013

Fig. 17. Comparison between the results of the Skillingaryd measurements and the CCI values.
— — — Skillingaryd measurement. ———— CCI-values.

Table 2.
The quotient between the Skillingaryd results and the CCI-values at various periodicities and line distances.

	1 m.	10 m.	100 m.	300 m.	1000 m.	3000 m.
$16^{3}/_{4}$ p:s	1,32	1,49	1,93	2,62	5,54	25,7
50 »	1,29	1,45	1,92	2,67	6,47	28,9
300 »	1,24	1,40	1,87	2,80	8,50	22,2
800 »	1,21	1,34	1,83	2,81	9,00	13,2
2000 »	1,10	1,29	1,78	2,78	8,10	7,6

resistance was connected in series with the primary line, and the voltage over this resistance was separately compensated. The angle sought was then obtained as the difference between the angles observed in the two compensations.

The full series of measurements comprised the frequencies $16^{2}/_{3}$, 30, 45, 65, 100, 140, 200, 300, 400, 600, 800, 1200, 1600 and 2000. As in the German measurement series, both 50- and 150-cycle frequencies were avoided on account of the risk of interference with possible disturbances from power lines in the neighbourhood.

The results of the measurements are given in the diagrams figs. 16 and 17, and in the Tables.

On the curve sheet, fig. 16, the observed values have been marked by crosses. For every line distance, that earth conductivity has been computed which gives the best agreement between the values measured and the voltages obtained by the Pollaczek formulas. It was then noted that excellent agreement could be obtained at the higher frequencies, and that the values which had to be used for earth conductivity did not differ much in the 5 line distances. The computed values are given in full-drawn curves. At lower frequencies the measured values are dis-

Table 3.

Measured values of induced voltages in the secondary lines, expressed in volt per 1 amp. in the primary line.

Frequency	Induced voltage at distance				
	1 m	100 m	300 m	1000 m	3000 m
$16^2/_3$	1,37	1,12	1,03	0,62	0,199
30	1,84	1,24	1,09	0,65	0,218
45	2,46	1,43	1,20	0,70	0,235
65	3,36	1,72	1,37	0,78	0,255
100	4,97	2,29	1,73	0,94	0,291
140	6,82	2,96	2,14	1,12	0,325
200	9,51	3,93	2,76	1,38	0,365
300	14,0	5,47	3,73	1,74	0,385
400	18,3	6,99	4,61	2,05	0,382
600	26,7	9,77	6,24	2,58	0,386
800	34,7	12,24	7,52	2,96	0,387
1200	50,8	16,85	9,87	3,50	0,367
1600	66,7	23,27	11,95	3,88	0,355
2000	82,7	25,55	13,72	4,10	0,329
	1,23	1,21	1,20	0,675	0,202

Table 4.

Values of the phase angle observed between the inducing primary line current and the induced voltages in the secondary lines.

Frequency	Line distance				
	1 m	100 m	300 m	1000 m	3000 m
$16^2/_3$	144° 35′	163° 35′	168° 40′	171° 10′	174° 0′
30	127° 50′	152° 20′	159° 30′	164° 10′	169° 0′
45	118° 25′	142° 20′	151° 10′	158° 0′	166° 0′
65	111° 20′	133° 30′	143° 20′	152° 0′	164° 40′
100	105° 25′	124° 55′	134° 40′	145° 25′	164° 0′
140	102° 45′	119° 45′	129° 15′	142° 40′	163° 30′
200	100° 45′	116° 15′	125° 30′	140° 0′	166° 15′
300	99° 25′	113° 55′	124° 10′	140° 0′	173° 50′
400	99° 0′	113° 25′	123° 55′	141° 40′	177° 40′
600	98° 40′	113° 30′	125° 10′	144° 50′	183° 40′
800	98° 35′	114° 25′	127° 35′	150° 30′	186° 40′
1200	98° 45′	116° 0′	131° 40′	159° 35′	192° 0′
1600	98° 50′	117° 45′	135° 25′	166° 50′	195° 0′
2000	99° 10′	119° 5′	139° 20′	173° 10′	196° 40′

tinctly higher than the computed ones. The reason for this must be that at low frequencies the earth potentials of the return current, in addition to the pure induction voltages, play an important role. That this is so is distinctly indicated by Table 3, giving the phase angles measured between induced voltage and inducing current. Instead of approaching 90° as in Table 6

Table 5.

Earth conductivity, computed from the mutual induction observed, and expressed in 10^{-15} c. g. s.

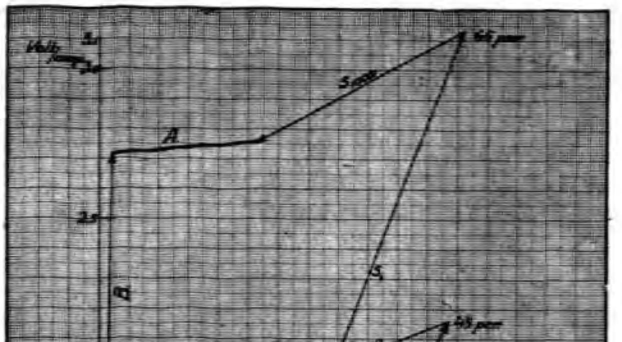
Frequency	Line distance				
	1 m	100 m	300 m	1000 m	3000 m
$16^2/_3$	—	—	—	—	0,76
30	0,5	—	—	0,17	2,7
45	2,9	0,46	0,28	0,83	4,0
65	5,5	1,7	1,1	2,0	5,0
100	6,4	3,6	2,5	3,2	5,4
140	5,6	4,4	3,5	3,9	5,3
200	6,2	5,0	4,1	4,1	5,2
300	5,8	5,2	4,3	4,3	5,2
400	5,6	5,1	4,4	4,3	5,2
600	5,4	5,2	4,3	4,1	5,0
800	5,8	5,5	4,5	4,0	4,9
1200	5,6	5,5	4,5	4,0	4,9
1600	5,2	5,4	4,6	3,9	5,0
2000	4,8	5,2	4,7	4,0	5,3

Table 6.

Mutual induction in μ H/km, computed by the use of an average value of earth conductivity suitable to each line-distance (selected to give the best agrement with the values observed at higher frequencies).

Frequency	Line distance				
	1 m	100 m	300 m	1000 m	3000 m
	Earth conductivity value used in the computation. In 10^{-15} c. g. s.				
	5,7	5,2	4,4	4,1	5,1
$16^2/_3$	1770	863	669	446	226
30	1710	805	610	390	180
45	1670	768	570	351	149
65	1635	731	536	319	123
100	1595	691	495	279	95,5
140	1560	660	465	250	76,2
200	1500	620	431	221	59
300	1480	581	393	189	42
400	1450	555	366	166	31,0
600	1415	519	329	136	20,2
800	1380	490	301	117	14,7
1200	1345	453	265	91,0	9,36
1600	1320	427	241	75,0	6,83
2000	1300	405	222	64,2	5,40

(which is computed according to Pollaczek's theory), the phase angle rises considerably with reduced frequency. To obtain proof that the earth potential of the return current actually has this effect, a special measurement was made, when the induced voltage was measured in a



R 2089 Fig. 18. Vector diagram of the measured voltages in the 1-metre line, the 1000-metre line and the loop.

S_1 = 1-m line values; S_{1000} = 1000-m line values; B = loop values; A = the resultant of the three values observed.

Table 7.

Computed phase angle values between inducing current and induced voltages, when the uniform earth conductivity value 4,4 · 10⁻¹⁵c. g. s. is used.

Frequency	Line distance				
	1 m	100 m	300 m	1000 m	3000 m
16²/₃	95° 0′	100° 15′	103° 35′	110° 20′	124° 25′
30	95° 10′	101° 0′	104° 55′	113° 15′	130° 10′
45	95° 20′	101° 35′	105° 50′	115° 5′	135° 10′
65	95° 25′	102° 5′	106° 45′	117° 30′	139° 55′
100	95° 30′	102° 45′	108° 10′	121° 0′	147° 0′
140	95° 40′	103° 20′	109° 25′	123° 55′	152° 30′
200	95° 50′	104° 10′	111° 10′	126° 50′	158° 10′
300	96° 0′	105° 0′	112° 35′	131° 30′	165° 30′
400	96° 5′	105° 50′	113° 50′	134° 50′	171° 10′
600	96° 15′	106° 45′	116° 50′	140° 30′	177° 20′
800	96° 25′	107° 50′	118° 30′	145° 0′	180° 5′
1200	96° 35′	109° 5′	121° 40′	151° 45′	181° 45′
1600	96° 45′	110° 15′	124° 5′	156° 35′	181° 20′
2000	96° 50′	111° 20′	126° 10′	160° 15′	180° 40′

rectangular loop consisting of the 1 metre line (S_1) and the 1000 m. line (S_{1000}) and cross lines put up at right angles to these lines to close the loop at the ends, (for this special purpose a 1 km. long tarred wire was laid out across country at the north end.) This loop was thus insulated

Table 8.

Observed induction and resistance values in the 7 km primary line, earthed at the ends.

Frequency	Induction (μ H)	Resistance (ohm)
100	—	55,0
140	—	55,1
300	17,00	55,4
300	16,90	55,9
400	16,85	56,3
600	16,80	58,1
800	16,70	59,5
1200	16,50	63,6
1600	16,55	67,9
2000	16,50	71,2

Table 9.

Observed mutual induction values, in μ H/km, between the primary line and a rectangular loop consisting of the 1-m line, the 1000-m line and cross lines between their ends.

Frequency	Mutual induction	Angle
16²/₃	1331	90° 43′
20	1329	90° 44′
45	1329	90° 44′
65	1326	90° 50′
100	1330	91° 0′
140	1330	91° 30′
200	1325	92° 0′
300	1310	92° 0′
400	1305	92° 0′
600	1305	92° 15′
800	1302	93° 15
1200	1304	94° 15′
1600	1304	94° 25′
2000	1312	95° 20′

from earth. If the potential difference between the earths of either line S_1 and S_{1000} were without significance, a voltage vector diagram of the values observed in S_1, in S_{1000} and in the loop, would form a triangle. But this was not the case, as we see in fig. 18, where vector diagrams are given for the voltages at the four lowest measuring frequencies. The three vectors give a resultant which must be caused by the difference in earth potential. It is very striking that the resultants are of almost the same size and direction as the total potential difference, measured by direct current, of the two cross lines.

In view of this we may assume that the full-drawn curves of fig. 16 give a correct picture of the induction even at low frequencies. When drawing a vector diagram of the voltages thus obtained — with phase angles computed according to the theory (Table 6) — the three vectors of S_1, S_{1000} and the loop respectively, actually form closed triangles, which confirms that the extrapolated curves may represent the true values.

An average value of the earth conductivity was computed for the five line distances. In doing this, the values for the 3000 m. line were first corrected, as the distance between the lines in this case is not small in comparison to the length of line. Pollaczek has given the necessary correction as the quotient of the diagonal of the rectangle of parallelism and the length of the paralellism. After making this correction, the average conductivity value for the 3000 m. line was again computed, and subsequently the final average value of all the five lines was determined. This value was $4{,}4 \cdot 10^{-15}$ c. g. s. In fig. 16, dotted curves indicate the induction coefficients obtained for the several distances when using this uniform conductivity. It will be noticed that these dotted curves are very close to the full-drawn.

When plotting the dotted curves in fig. 17, the uniform value of the earth conductivity has been used. The C C I standard curves have also been plotted in the same diagram for comparison.

The great divergence between the Skillingaryd curves and the C C I curves is very striking. At $16\,^2/_3$ cycles and 3 km. line distance, for instance, the induction observed at Skillingaryd is about 20 times larger than in central Europe. This in its turn means that in Sweden far greater disturbing effects must be expected from power lines in parallel communication lines than in the plains of the Continent. To attain an equal freedom from disturbances, more rigorous steps are consequently required in Sweden. This circumstance is of course economically unfavourable.

The Skillingaryd measurements further show that Pollaczek's theory at least in one instance has been verified without giving the earth conductivity as a function of the frequency. As appears from the above, the earth conductivity then proved to be several times smaller than the values observed in the German measurements. In the same connexion it is of interest that analogous systematic induction measurements have in recent years been made at different places in the United States. Using Carson's computations, values of earth conductivity slightly exceeding the C C I values were then observed. The American measurements indicate that, at least in the places where tests have so far been made, the conditions are similar to those in Germany.

The question might possibly be raised whether the measurements at Skillingaryd may be considered representative of Swedish conditions, or

Date	Power line	Telephone line	Part of Sweden, where the parallelism is	Length of the parallelism	Inducing current	Measured voltage	Computed voltage	
							According to the CCI-curves	According to the Skillingaryd tests
Febr. 1929	Stockholm—Untra	Stockholm—Gävle	Eastern Sweden	132 km	5,4 amp.	29 volt	5.5 volt	34 volt
March 1929	Majenfors—Malmö—Trälleborg	Malmö—Landskrona	Southern Sweden	31 km	30 amp.	48 volt	83 volt	180 volt
March 1929	Majenfors—Malmö—Trälleborg	Malmö—Landskrona	Southern Sweden	27 km	30 amp.	11 volt	28 volt	91 volt
May 1930	Jössefors—Säffle	Arvika—Säffle	Western Sweden	60 km	8 amp.	91 volt	19 volt	65 volt
March 1931	Trollhättan—Västerås	Enköping—Örebro	Central Sweden	87 km	97 amp. at Västerås* 51 amp. at Örebro*	340 volt	20 volt	235 volt

* Capacity current at an arranged earth fault in one phase at Västerås. The physical circuit was then set for a break at Moholm (204 km. from Västerås).

R 2085 Fig. 19. Part of the laboratory compartment ni the State Railway dynamometer car.

The abovementioned measurement of induced voltage from the power line Trollhättan—Västerås was made on March 15th this year in connexion with certain experiments arranged by the Board of Waterfalls to test the quenching of arcs when using Petersen coils in the power line. Artificial flash-overs from one phase to earth were then arranged at Västerås. During the fraction of a second while the arc lasted, a powerful capacity current flowed in the faultless phases. This current caused strong induction in the parallel telephone and telegraph lines, although the average distance between these lines and the power line is several kilometres. The results showed that the induced voltage in the Enköping—Örebro communication lines was no less than 340 volt. On account of its brief duration, this voltage could not be observed by ordinary A. C. instruments, and it was therefore necessary to use an oscillograph. The State Railway Administration "Dynamometer car", the equipment of which includes an oscillograph, was kindly lent for this purpose. The car was placed near the Örebro station, close to a test pole where communication lines suitable for the measurements were available.

Figs. 19 and 20 are photographs of the laboratory compartment of the dynamometer car, taken during the measurements on March 15th.

whether the Skillingaryd field possibly is particularly unfavourable from an induction point of view. Measurements with 25- and 50-cycle currents have in the course of years been made at different places where 3-phase power lines and communication lines run parallel. The induction has thus been measured from the power lines Trollhättan—Västerås, Västerås—Enköping, Uppsala—Enköping, Enköping—Strängnäs, Stockholm—Värtan, Hammarforsen—Sundsvall, Arvika—Säffle and Majenfors—Malmö—Trelleborg. In every case, except the last named, the induction proved to be several times larger than that computed by the C C I curves. To show the divergences, and to what extent they agree with the Skillingaryd results, the computed and observed values for some of the parallelisms are given below. The computation has been done by dividing the parallel stretches into sections, generally 1 km. in length. At crossings a more exact division has been made, the lengths of the sections being then only 100 or 200 m.

These values show that the induction effect in Central Sweden obviously is somewhat larger than in the Skillingaryd district. In south-western Skåne, on the other hand, the induction effect proved strikingly low, and according to the theory the explanation should be that the earth conductivity in that district is particularly good.

R 2086 Fig. 20. The laboratory compartment in the State Railway dynamometer car.

The measurements on the lines Hammarforsen—Sundsvall and Untra—Stockholm mentioned above were carried out both in winter and summer. The results from the first named line were very interesting, in that the mutual induction proved to be c. 20 per cent. larger in winter than in summer. The latter line, however, showed no trace of a seasonal difference. It has been suggested that the particularly high induction in Sweden can be explained by the "more or less frozen state" of the ground. This supposition is of course absurd, as any frozen layer must be infinitely thin compared to the depths that are of importance in this case. The electrical differences at the parallelism Hammarforsen—Sundsvall in winter and summer may possibly be explained by the seasonal difference in water level in the great river near the power line.

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Laying and Fitting of Lead-sheathed Cables.

By *E. Olson.*

The rapidity with which cable manufacturing has developed during the last 15 years has caused quite different demands to be made on the men using the cables than was formerly the case. Outwardly, there is not much difference in the cables, but their internal quality has changed considerably. A careful study of working conditions, by which a complete knowledge of what is required of a good cable has been gained, comprehensive investigations of materials, and improved manufacturing, measuring, and control methods, have made the cables better, more durable, and more adapted to their purpose.

To get the full benefit of all the advantages of a modern cable, the first essential is recognition of the factors having a detrimental effect on the cables, and how to counteract these, a knowledge of which cables and fittings give the best working result in each instance, and how the cables should be laid and fitted to retain their good qualities.

All planning work aims at producing a plant all the parts of which are equally reliable, or, in technical terms: the plant must be of uniform strength. Electrical power lines should also be of uniform strength, but another aspect must be considered here, which is particularly prominent in a power line consisting of both aerial wires and cable. In durability and reliability cables are superior to aerial wires, but any faults occurring in a cable line are more difficult to repair. The following practical rule should be followed when planning a line: The more difficult a repair will be, and the more time it will take, the greater security must be provided against any faults occurring! A submarine cable cannot be repaired in winter in very cold weather, and the odds against faults occurring should therefore be the largest possible.

A well planned and well laid cable line has long been considered the most reliable part of an electrical plant, and if modern materials are used, there is consequently no difficulty in obtaining the desired durability. This applies not only to the cables but also to fittings, i. e. joint and end boxes and distribution heads. The old idea that the boxes are always the weakest points of a cable line is out of date. In this sphere also the labours of recent years have led to considerable progress.

Choice of cables. The copper core is usually dimensioned according to the load, with due allowance for both ohmic and inductive voltage drop. For high powers, one should always examine whether a larger number of small cables would not be more advantageous than a smaller number of heavy ones. The heavier a cable, the worse the heat conductivity, the more troublesome the laying, and the harder the fitting. If the choice is between one heavy and two smaller cables, the latter alternative is usually better, as it generally offers reserve opportunities.

Single phase cables are often preferable to 3-phase in cable lines for from 20 kV upwards. By special methods of armouring and manufacturing it is possible to reduce the losses in armouring and lead sheath to only a small fraction of the copper losses. The single phase cable is more easily cooled, easier to handle in laying, and needs fewer joints. The greatest advantage, however, is that a reserve is obtainable at considerably lower cost than if a 3-phase cable were used. Four single phase cables provide practically the same reserve as two 3-phase cables.

The difficulties of transport usually determine the length of underground cables. A cable drum of a given weight takes a single phase cable three times longer than a 3-phase cable, and the number of joints will therefore be correspondingly reduced. Submarine cables, which should preferably be made in one length, are the only ones where the length is limited by the equipment of the cable factory.

The old method of increasing the reliability

R 1972 Fig. 1.

of a cable line by using cables for higher voltage is nowadays quite unnecessary. The only result is a more expensive plant, where the cables, on account of greater difficulties in cooling, will not stand as large a load.

The protection of the cables outside the lead sheath is selected with due regard to the chemical or mechanical stresses to which the cables will be exposed when laid. Bare lead cable may be used where the cable will be exposed to neither chemical nor mechanical injury. Unarmoured but asphalted cable is laid where chemical but no mechanical damage is expected. Armoured cable is used everywhere else. Band armouring is used when the cable will not be exposed to tensile stresses. If such occur, the cable is armoured with round, flat, or z-shaped iron wire.

When planning a cable line, due allowance should always be made for the fact that heat is produced in the cable, and for the convenient conduction of this heat. When cables are laid in the ground, this should be firm and clean, and the cable should preferably be embedded in a layer of clean gravel. Indoor cable conduits should be roomy and easily accessible for cleaning and inspection.

Laying. Underground cables are either unrolled from a cart or lorry driving along the cable trench, or else they are drawn out from a fixed cable drum. The latter method of laying is the most usual and most costly, and requires more care to avoid damage to the cable. For long and heavy cables, an ample number of laying-rollers should always be provided, and the workmen be given rope nooses to be fixed on the cable as shown in fig. 1.*)

*) This method has been worked out by Mr Laurell of the Stockholm Electricity Works.

The laying should be done so that the cable is bent as little as possible while being put into position. Each time the cable is bent, the lead sheath will stretch, and vacuum blisters will form between the lead cover and the insulation. Ionization and incandescent phenomena, with consequent destruction of the insulating layer, are liable to occur in these.

The temperature of a cable must be at least 5°C. if it is to be bent without risk. This practically precludes the taking up of long cables in the winter, and makes the laying considerably more difficult.

Submarine cables are usually laid from a vessel, on which the cable drum is fixed and well stayed. Powerful braking devices must be provided, so that the running out of the cable can be conveniently controlled. The vessel is moved along the line where the cable has to be laid either by towing, by warping along a rope, or by kedging. These methods of laying are illustrated in figs. 2, 3 and 4. Fig. 5 shows a very long cable stowed in a lighter for laying in a lake, on the same principle as the transatlantic cables. This method of laying is not quite suitable for heavy high tension cables. When loaded in the ship, the cable will be given a turn in each coil, which may damage the comparatively thick insulation of a high tension cable. Rotary drums of the kind shown in fig. 6 are therefore better for such cables. A drum of this kind was used when laying the Öland cable, and it proved excellent, although the total weight of this cable

R 1873 Fig. 2.

R 1974 Fig. 3.

was 180 tons. The drum may rest on either rollers or balls, or else it may be built into a tank, as shown in fig. 7, in which the whole drum with the cable floats, allowing the bearing pressure to be conveniently regulated by raising or lowering the level of the liquid.

Choice of Fittings. Certain general rules may be given for cable fittings. A joint-box must be of the same mechanical and electrical strength as the cable itself. The connexion between the conductors must not alter the ohmic resistance of the conductor, and the boxes must be easily fitted. The insulation must be as like that of the cable itself as possible, so that no "sliding voltages" can arise. The distance between the conductors must be sufficiently strongly fixed to neutralize the impact effect of occurring short circuits. The boxes must be tight, and provided with expansion room inside the box, so that changes of volume of the compound in the box consequent on changes of temperature cannot cause variations of pressure large enough to bring about direct connexion between the insulation in the box and the surroundings.

What has been said of joint-boxes applies in pertinent parts also to distribution heads, with the additional condition that the leading-in insulators must have a higher flash-over voltage than the insulators which carry the bare conductors to which the cable is to be connected.

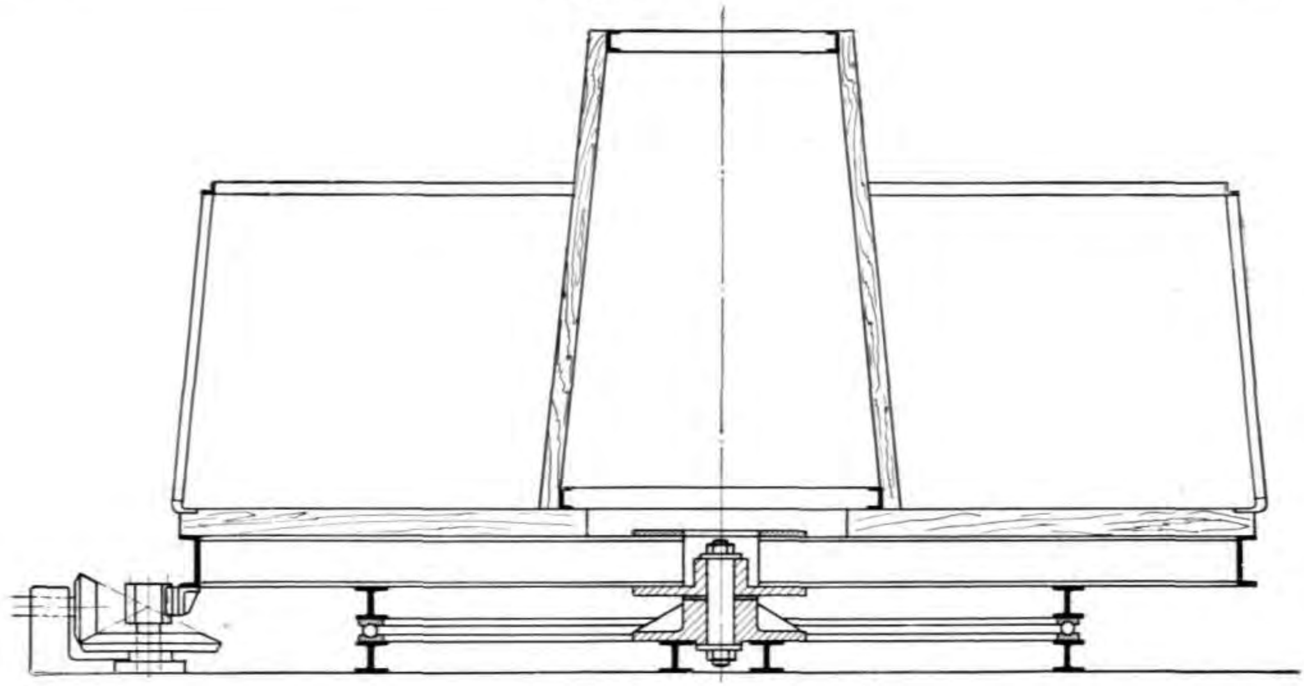
Fig. 9 illustrates a joint-box, filling the above requirements well, for cables up to 6 600 volt. The insulation consists of paper sleeves impregnated by an oil compound, and held together by a strong wrapping of similarly impregnated paper. Between the two halves of the box a bitumen packing is placed, which, when screwed up while hot, easily enters all inequalities and fills the space between the flanges completely. The upper part is provided with room for expansion. The filling hole is placed so that this cannot be filled with compound.

Joints for high voltage cables are most reliable if the boxes are filled with oil compound instead of ordinary compound. Fig. 8 shows such a box for a 33 kV 3-phase cable with each phase lead covered. The insulation consists of an oil-impregnated paper sleeve placed in a thin sheet iron tube. To make the voltage drop between the joint sleeve and the lead sheath less sudden, a serving of asbestos yarn is put next to the lead sheath, gradually diminishing in thickness from the lead sheath. Fig. 10 shows the effect on the voltage distribution of this serving.

The three single phase boxes are connected to a common expansion vessel, and the whole is

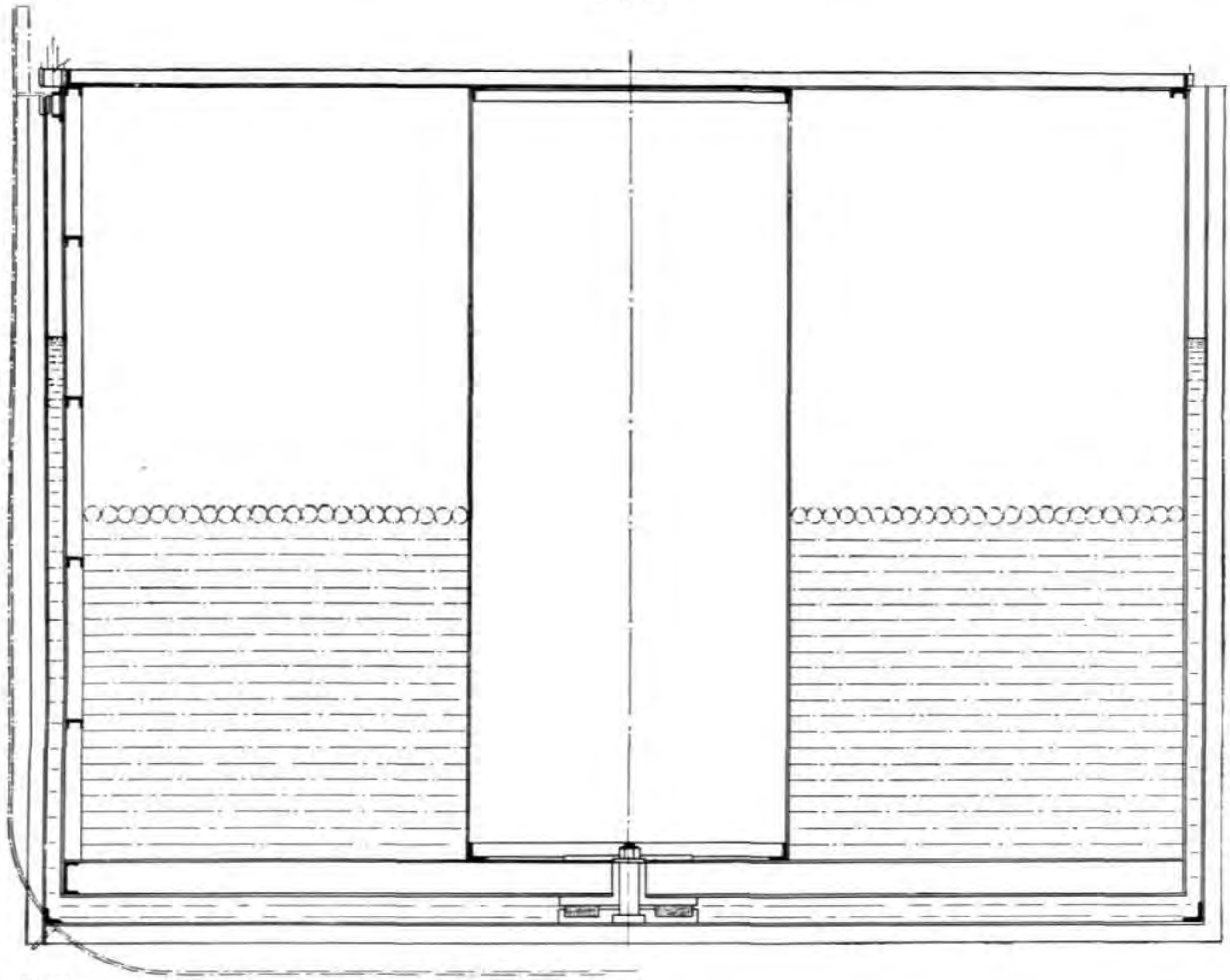
R 1975 Fig. 4.

R 1976 Fig. 5.



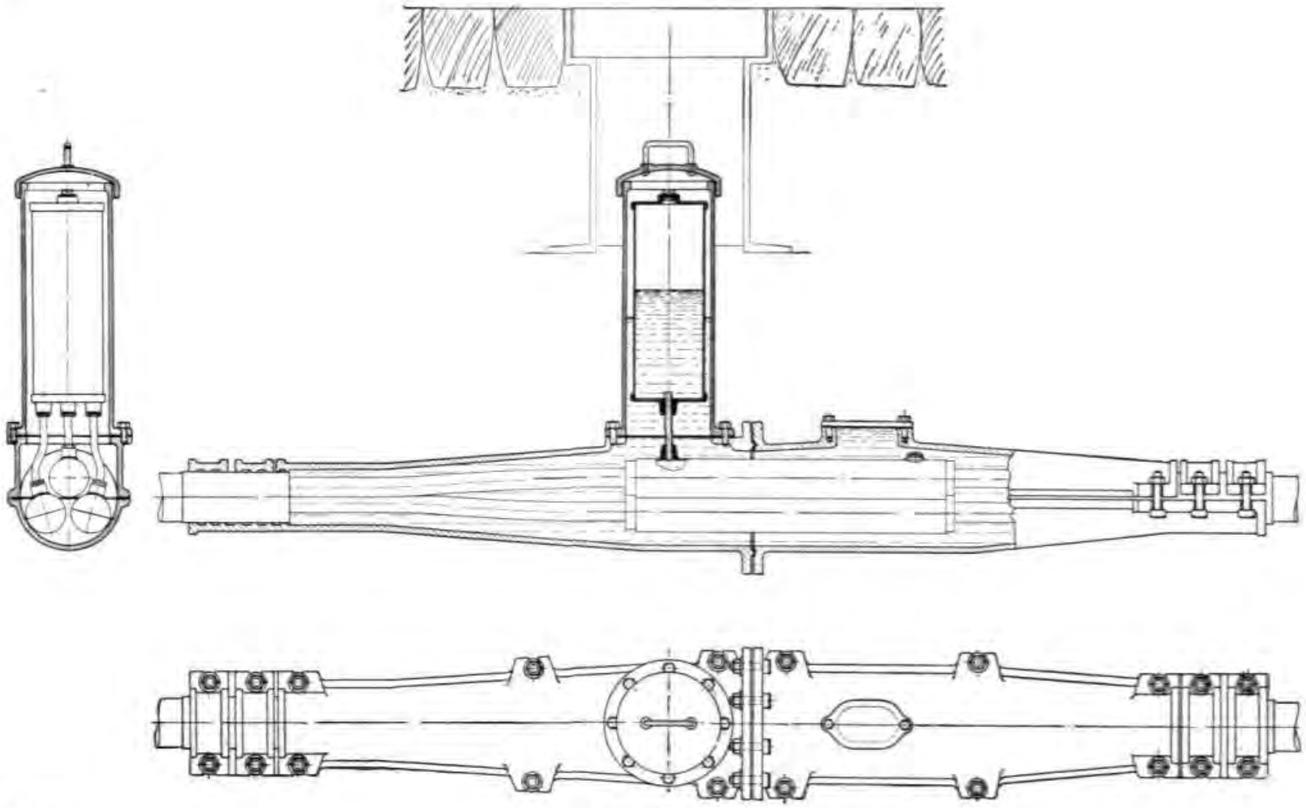
R 1987

Fig. 6.



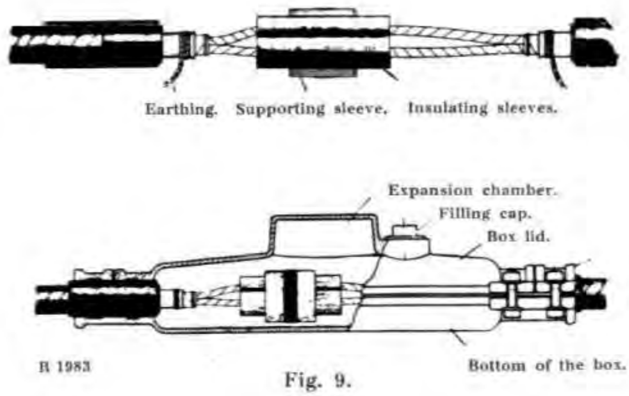
R 1985

Fig. 7.



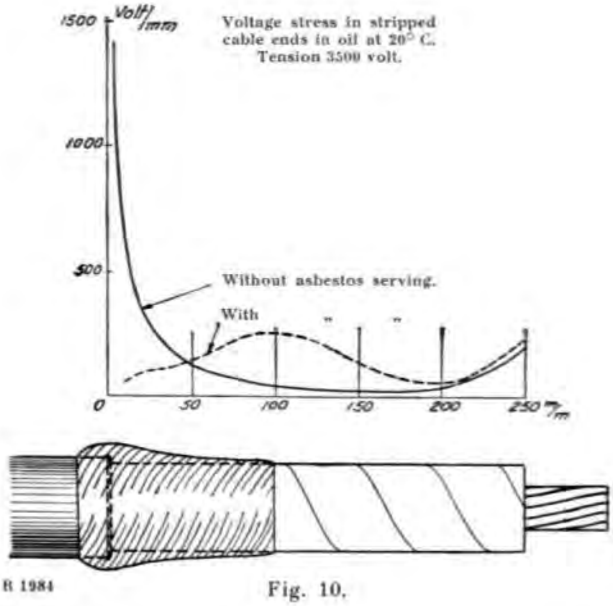
R 1988

Fig. 8.



R 1983

Fig. 9.



R 1984

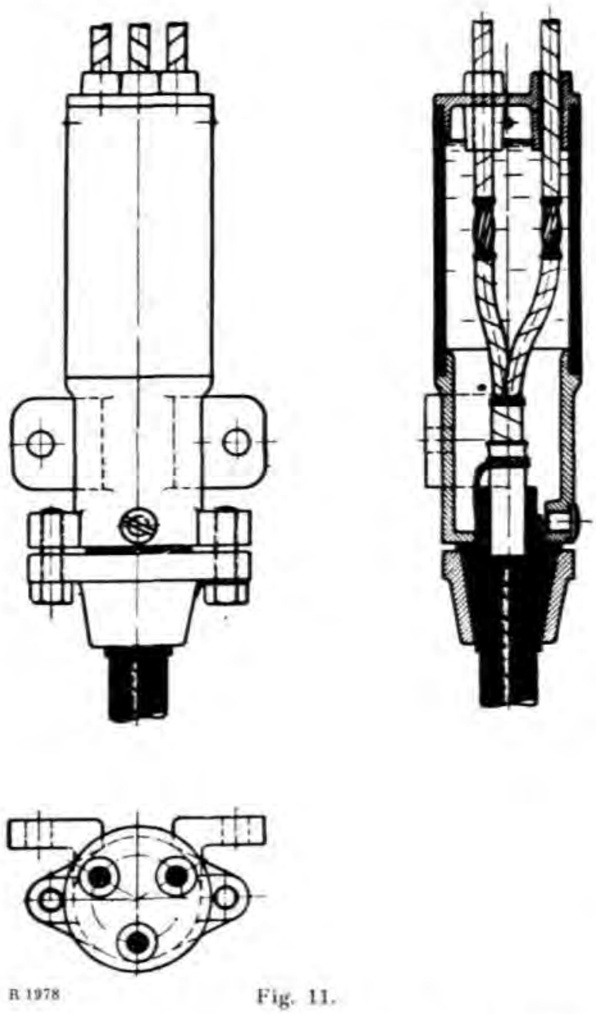
Fig. 10.

placed in a powerful cast iron protective casing, in its turn filled with asphalt.

Single phase boxes are as a rule made of unmagnetic material, and should be provided with expansion vessels and may also conveniently be fitted with a vacuum gauge, so that the internal pressure may be easily observed.

An indoor cable termination for up to 11 000 volt needs no box if the room where the connexion is made is perfectly dry and has a fairly even temperature, and if the cable end is not under pressure.

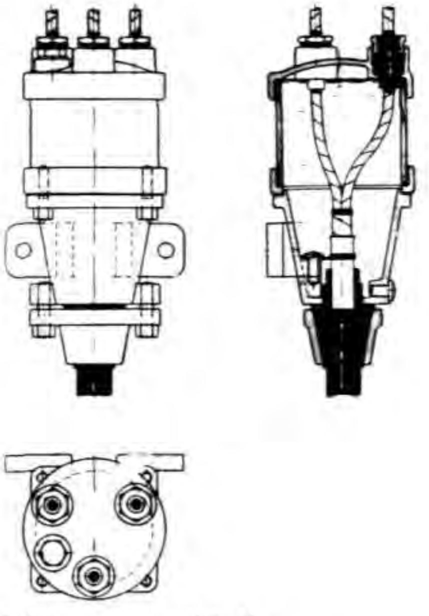
A perfectly reliable cable termination for up to 3 300 volt can be obtained with boxes of the design shown in fig. 11, if the temperature does not vary too much and no moisture ordinarily occurs, and if the slope of the cable is not more than 15: 100. The lower part, with a mechanical clamping device, is of cast iron, but the upper part is wholly of bakelite. The insulation of the cable conductors continues through the box to the place where they are connected, and is above



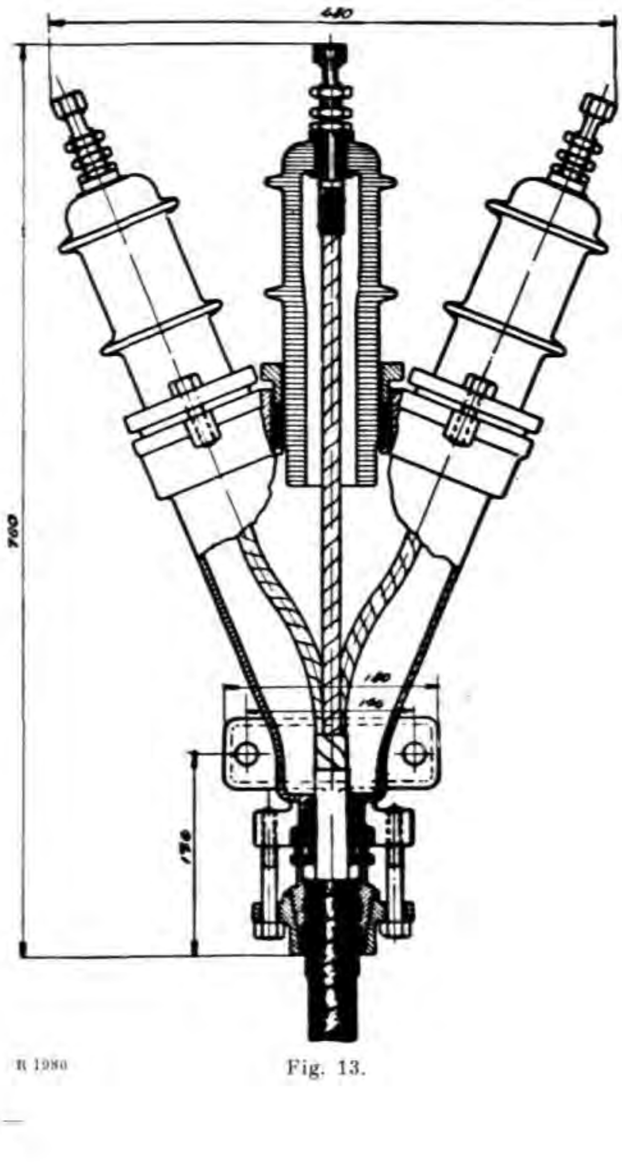
R 1978 Fig. 11.

the box wrapped with oilcloth tape painted with shellac or insulating lacquer. This design requires small dimensions, yet gives long distances between the phases and earth.

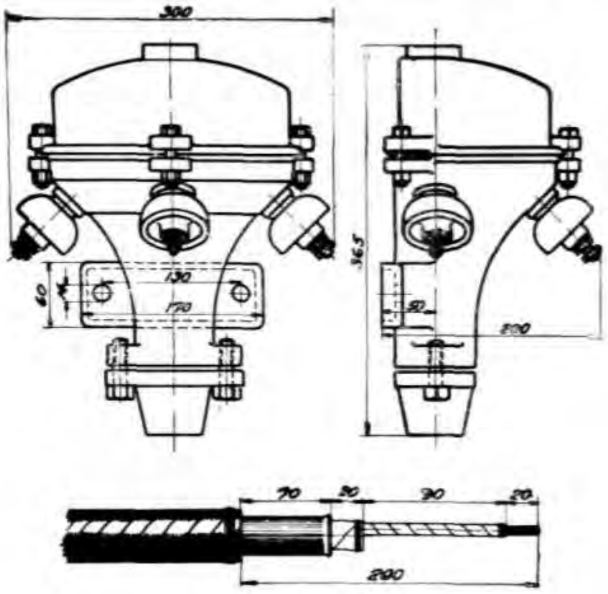
When the room where the cable terminates is very damp, or if the cable is under pressure, entirely closed boxes are used, effectively caulked where the wires are taken out. This necessitates the use of leading-in bolts to carry the conductors through the insulators. A simple pressure box which can be used for cables up to 3 300 volt is shown in fig. 12. Here also the upper part



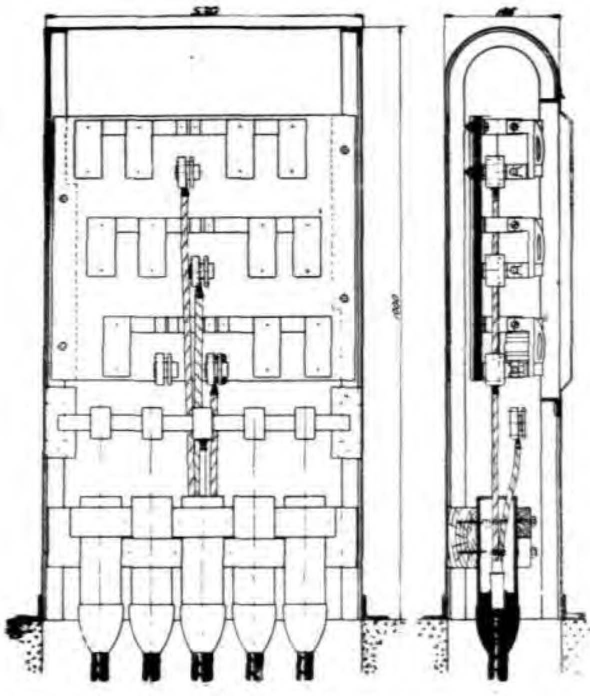
R 1979 Fig. 12.



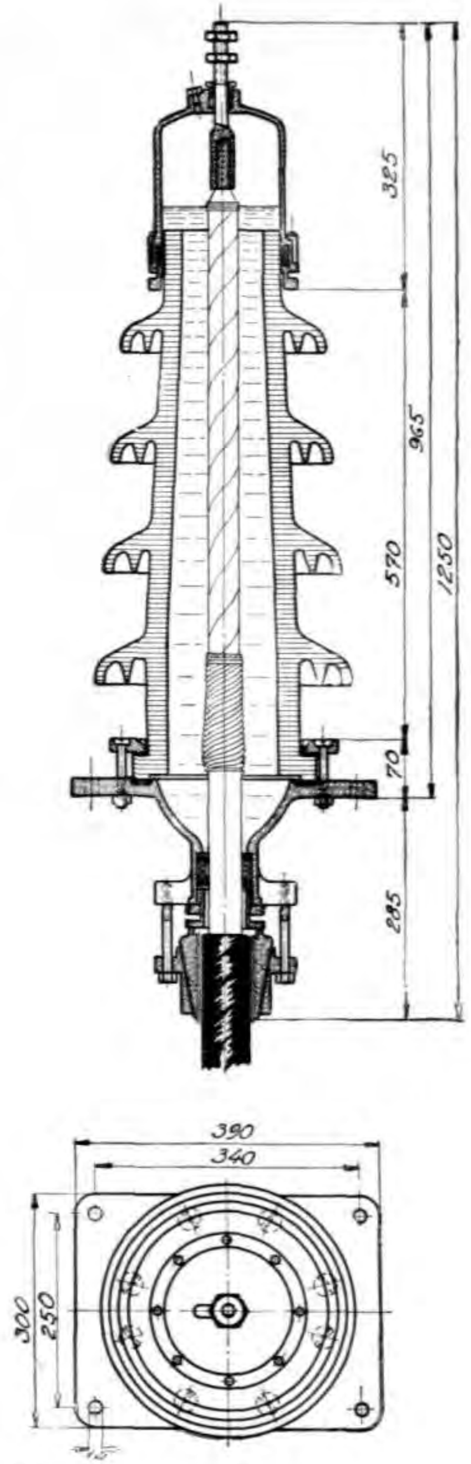
R 1980 Fig. 13.



R 1981 Fig. 14.



R 1977 Fig. 16.



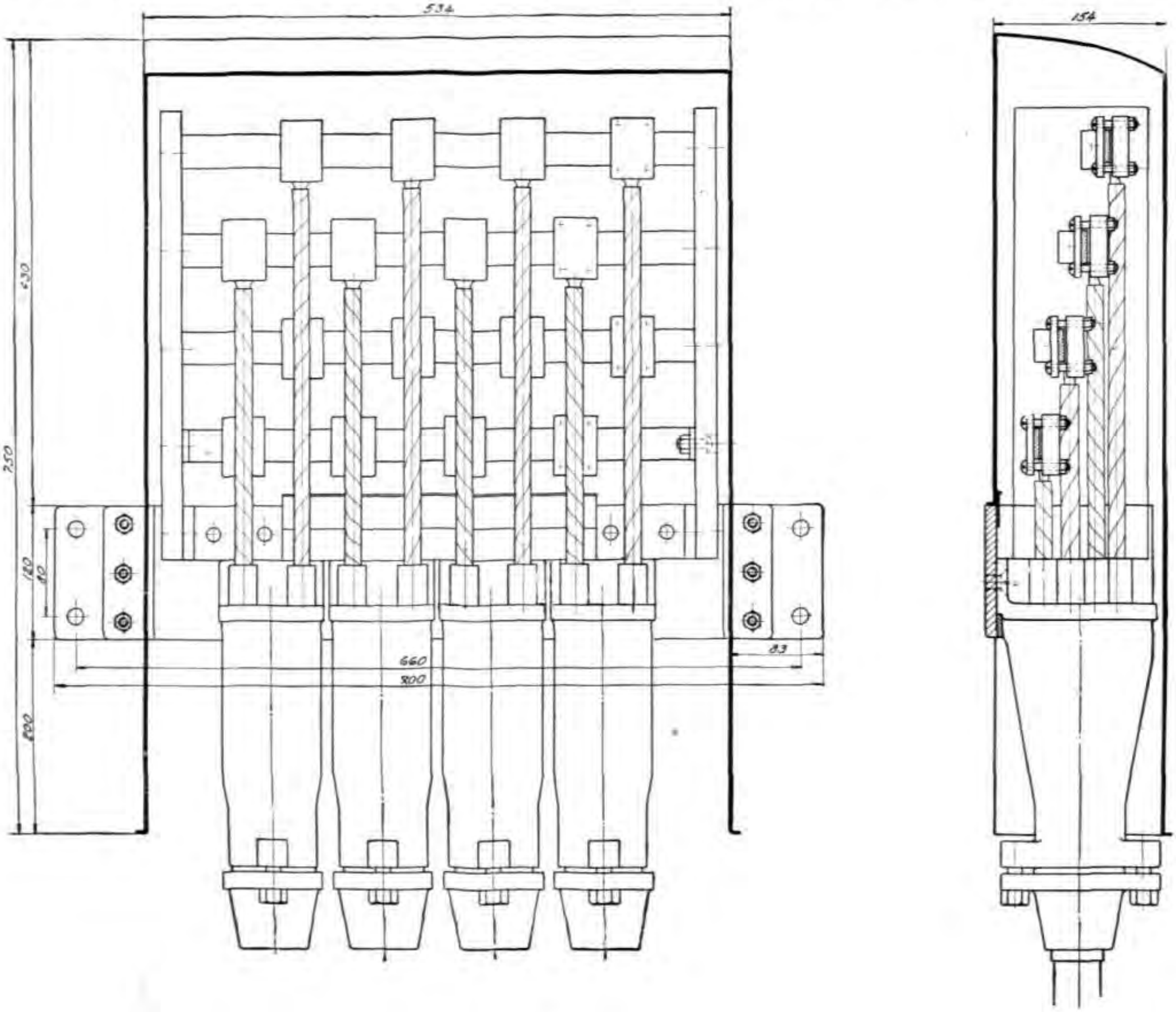
R 1986 Fig. 15.

is made of bakelite. The conductors of the cable are joined to another insulated cable, e. g. a rubber insulated one, by a smooth jointing sleeve which passes through a packing box with rubber-lead packing. The upper portion of the box serves as an expansion chamber.

Other indoor cable terminations, where the estimated pressure does not exceed 5 kg per cm^2, are best made as in fig. 13, illustrating a standard 11 kV indoor 3-phase box. Rubber-lead packing is used both for the insulators and for the leading-in of the cable. Tow steeped in red lead is wrapped round the leading-in bolt—an old and well tried packing. The box is filled with oil compound, and room for expansion is either obtained by filling the box completely with oil compound at a temperature of 150°, which in cooling will give sufficient room for expansion in the upper part of the box, or by screwing an expansion chamber to the middle leading-in bolt.

Figs. 14 and 15 illustrate a couple of outdoor cable boxes, the first for up to 3.3 kV, and the latter a single phase termination box for 55 kV. Both are made according to the rules given above, and have proved absolutely reliable in use.

Boxes placed above ground have in recent years been increasingly used for branching the cables, instead of the formerly used underground



R 1989

Fig. 17.

joint boxes. Such boxes offer several advantages, and as they are no more expensive, there is every reason to use them. Fig. 16 shows a test hut for five 4-conductor cables for maximum 200 amp. The measurements given indicate that the size is relatively small, and there should be no difficulty in finding a suitable place for it in any town or village.

Outdoor boxes are usually exposed to greater variations of temperature than indoor ones, and as they have to do their work in any wheather it is important that the leading-in insulators should be designed to provide an ample flash-over voltage under any conditions. Outdoor cable boxes should therefore never be purchased without making sure that the porcelain is suitable.

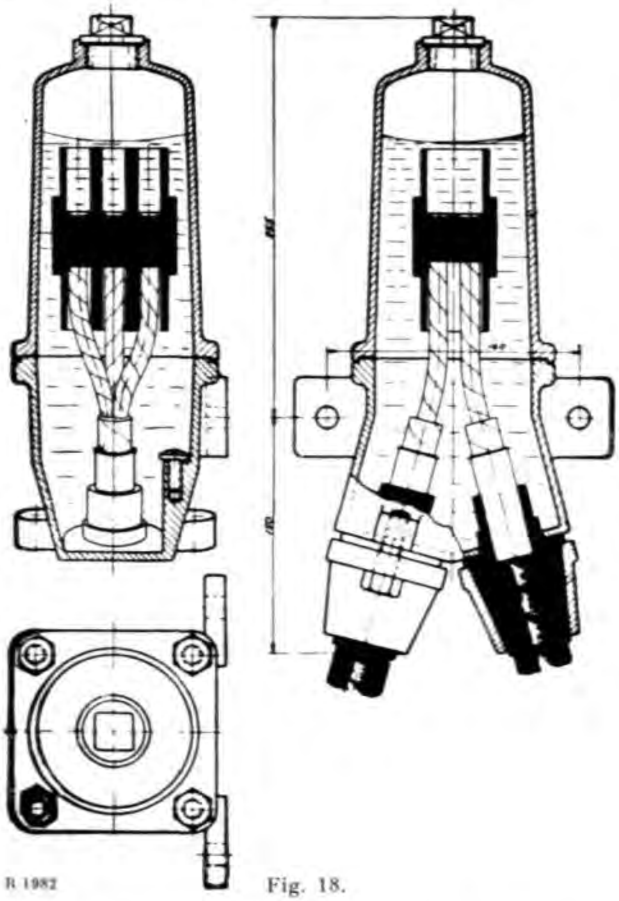
If cables are branched without fuses, and if they are not required to be easily separated when live, cable boxes of the type shown in fig. 17 are used. This box is made to be fixed directly on a wall or on a couple of poles fixed in the ground. The cables terminate in boxes which are put into the large box from the front, and the conductors are connected to the collecting bars by clamps without soldering.

In such parts of a country where the ground is covered by snow, and frozen during a large part of the year, cable fittings of the type shown in fig. 18 may suitably be used for both joints and branchings. Such boxes should preferably be placed above ground, where they are always accessible. The principle "no underground boxes in a new cable line" is nowadays frequently adopted, and though it is acknowledged that this principle gives increased reliability in working, it is perhaps not generally known that it is also frequently both simpler and cheaper than the older system.

Fitting. A good fitter who knows his job is of paramount importance to get a good cable installation. The cost of putting up modern, easily fixed cable fittings will always be only a small fraction of the total cost of the installation, but as the whole result will depend on the care with which it is fitted, too much stress cannot be laid on having this work done by none but really first class workmen. The training of the men is also of great importance and can hardly be overestimated. It pays to let the men who are going to do cable work learn this thoroughly, either in some large electricity works or in a cable works.

Above all, the work requires cleanliness and precision. The distance between conductors of different voltages is very small in a cable in comparison to what it is in other parts of an electrical plant, and consequently an apparently insignificant mistake in the fitting may easily spoil the result. An absolutely essential condition is that the boxes are kept free of every trace of moisture. Even perspiring hands are dangerous, and a person afflicted in that way must remember to wash his hands frequently with benzine when occupied with cable fittings. For work on high voltage cables, the fitter must wear rubber gloves whenever he touches the cable insulation directly. The fittings must be kept perfectly clean, and the work should preferably be done in a tent, which in damp weather must be heated.

The most suitable season for cable labour is the early summer, when the relative moisture of the air is low, and the most unsuitable is the autumn, when the relative moisture often approaches saturation point. This is a point which electricity works in particular would do well to remember when ordering their cables.



R 1982 Fig. 18.

Cable compound and oil should be carefully heated, so that they are not burnt, and the temperature must always be checked by a thermometer. Too hot compound is as bad as too cold. For cables impregnated with resin oil, too hot compound is particularly dangerous. Such oil contains substances which are vaporized at 150—200° C., and the compound will then become porous and sensitive to moisture. The old rule, that the temperature of the compound must be 150° C. when poured into the box, is made to be followed!

The laying and fitting of the oil-cellulose insulated high tension cable is a special branch of electrotechnics, and what has been said above is only intended as a few brief but necessary hints on the subject for engineers and executives engaged in power transmission work.

On Transmission Levels and Level Measurements in Long Distance Telephone Lines.

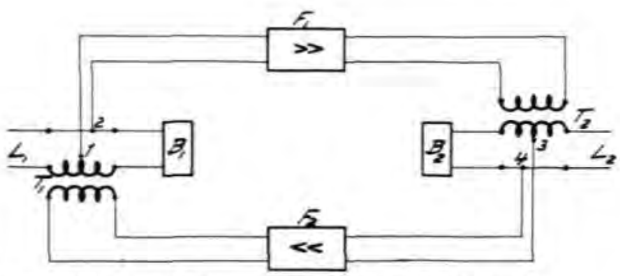
By *I. I:son Svedberg.*

The present paper gives a brief account of the principles of telephone communication by two- and four-wire systems. The conception transmission level is defined, and the level values recommended by the CCI are quoted. A method for measuring transmission levels elaborated by Svenska Radioaktiebolaget is described, and full details are given of the instruments for transmission measurements built on this principle. The method is based on the use of an amplifier instead of an auxiliary generator for level measurements. A correct frequency and curve shape is automatically obtained when the instrument is calibrated, and measurement errors caused by asymmetry of harmonics are eliminated. This latter problem is dealt with, and devices for avoiding errors of measurement caused by its influence in attenuation measurements are described. The mode of employing the new instrument for measurements according to the old method is finally also described.

Long distance communication is a conception which has been steadily expanding in telephony. The thermionic valves have provided a means of overcoming the line attenuation, and the distance at which telephone communication is possible has continuously grown with their perfection. This has, however, given rise to a number of new problems regarding the choice of the most suitable repeaters to use, where to connect them in the line, and how to supervise their working.

The Principles of Telephone Repeaters.

A thermionic valve being able to amplify an impulse in one direction only, some special circuits must be used to obtain amplification in both directions. For this purpose, a bridge circuit



R 2058 Fig. 1. Circuit diagram of 2-wire repeater.

with a differential transformer as in fig. 1 is employed to lead the currents of the two directions of speech each over its repeater.

A current from the line L_1 is diverted in such a manner that half the power goes to the input side of the repeater F_1 and the other half to the output side of repeater F_2. As the repeaters are active in one direction only, the latter part of the current is of no importance. The first half, on the other hand, is amplified by F_1 and led to one winding of the transformer T_2. The other winding of the same transformer is connected on the one side to the line L_2 and on the other to the *line balance* B_2, a device designed to give the same impedance as the line. The centre tap of this winding goes to the input side of the repeater F_2. The amplified current from F_1 will therefore, as B_2 and L_2 offer equal resistances, be equally divided between them.

The current from L_1 will therefore continue to L_2, amplified by F_1. The repeater F_2 will not then be affected, as no potential difference occurs between the points 3 and 4, the voltage drops over B_2 and L_2 being equal.

Similarly, the repeater F_2 will act in case of speech in the direction from L_2 to L_1, while F_1 will not be affected if the impedances of L_1 and B_1 are equal.

The condition requisite for a satisfactory working of this arrangement is obviously that line balances can be made to imitate the lines sufficiently accurately. If the agreement is not complete, part of the amplified current will go through the repeater serving the other direction, causing echoes, distortion, or even oscillations in the repeater.

The greater the number of repeaters in a line of communication, the more insistent must be the demand that each functions as perfectly as possible. To avoid the necessity of balancing every single repeater, the speech currents in each direction can be led in separate pairs of lines, and one-direction repeaters be connected in each pair according to fig. 2. This may be regarded as arising out of fig. 1 by a division of the repeaters F_1 and F_2 into several stages, suitably placed along the line. The real difference in the systems thus lies in the number of lines required for a conversation, and they are therefore designated *two- and four-wire repeating systems respectively.*

Transmission Level.

When a line is to be equipped with repeaters, these should naturally be as few as possible. The number will be determined by the line attenuation, and by the amplification of each repeater. The conception *transmission level* is used in order to obtain a suitable expression for these quantities and their mutual relationship.

By the transmission level of a power, current, or voltage, we understand the ratio of either of these to a quantity of the same kind selected as a standard of comparison.

For reasons of expediency, the natural logarithms of this ratio are used for expressing current and voltage levels, and half the natural logarithms of the ratio for defining the power level.

If for instance the power P obtains in a point of the line, and P_0, which is regarded as a standard of comparison, in another, the power level in the first point is

$$p = {}^1/_2\, {}^e\log \frac{P}{P_0} \text{ nepers} \quad (1)$$

When $P = P_0$, p will be $= 0$, and hence the power P_0 is said to correspond to *zero level.*

By international agreement, *1 milliwatt* has been established as zero power level.

If over a *resistance of 600 ohms, phase angle $=0$,* we have the power corresponding to zero level, the voltage over this resistance is further regarded as the zero voltage level, and the current through it as the zero current level. If we symbolize these by V_0 and I_0 respectively, we thus get

$$\frac{V_0^2}{600} = 10^{-3} \quad (2)$$

or $\quad V_0 = 0.775$ volt (R. M. S. value)

and $\quad 600 \cdot I_0^2 = 10^{-3} \quad (3)$

or $\quad I_0 = 1.29 \times 10^{-3}$ amp. (R. M. S. value)

We will now assume the voltage V_1 between the branches at a certain point of a line of infinite length. If the line attenuation per kilometre is β, the voltage at a point s kilometres from the first point in the direction of the transmission will be

$$V = V_1 \cdot e^{-\beta s} \quad (4)$$

We substitute the transmission levels

$$v_1 = {}^e\log \frac{V_1}{V_0}$$

$$v_2 = {}^e\log \frac{V}{V_0}$$

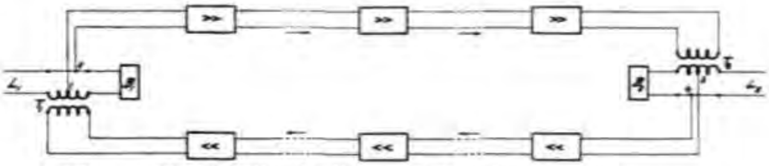
and divide equ. (4) by V_0

$$\therefore \frac{V}{V_0} = \frac{V_1}{V_0} \cdot e^{-\beta s}$$

Taking the logarithms in this expression, we get

$$v = V_1 - \beta s \quad (5)$$

The voltage level is thus a rectilinear function of the length of the line. The difference between the levels at two points is equal to the total attenuation for the length of line between them.



R 2059 Fig. 2. Circuit diagram of 4-wire repeater.

The same is applicable to power levels, for with analogous symbols we get

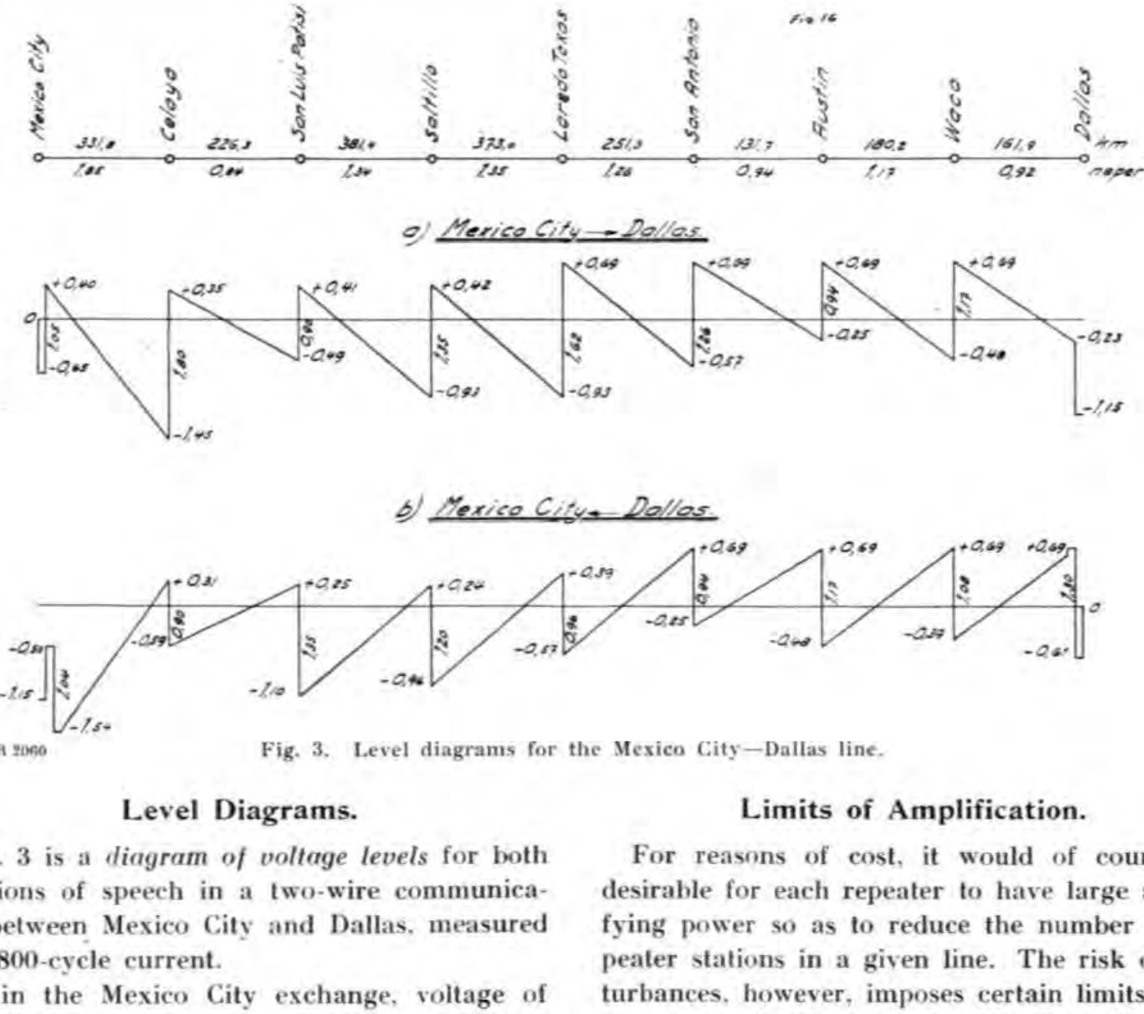
$$\left.\begin{array}{l} P = P_1 \cdot e^{-2\beta s} \\ p = {}^1/_2\,{}^e\log \dfrac{V}{V_0} \\ p_1 = {}^1/_2\,{}^e\log \dfrac{V_1}{V_2} \end{array}\right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

and

$$p = p_1 - \beta s \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (7)$$

will be —0.23 nepers. Various exchange equipment reduces it by 0.92 nepers to —1.15 nepers. The *over-all transmission loss* for the distance Mexico City—Dallas, 2037.6 kilometres (1266 miles), is thus 1.15 nepers.

For the opposite direction a diagram as in fig. 3b is obtained.



R 2060

Fig. 3. Level diagrams for the Mexico City—Dallas line.

Level Diagrams.

Fig. 3 is a *diagram of voltage levels* for both directions of speech in a two-wire communication between Mexico City and Dallas, measured with 800-cycle current.

If, in the Mexico City exchange, voltage of zero level is fed from a generator to the terminals of a subscriber's line, the level in the exchange equipment will drop to —0.65 nepers (fig. 3a). The voltage is increased in a two-wire repeater by 1.05 nepers, and at the beginning of the Celaya line the voltage level is consequently +0.40 nepers. The line attenuation for this line is 1.85 nepers, and the level will consequently drop, according to the above, to —1.45 nepers at Celaya. The repeater in this exchange raises the level to +0.35 nepers, and so on. At Dallas, the incoming level

Limits of Amplification.

For reasons of cost, it would of course be desirable for each repeater to have large amplifying power so as to reduce the number of repeater stations in a given line. The risk of disturbances, however, imposes certain limits. The lowest permissible input level is determined by the consideration that speech must be loud enough to dominate completely any cross talk from neighbouring lines or other disturbances. The output level is similarly limited, as no cross talk must be produced in other lines.

In 2-wire repeaters the difficulties of balancing the lines must also be considered. The greater the amplification, the more accurate must obviously the balance be.

In practice, the most suitable level limits for cable lines have been found to be (CCI, "White Book", 1926):

	For 2-wire repeaters	For 4-wire repeaters
Input level:	−1.6 nepers	−3.0 nepers
Output level:	+0.6 „	+1.1 „

The greatest expedient attenuation between two repeaters will accordingly be 2.2 nepers for a 2-wire system and 4.1 nepers for a 4-wire system.

The values are generally kept well within these limits, and the problem will then be to distribute the amplification in the most effective manner to the various stations along the line.

For 2-wire repeaters the CCI recommends the following procedure, which gives an over-all transmission loss of 1.30 nepers.

Assume for instance a line to be divided into five sections with an attenuation of b_1, b_2, b_3, b_4, and b_5 respectively. Let the amplification in the first repeater be f_1, in the intermediate repeater stations f_2 and f_3, and finally in the terminal station f_4. We then select

$$\left.\begin{array}{l} f_1 = b_1 + \frac{b}{2} - 0.65 \\ f_n = {}^2/_2\, b_n + {}^1/_2\, b_n + 1 \\ f_4 = b_5 \frac{b}{2} 4 - 0.65 \end{array}\right\} \ldots\ldots\ldots\ldots\ldots (n = 2 \text{ or } 3)$$

Each intermediate repeater thus compensates the attenuation in half a section on either side of it. The terminal repeaters deal with half a section on the line side and all but 0.65 nepers on the exchange side.

Over-all Transmission Loss and Transmission Levels in International Telephony.

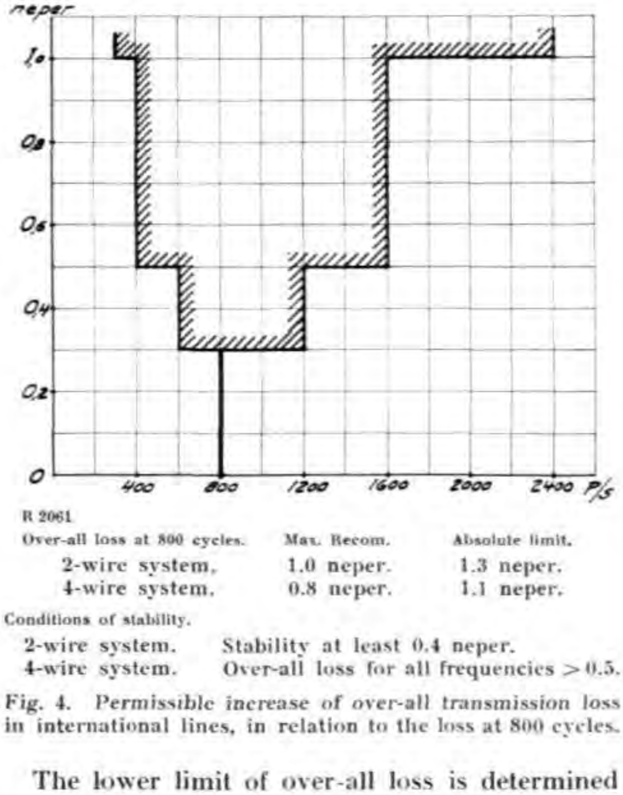
At the CCI conference in Brussels in June 1930, certain standards for the selection of over-all loss values in International communications, and level values at frontier exchanges, were established, and for the frequency dependence of the two.

The maximum over-all transmission loss in a 2-wire system was thus fixed at 1.3 nepers, and in a 4-wire system at 1.1 nepers at a frequency of 800 cycles. The conference, however, considered it desirable that these values be kept within 1.0 and 0.8 nepers respectively, provided that the stability of the line or cross talk attenuation in the line were not thereby reduced below the limit values set by the CCI. Nor must the noise voltage reach larger maximum values than those normally permitted.

The over-all transmission loss at other frequencies may exceed the *loss actually measured at 800 cycles* by the following amounts, in 2-wire as well as in 4-wire systems:

Frequency range	Permissible increase of overall transmission loss in relation to the loss at 800 cycles
600—1200 cycles	0.3 nepers
400—600 „ / 1200—1600 „	0.5 „
<400 „ / >1600 „	1.0 „

These limits for the variation with the frequency of the over-all loss is graphically illustrated in fig. 4.



R 2061

Over-all loss at 800 cycles.	Max. Recom.	Absolute limit.
2-wire system.	1.0 neper.	1.3 neper.
4-wire system.	0.8 neper.	1.1 neper.

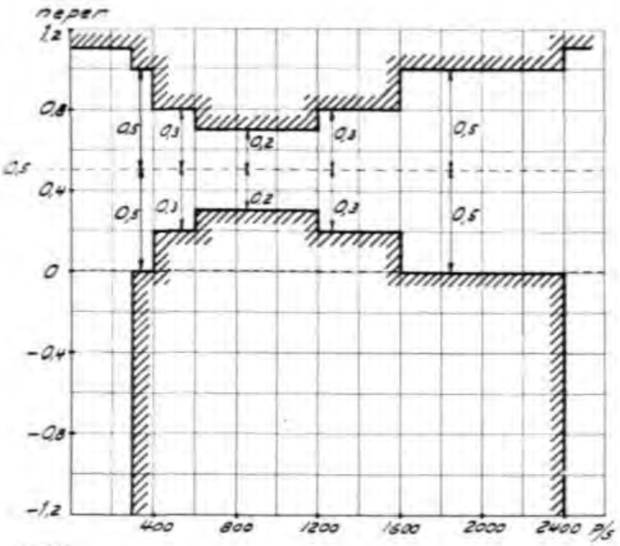
Conditions of stability.

2-wire system. Stability at least 0.4 neper.
4-wire system. Over-all loss for all frequencies >0.5.

Fig. 4. Permissible increase of over-all transmission loss in international lines, in relation to the loss at 800 cycles.

The lower limit of over-all loss is determined with due regard to the stability of the system. In 4-wire systems the over-all loss must not fall below 0.5 nepers at any frequency, and in 2-wire systems the margin of safety for stability must be at least 0.4 nepers, i. e. an increase of amplification in a repeater by 0.4 nepers must not cause the system to oscillate.

According to the CCI rules, the transmission level at frontier exchanges of international 4-wire systems must be kept within the bounds shown



R 2062

All level values must be between the shaded areas. Normal level 0.5 neper.

Fig. 5. Permissible power level at frontier stations of international 4-wire lines, measured on the output side in the direction of the frontier.

in fig .5. The normal power level on the output side of the repeater, measured in the direction of the frontier, shall be +0.5 nepers at 800 cycles, and the following deviations from this level are allowed:

for the frequency range	600—1200	cycles	± 0.2 nep.
" " " "	400—600	"	± 0.3 "
" " " "	1200—1600	"	
" " " "	300—400	"	± 0.5 "
" " " "	1600—1400	"	

Nowhere in the frequency range used must the power level exceed +1.1 nepers.

Measurement of Transmission Levels.

When the transmission levels at each of the repeater stations of a certain line have been decided upon, provision must also be made for ensuring good transmission by checking that these values are kept within the tolerances allowed.

The principle of determining the transmission level is to send out a current of known frequency from an audio-frequency generator *G* at one terminal station (*A* in fig. 6). The current is measured by thermo-couple and galvanometer (*T*), and the outgoing level is adjusted by a suitable attenuator to zero level at the beginning of the line. At the other end of the line, *C*, a resistance corresponding to the characteristic impedance of the line is connected, and the voltage over this resistance is measured by means of a voltmeter *V*, which gives the value of the voltage attenuation in the whole line. The voltage level behind a repeater is determined in the same manner by measuring it with a voltmeter *V*. From the voltage-level values obtained, the power level may also be computed as described below.

Special voltmeters must be used for these measurements. Their measuring range must correspond to voltage levels from —3.5 nepers to +2 nepers (i. e. from 0.024 to 5.74 volt, *R. M. S.* value) at all audio-frequencies (200—5000 or even 10 000 cycles). For measurements at an intermediate station, they must further possess an

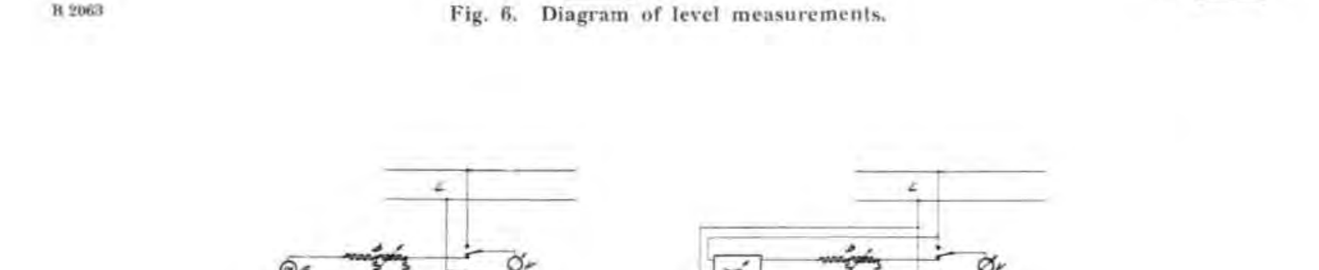


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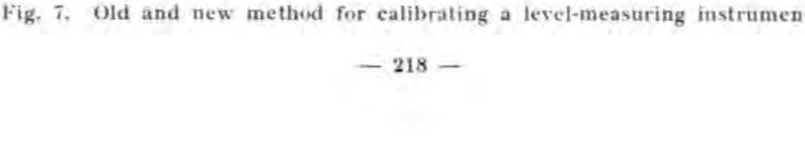
Fig. 6. Diagram of level measurements.



R 2064

Fig. 7. Old and new method for calibrating a level-measuring instrument.

input impedance large enough (100 000 ohms) to prevent their affecting the level of the line when connected. Valve voltmeters of one kind or another must therefore be used.

In actual measuring practice (cf. fig. 6) the line voltage is first observed on the voltmeter V, which is then switched to a calibrating circuit, where the proportion of a known voltage required to give the same reading over again is ascertained.

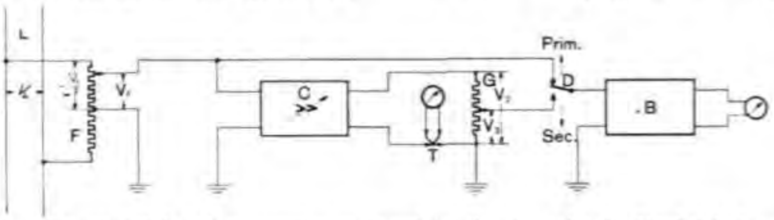
This known auxiliary voltage must be of the same frequency as the line voltage. To make the comparison in the valve voltmeter correct, it should also be of the same curve form. So far, a separate local generator G (Fig. 7a) has been used for the generation of this voltage, which is fed to the artificial line b over a thermocouple with a galvanometer T. Each time the measuring frequency is changed, the generator

rather important advantage is also that when portable sets are used for measurements, heavy and bulky generators need not be carried.

For practical reasons the measuring apparatus should preferably use approximately constant input voltage to the valve voltmeter, and an adjustable, calibrated voltage divider is therefore employed, permitting a known part of the line voltage, sufficiently large to give a suitable deflection to the valve voltmeter, to be taken out.

The high input impedance necessary requires this potentiometer to be of the special design set forth in the following description of the Measuring Set.

The principle of measuring is shown in the circuit diagram, fig. 8. Let the voltage level in the line L, and with that over the *primary potentiometer* F, be p nepers, which, according to the definition on page 00, corresponds to a voltage



R 2065

Fig. 8. The principle of measurement used in the Svenska Radioaktiebolaget set.

G must consequently be adjusted to the same frequency, and the current adjusted until a certain reading is obtained on the galvanometer T. The valve voltmeter reading is then adjusted by means of b until it coincides with that obtained from the line voltage. The voltage level at the input terminals of the valve voltmeter is then directly read on the artificial line b.

The method has some drawbacks, however. Setting the generator to each new measuring frequency means a loss of time. There is also some risk of one station misunderstanding the sending station when the frequency to be used for measuring is announced. These drawbacks are automatically avoided by the method used by Svenska Radioaktiebolaget in its Transmission Measuring Set type TRM. In this apparatus, the auxiliary voltage is obtained, as shown in fig. 7b, from an amplifier F fed by the actual line voltage, which thus positively gives the correct frequency for comparison, without being specially set to it. The same curve shape of the voltages compared is also obtained, which is not invariably the case with the older method. A

$$V_1 = 0.775 \cdot e^p \text{ volt.}$$

At a certain setting of the primary potentiometer, corresponding to the reading m nepers, we have over its contact a voltage V_F and the scale is made such that

$$\frac{V_F}{V_1} = k_1 e^{-m},$$

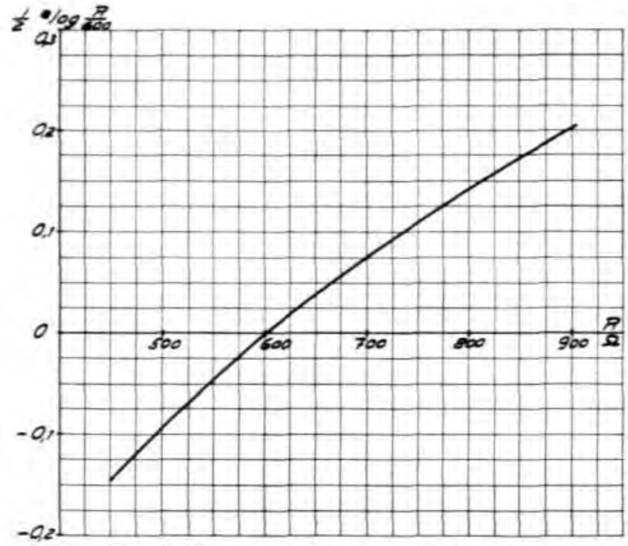
where k_1 is a constant and m may be varied in steps of 0.5 nepers.

We consequently have

$$V_F = V_1 k_1 e^{-m} = 0.775\ k_1 e^{p-m} \text{ volt.}$$

When the switch D is in position "Prim.", this voltage is fed to the valve voltmeter, which is designed to be deflected to about midway on the scale by $0.775 \cdot k_1$ volt, i. e. when $p - m = 0$.

The first step in the measuring procedure will therefore be to select, with the switch D in the "Prim." position, a step on the primary potentiometer which will give a deflection approximately midway on the scale, and to observe this exactly. The sensitivity of the valve voltmeter should preferably be adjusted so that this deflection is always the same, e. g. midway on the scale.



R 2066 Fig. 9. The correcting term $\frac{1}{2}\,{}^{e}\log\frac{R}{600}$

The voltage V_F, and consequently the level, is then finally determined by comparing it to a known voltage V_3 taken out from the *secondary potentiometer* G in the output circuit of the amplifier C. By the previous adjustment of the primary potentiometer, the voltage V_F has been adjusted to a value suitable for the amplifier. The output of this is regulated by a variable resistance so that the thermo-galvanometer T gives a certain reading. The current through G is thereby fixed, as well as the voltage V_2.

The switch D is now set in the "Sec." position, and the sliding contact on G is moved until the same reading is obtained on the valve voltmeter as in the "Prim." position. We then have

$$V_3 = V_F.$$

The scale of D is calibrated to give directly a value n nepers, determined by

$$\frac{V_3}{V_2} \text{ being} = k_2 \cdot e^{n},$$

where k_2 is a constant, and n varies continuously from $n = -0.20$ to $n = +0.7$.

We thus have

$$k_2\, V_2 \cdot e^{n} = 0.775\; k_1 - e^{\,p-m}.$$

If the design is such that

$$k_2\, V_2 = 0.775\; k_1$$

e^{n} will thus be $= e^{p-m}$, or $p = m + n$.

The voltage level will consequently be the sum of the scale readings on the two potentiometers F and G.

Calculation of Power Level from Voltage Level.

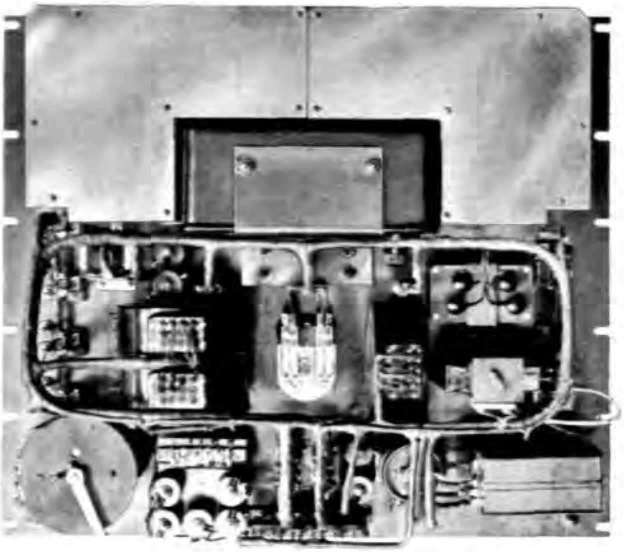
If the voltage V is measured over a resistance R, the power level will, according to the definition, be

$$p = \tfrac{1}{2}\,{}^{e}\log\frac{\frac{V^2}{R}}{P_0} = \tfrac{1}{2}\,{}^{e}\log\frac{\frac{V^2}{R}}{\frac{V_0^2}{600}}$$

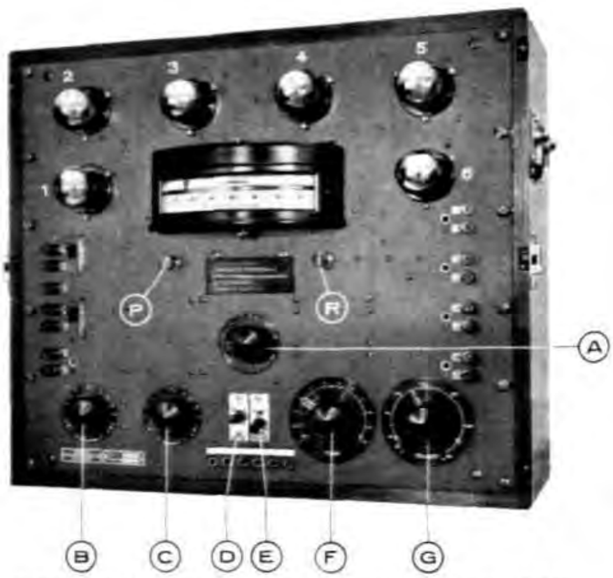
or

$$p = e\log\frac{V}{V_0} - e\log\sqrt{\frac{R}{600}} \text{ nepers},$$

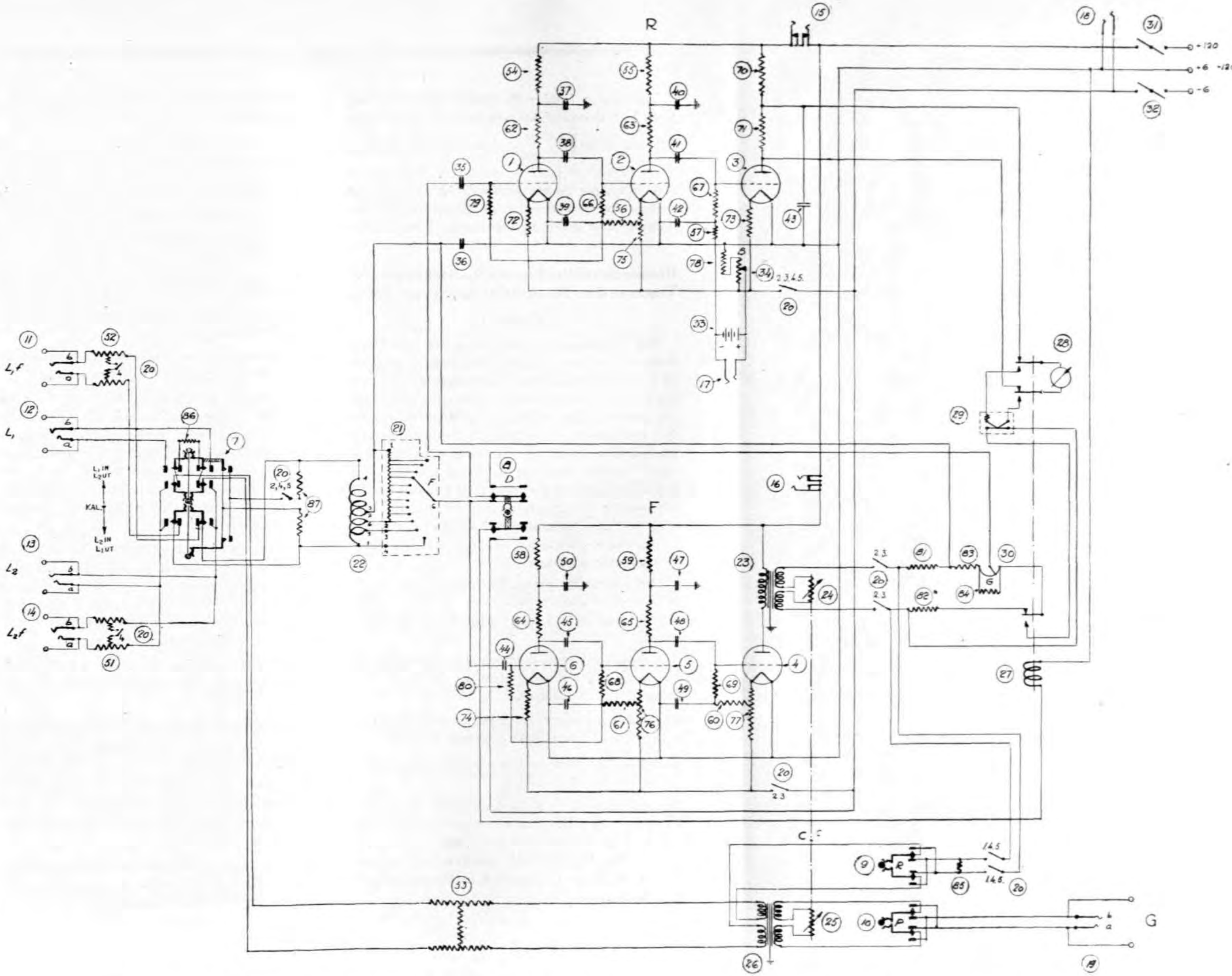
where $e.\log\frac{V}{V_0}$ obviously is the voltage level.



R 2067 Fig. 10. Transmission Measuring Set, Type TRM. Back view.



R 2068 Fig. 11. Transmission Measuring Set, type TRM. Front view.



The contacts marked (20) all belong to the main switch A, and the figures at the respective contacts signify that they are closed for the corresponding position of the switch A.

Fig. 12. Circuit diagram of the Svenska Radioaktiebolaget Transmission Measuring Set.

The power level p is consequently obtained from the measured voltage level by subtracting from this e log $\sqrt{\frac{R}{600}}$*, where R is the resistance over which the level is measured. When R = 600 ohms, the power level will be equal to the voltage level.* The value of the correction for varying *R* is given in the curve of fig. 9.

Description of the Svenska Radioaktiebolaget Transmission Measuring Set, Type TRM.

General.

The Transmission Measuring Set type TRM designed by Svenska Radioaktiebolaget consists of a valve voltmeter with calibrating devices. Its external appearance and mechanical construction are shown in figs. 10 and 11. As indicated above, the instrument is designed for measuring the transmission levels of telephone lines, and requires, unlike other appliances of the kind, no auxiliary generator for doing this. Combined with a generator, the apparatus may be used for sending out zero transmission level and for determining loop attenuation of lines, and the gain of telephone repeaters.

The measuring range for transmission levels is from +2 to —3.5 nepers. Gain up to 5 nepers, and attenuation up to 3.5 nepers, can be measured.

A complete circuit diagram is given in fig. 12. We note the following details, visible on the front of the instrument.

The valve voltmeter, consisting of the valves 1, 2, and 3, with their coupling units.

The amplifier, made up in a similar manner by the valves 4, 5, and 6.

The galvanometer (Cambridge Pattern *R*), serving partly as a D. C. indicator in the anode circuit of the last voltmeter valve, and partly —in conjunction with a thermal converter— as an A. C. milliammeter in the calibrating circuit.

The main switch A, by which the set is adjusted for the various measurements which can be made. It comprises all the contact devices marked 20 in the diagram. The figures against each contact group indicate that this is closed in the corresponding main switch positions, and correspond to the following uses.

1. Sending out zero level.
2. Measurement of incoming transmission level (i. e. level at terminal station).
3. Measurement of transit level (i. e. level at intermediate station).
4. Gain measurement.
5. Measurement of loop attenuation.

The potentiometer B, for regulating the grid bias of the end valve of the voltmeter, and for setting the galvanometer needle to suitable deflection.

The resistance C, for regulating the current in the normal circuit of the instrument.

The measuring switch D. This has three positions. In position "Prim." the valve voltmeter is connected to the voltage to be measured. In position "Sec." it is switched over to a known, adjustable voltage taken out from the normal circuit. The third position, "Norm.", is used when adjusting the current in this circuit.

The line switch E, for change-over of incoming and outgoing lines in gain- or loop attenuation measurements, so that both directions of a 2-wire circuit can be quickly measured. It has also an intermediate position, "Cal.", used for adjusting the normal level.

The primary potentiometer F, in parallel with the incoming line, a voltage divider in steps of 0.5 nepers.

The secondary potentiometer G in the normal circuit. The calibration voltage for the valve voltmeter is taken from its sliding contact.

The push-button switches P and R, between them forming a device for eliminating errors when measuring with asymmetrical alternating current.

Other details of the Transmission Measuring Set will be described below in connexion with their use in various measurements.

The two first positions of the main switch are the most important, and are therefore dealt with more fully. They serve for adjusting the normal circuit and the valve voltmeter of the instrument. All other measurements are a combination of these two.

1. Sending out Zero Transmission Level.

An audio-frequency generator is connected to the "Generator" terminals of the instrument, and the line to one of the terminals L_1 or L_2. The measuring switch D is set to the "Norm." position, which sets the connexions as in the simplified diagram fig. 13. Let us first assume the line switch E to be in the central position as in the figure. The current from the audio-frequency generator will then go over the transformer 26 through some resistances to the attenuator 53, which ends in resistance 86. The current is measured by the thermo-couple 29 and the galvanometer 28. The circuit is earthed over the condenser 36, and the resistance 81 is connected in for the sake of symmetry. The instrument is designed so that when the current is now regulated by the resistance C until the galvanometer needle takes up a central position on the scale, zero voltage level will be obtained over the resistance 86. By changing the line switch E to the position L_1 *OUT* or L_2 *OUT*, the line connected to the corresponding terminals will take the place of resistance 86, and if the line characteristic is 600 ohms, the voltage level there will of course be zero level. The whole sending device may be regarded as a kind of "normal generator". The internal resistance of such a generator must be constant at 600 ohm. This object is attained in the *TRM* by making the attenuator 53 so large that alterations of resistance 25 will be imperceptible in the internal resistance of the generator.

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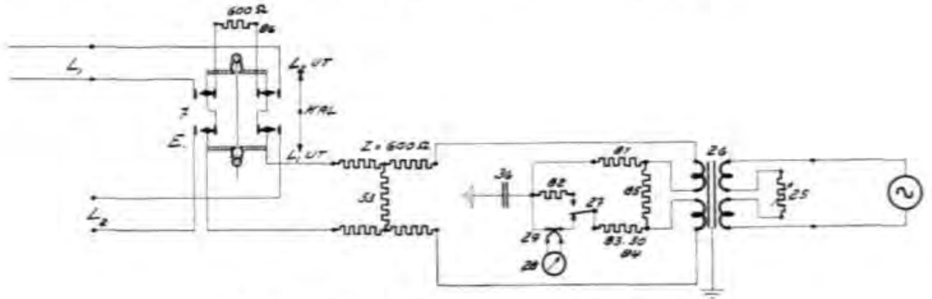

Fig. 13. Sending out zero transmission level.

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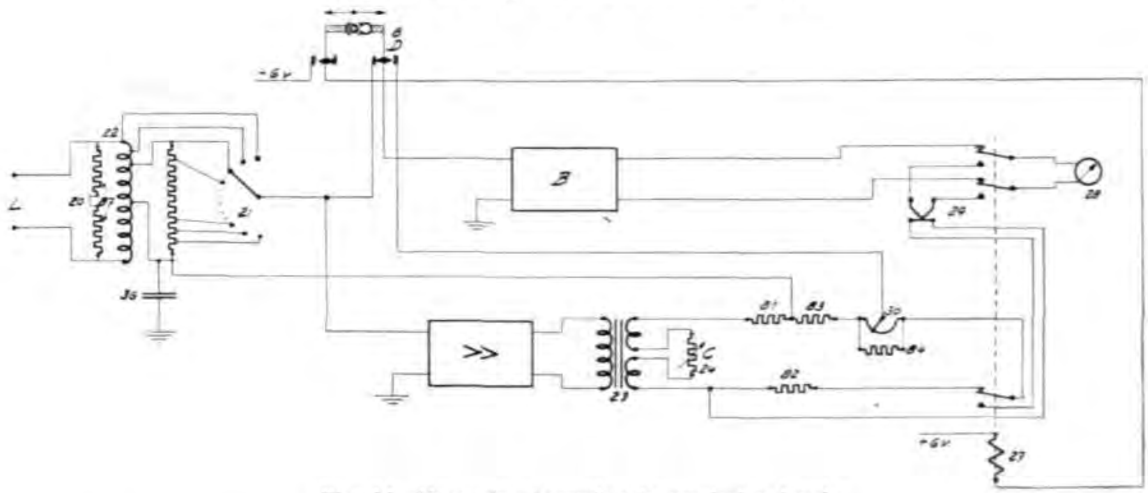

Fig. 14. Measuring incoming transmission level.

2. Measuring an Incoming Transmission Level (level at terminal station).

A zero level is assumed to be sent out from one end of the line as described above. The other end of the line is connected to the line terminals L_1 of a Transmission Measuring Set, the main switch of which is set to position 2. The connexions in this case are shown in fig. 14. The line switch is assumed to be set to L_1 *IN*.

A terminal resistance 87 of 600 ohm, and a choke coil 22, the centre tap of which is earthed through condenser 36, are connected in parallel with the incoming line. This arrangement gives perfect symmetry of currents in the two line branches. The choke coil also serves as an autotransformer, being tapped at every 0.5 neper ratio difference. Between the centre point and the nearest tap, a resistance is placed, also divided into steps of 0.5 nepers. All the taps are taken to a switch *F*.

The choke coil, the resistance, and this switch between them form *the primary potentiometer*. The *amplifier*, feeding the normal circuit, is connected in parallel with this.

The measuring is done as follows, in accordance with the principle stated above:

a. With the measuring switch *D* in "Prim." position, the primary potentiometer dial *F* is turned to the setting which brings the galvanometer needle nearest to the centre of the scale. (This is marked by a red line and the number 60.)

b. By means of dial *B*, the galvanometer needle is adjusted exactly to the 60-mark on the scale.

c. The measuring switch is depressed in "Norm." position. Relay 27 is then energized, and galvanometer 28 is connected to thermocouple 29 in the normal circuit. The galvanometer needle is brought to the centre of the scale by dial *C* (normal circuit).

d. The measuring switch *D* is set to the "Sec." position, and dial *G* (the secondary potentiometer) is turned until the central reading is again obtained on the galvanometer scale.

e. The sum of the readings *G* and *F*, obtained on the *inner* scale of the potentiometer *G*, will be the incoming level. The scale graduations are made so that the readings always have to be added, whether the levels be positive or negative.

3. Measuring a Transit Transmission Level

(level at an intermediate station).

The main switch *A* is set in position 3. This disconnects resistance 87 over the "incoming line" (fig. 12), which in this instance is a *parallel connexion* to the line measured, and the measurement is taken in exactly the same way as described for 2. The input impedance of the apparatus is in this case large enough not to affect the line level appreciably.

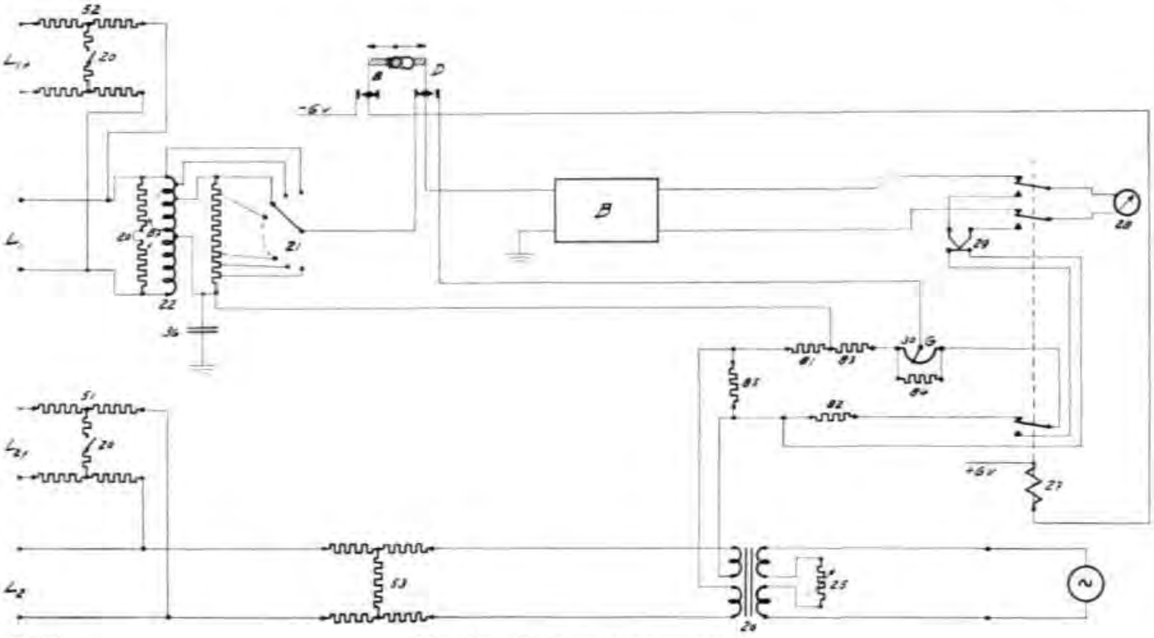

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Fig. 15. Gain measurements.

4. Gain Measurements.

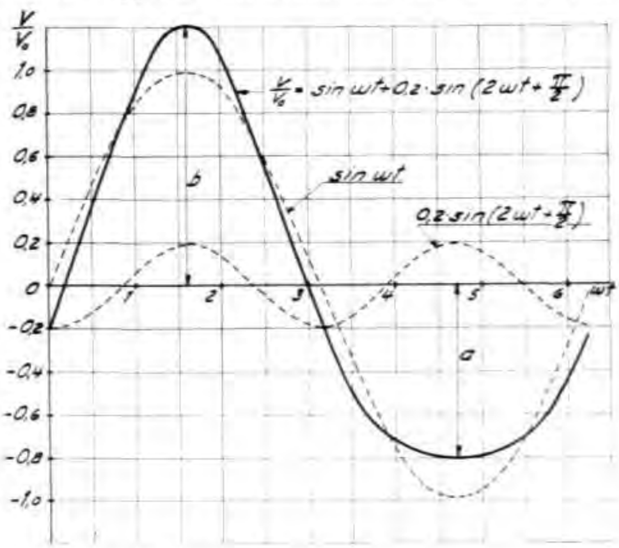
As the Transmission Measuring Set contains devices both for sending out a certain normal level and for measuring an unknown level, these may be readily combined for measuring the attenuation in a network, e. g. a cable loop or a repeater, which latter may be regarded as introducing a negative attenuation. We will assume that the degree of amplification of for instance a 2-wire repeater is to be determined.

The two line terminals of the repeater are then connected to the L_1f and L_2f terminals of the Transmission Measuring Set, and 600-ohm resistances are connected to the repeater as balances. The gain adjustment for the direction to be examined is set to the position desired, while the gain in the opposite direction is completely supressed by setting the potentiometer to zero. We assume that the gain in a direction from "West" to "East" is to be measured, and that the "W" side of the repeater is connected to L_2f, and its "E" side to L_1f. The procedure is as follows:

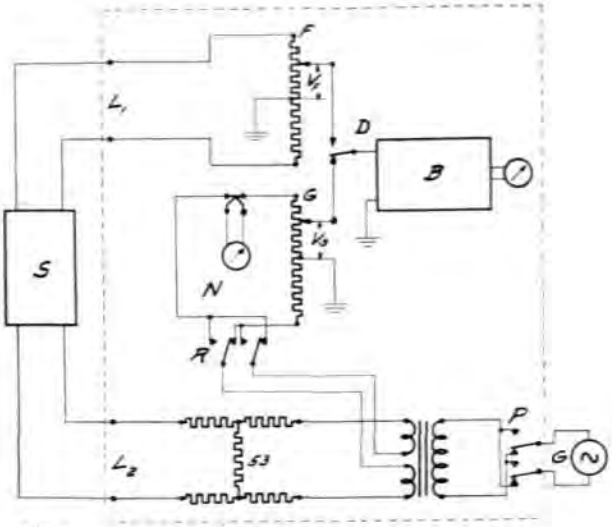
a. The main switch *A* is set in position 4. The connexions will then be as in fig. 15, where, however, the line switch *E* is left out to simplify the diagram.

b. Zero voltage level of the desired frequency is set at the line terminals as described in 1 above. As the attenuation of the artificial line 51 connected in parallel to this tap is 1.5 nepers, the "W" side of the repeater connected to L_2f will thus always receive a voltage of —1.5 neper level. Increased by a certain amount in the repeater, this is fed over the artificial line 52 (1.5 nepers) to the input choke coil of the Measuring Set, where it is measured as described in 2 above.

c. The gain sought is the sum of the *outer* scale readings (*c-c*) on *F* and the graduation marked in the same manner on *G*. To measure the amplification of the repeater in the opposite direction, the line switch *E* is reversed and the procedure repeated. The potentiometers of the repeater must of course also be re-set.



R 2072 Fig. 16. Sine curve, deformed by harmonics.



R 2073
Fig. 17. Circuit diagram for elimination of errors of measurement caused by asymmetry of harmonics.

5. Loop Attenuation Measurements.

The two ends of the line the attenuation of which is to be measured are connected to the L_1 and L_2 terminals.

The main switch *A* is set in position 5, and the measurements are taken as described in 4 above.

The readings are in this case (as in 1 and 2) taken on the *inner* of the double level-scales (*a-a*, *b-b*) of the primary potentiometer and on the corresponding scale of the secondary potentiometer. This, it will be readily understood, will give us the value of the attenuation with *reversed sign.*

Elimination of Errors of Measurement caused by Asymmetry of the Measuring Current.

When the attenuation of a network, e. g. a loop, is measured, the results obtained are sometimes different if the branches are exchanged, even if these are perfectly symmetrical. This happens if the measuring current used has so-called asymmetric harmonics, i. e. its positive and negative half-waves are not of the same amplitude, which may be caused by the generator producing harmonics which do not pass through zero simultaneously with the fundamental frequency. Fig. 16 is an extreme instance of a sine curve deformed in this way, of the equation

$$V = V_0 \sin \omega\tau + 0.20\, V_0 \sin\left(2\,\omega\tau + \frac{\pi}{2}\right),$$

where the difference in the peak values of the two half-waves *a* and *b* is very distinct. Such asymmetry may arise even if the generator used gives off a pure sine voltage. If the line contains sources of distortion (iron cores, repeaters) these may generate harmonics which arrive at the measuring point after different times of propagation, and there combine with the fundamental frequency into an asymmetric voltage curve.

We will now consider the connexions for loop attenuation measurements, as illustrated in fig. 17. Current is fed from the generator *G* to the normal circuit *N* and to the loop *S* measured, which latter terminates in the potentiometer *F*. The voltage V_F is determined by equalizing it to the adjustable calibrated voltage Vg at the secondary potentiometer *G* by means of the valve voltmeter *B*. To retain the symmetry of the line, only *half* the input voltage can be measured, as the tap of the voltage divider connected to the cathode of the valve voltmeter is thereby also earthed. The last stage of the valve voltmeter being designed as a half-wave rectifier, and thus only affected by one of the half-waves of the input voltage, it is obviously essential that *the same* half-wave of the current is measured at *F* and at *G*, if there is any asymmetry of harmonics. If we assume, for instance, that the amplitude corresponding to *a* in fig. 16 is measured at *F*, and the one corresponding to *b* at *G*, and that *a* is smaller than *b*, the value obtained for the attenuation in *S* will be too large, as the voltage will appear to be reduced more than what corresponds to the actual attenuation. If the switch *P* is changed over, the direction of the current will be altered at both measuring points, and the half-wave of greater amplitude will then be measured at *F* and the smaller at *G*. In that case too small a value for the attenuation will obviously be obtained. If the switch *R* is now also changed over, the direction of the current is reversed only in the normal circuit, and the same half-wave (viz. *b*) will then be measured at both potentiometers, and a correct attenuation value will be obtained. If, finally, *P* is changed while *R* remains in the latter position, a correct result will also be obtained, as in this case also *the same* half-wave (*a*) will be compared. The four possible combinations of the switches *P* and *R* will thus give two correct, one too small, and one too large value.

In the Transmission Measuring Set, type TRM, *P* and *R* are designed as push-button switches. The rule for their use is that *one measurement is made for each position of P. If the same result is obtained, R is in the correct position. But if different results are obtained, R should be changed over and new measurements made.*

If asymmetry is generated by the object measured, as sometimes happens for example in a repeater, agreement in values will not always be obtained with any of the four combinations of *P* and *R*. The combination giving a value nearest to the average value is then selected, and the observations are completed with the switches in that position.

It should be noted that in level measurements according to 2 and 3 above, the effect of asymmetric harmonics is automatically eliminated, as the connexion between the primary and the secondary potentiometers via the amplifier will always cause the same half-wave to be compared by the valve voltmeter.

Measurement of Transmission Levels by Means of a Local Auxiliary Generator.

If a series of measurements is to be made of different levels, but of the same frequency, it may be expedient to employ the older method of feeding the normal circuit from a local auxiliary generator. The procedure will then be the same as in *loop attenuation measurements*. The main switch is set in position 5 and the incoming line is connected to L_1. The L_2 terminals remain empty. Otherwise the operation is carried out as in 5 above.

If the *incoming level* (over-all transmission loss) is to be determined, the line switch *E* is put in position L_1 *IN*. The line will then be terminated by resistance 87 in the instrument.

For measurement of a *transit level*, the same switch is set to "Cal.". This disconnects the load resistance, and the high input impedance required for the Transmission Measuring Set is obtained.

In either case the level values are read on the scales *G* and *F* in the same way as for measurements according to 2 and 3 above.

GOTHENBURG 1931
A.-B. John Antonsons Boktryckeri
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Printed in Sweden

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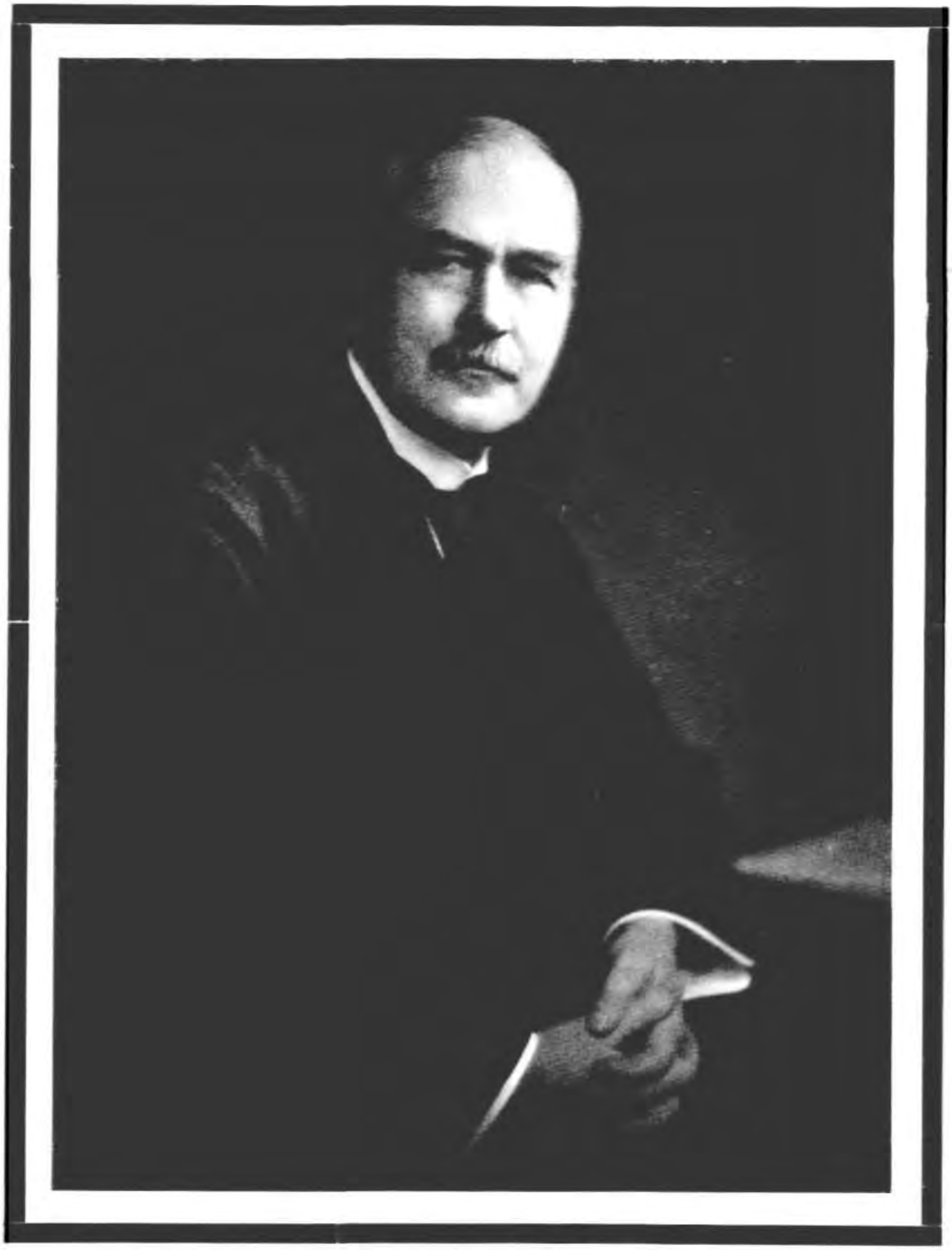

KARL FREDRIK WINCRANTZ.
Died on Febr. 6th. 1932.

In memoriam.

Karl Fredrik Wincrantz, born in Stockholm in 1874, graduated from the University of Technology in 1897, but already in 1893, while still a young undergraduate, he was engaged as an assistant in the Royal Board of Telegraphs, where he remained until 1900, when he entered the service of the Stockholms Allmänna Telefonaktiebolag as its Assistant Manager under Mr. H. T. Cedergren. During 1898—1906 he also served in the Royal Patent Office, where he was some time Secretary, some time Chief Engineer.

On the death of Mr. Cedergren in 1909, Wincrantz was appointed his successor as Managing Director of the A.-B. Stockholms-Telefon, formed the year before, which owned and ran the large private telephone net of Stockholm and neighbourhood. He led this firm untii 1918, when it was taken over by the Swedish Government.

The Aktiebolaget Stockholms-Telefon was then re-organized as the Allmänna Industriaktiebolaget H. T. Cedergren, which firm took over the Stockholm Telephon Cable Works at Älvsjö and workshops in Stockholm. Wincrantz was at the same time appointed Manager of the new firm.

In 1922, the Industri A.-B. Cedergren was amalgamated with Telefonaktiebolaget L. M. Ericsson, and with Mr. H. Johansson Wincrantz became a co-Manager of the enlarged company.

When it was resolved at the General Meeting in 1925 that the Concern should only have one Managing Director, Wincrantz was elected to the post, which he held until he retired in September 1930.

Wincrantz's contributions to the Swedish Telephone industry, in the three branches of erection, operation and manufacturing, made him a worthy successor to those great men who created and developed Swedish Telephony at home and abroad. The amalgamations with other firms and foundation of new ones in telephony and allied industries started at the beginning of this century and eventually resulting in the foundation of the present world-embracing Ericsson Concern, were continued by him with energy, purpose, and success, and on his retirement in 1930 he could lock back with satisfaction on what he had accomplished. The continued trying struggle of the last few years in the world market had undermined his strength. The ease and rest he hoped to find in private life could not, however, restore his health, and barely 18 months after his retirement he was overtaken by death, loved and respected by his friends, associates, and former subordinates.

Michael Faraday, the Founder of Electrotechnics. A Centenary.

By *Anna Beckmann*, Fil. Lic.

The progress of electrotechnics displays many interesting features. It might be said to have had its genesis in Örsted's discovery that an electric current affects a compass needle and that there is consequently a connexion between electricity and magnetism. With better reason, however, electrotechnics may be considered to have been born the day a scientist succeeded in demonstrating that an electric current could be generated in a circuit by magnetic forces. The honour of this discovery belongs to the great English scientist Michael Faraday, possibly the greatest experimental investigator the world has yet seen.

Electromagnetic induction was discovered by Faraday in 1831; so that the centenary of the birth of electrotechnics can be celebrated this year. In England the occasion was commemorated by great festivities. Scientists and engineers from all over the world gathered for joint meetings in London on September 22nd (Faraday's birthday) in memory of the man whose work has been of such significance to our time.

Seldom if ever has it been vouchsafed to a single man to make such a number of remarkable discoveries as did Michael Faraday. One would think that such magnificent results could only be reached by a person who had from infancy received a careful and extremely good education —but this was not the case with Faraday. He grew up in poor circumstances and was given a very deficient training. He acquired his knowledge by himself with remarkable industry.

Michael Faraday's parents belonged to a Yorkshire family. His father, James Faraday, was a blacksmith, his mother a farmer's daughter. Soon after their marriage in 1786 they moved to London, where they settled in Newington. Here Michael Faraday was born on September 22nd 1791, the third of four children. His parents were very poor, and the family often suffered from want and privation. This was partly because of the bad times and partly also because James Faraday was delicate and frequently unable to work. Michael's mother lacked booklearning, but she was a very energetic and capable housewife, never failing in tenderness. Faraday's parents belonged to a sect called the Sandemanians, who as a rule congregated weekly for meetings and devotions. Faraday was thus early imbued with religious faith, and retained this inflexibly all his life from childhood.

The education Faraday received otherwise consisted in bare instruction in the three R's. At the age of 13 he became errand-boy to a bookseller, who was also a bookbinder. He was so conscientious in his work that after a year his employer offered to teach him bookbinding for nothing. This gave Faraday his first opportunity, and he made good use of it. He mentioned this later in a letter to a friend: "I entered the shop of a bookseller and bookbinder at the age of 13 in the year of 1804, remained there eight years, and during the chief part of the time bound books. Now it was in those books in the hours after work that I found the beginning of my philosophy. There were two that especially helped me, the 'Encyclopædia Britannica', from which I gained my first notions of electricity, and Mrs. Marcet's 'Conversations on Chemistry', which gave me my foundation in that science.

Do not suppose that I was a very deep thinker, or was marked as a precocious person. I was a very lively, imaginative person, and could believe in the Arabian Nights as easily as in the Encyclopædia; but facts were important to me and saved me. I could trust a fact, and always cross-examined an assertion. So when I questioned Mrs. Marcet's book by such little experiments as I could find means to perform, and found it true to the facts as I could understand them, I felt that I had got hold of an anchor in chemical knowledge, and clung fast to it."

Faraday's employer gave him permission to attend some popular lectures in physics which were given in London 1810 and 1811. Here Faraday made the acquaintance of other young fellows who were, like himself, interested in natural science. He borrowed books from them and so extended his knowledge.

A member of the Royal Institution who was a customer of Faraday's employer noticed the keen interest of the youth in science, and in the spring of 1812 offered to let him attend four lectures by Sir Humphry the notes of which he subsequently worked up and illustrated with excellent drawings.

In the autumn of 1812 Faraday's apprenticeship was ended, and in October he was engaged as an expert bookbinder by a French emigrant in London. This individual was hot-tempered and most irrascible, and Faraday did not like his new job. He wanted very much to abandon business, which he considered selfish and inferior, in order to devote himself to science, the disciples of which all seemed to him magnanimous and noble minded. He then wrote to Davy, enclosing his lecture notes. Davy sent a kind reply by return, and in May 1813, when a post as assistant became vacant at the Royal Institution, he offered it to Faraday, who gladly abandoned his bookbinding for a life of science.

The Royal Institution is a private association founded in London in 1799. Its object is to promote science, and to work for the spread of useful knowledge, and for that purpose it arranges lectures, both popular and technical. It owns a house in the West End of London with chemistry and physics laboratories, as well as a very large scientific library, a collection of instruments, lecture rooms, reading rooms, etc.

Faraday became attached to the Royal Institution at the age of 22, and worked there all his life. At first his duties were unimportant, but his conscientiousness and great capacity for work, and above all his burning interest in science, gradually contributed to the improvement of his position. In 1825 he was elected a member, and the same year became Head of its laboratories. At this time his long activity as a lecturer at the institution began—he was a brilliant lecturer and held the attention of his audience not only by numerous skilful experiments but also by his verbal art. In 1832, when the Royal Institution was in economic difficulties and it was suggested that savings should be made by cutting down the salaries of the officials, a member, Mr. John Fuller, endowed a professorship in chemistry. Faraday became the first holder of this appointment, and was in 1833 made Fullerian professor for life.

When in 1813 he was engaged by the Royal Institution, he was given, as mentioned above, a very subordinate position. But he had the great advantage of working under the personal supervision of Davy, in whose scientific investigations he assisted, thus gaining a wide experience. At the same time he continued his spare-time studies and improved his knowledge with purposeful perseverance.

In the autumn of 1813 Davy set out on some travels, accompanied by Faraday. These lasted until the spring of 1815, included visits to France, Italy, Switzerland, and the Tyrol, and were of great importance to Faraday's education. He had the inestimable advantage of working as Davy's assistant all the time, and was also brought into contact with many prominent scientists, of whom several later became his warm and admiring friends.

On his return home he resumed his position as assistant at the Royal Institution. In 1816 Faraday's first paper appeared, published by the institution in its "Quarterly Journal of Science", an analysis of a kind of native caustic lime from Tuscany. The paper was not exceptional, but to Faraday this first public appearance was an important event. This paper was soon followed by several other short communications. In 1820 he wrote an account of two newly discovered compounds of chlorine and carbon, and one of iodine, carbon and hydrogen, a paper of such importance that it was included in the Philosophical Transactions of the Royal Society. During the same year he had eagerly collaborated with Stodart to produce improved and rustless steels, though without success.

While still engaged in chemical experiments and continuing his attempts to produce rustless steel, Faraday found time to devote attention to the new discovery which in 1820 aroused great interest in the scientific world, viz. Örsted's demonstration that the electric current affects a compass needle. Ampère had rapidly supplemented the work of the Danish scientist by more complete experiments, and had produced his theory of magnetism as caused by electric currents. During the summer of 1821 Faraday wrote an account for the Quarterly Journal of the newly discovered electro-magnetic phenomena; in doing this he repeated the experiments made by others, and thus obtained practical experience in the new sphere opened up for research. Already in October he was ready to publish his own observations on electromagnetism. He modestly writes: "After the great men who have already experimented on the subject, I should have felt doubtful that anything I could do could be new or possess an interest, but that the experiments seem to me to reconcile considerably the opposite opinions that are entertained on it. I am induced in consequence to publish this account of them."

The various opinions here mentioned by Faraday had to do with the direction of the magnetic force of the current. Certain investigators believed they had observed direct attractions and repulsions between a straight current-carrying wire and a magnet. Faraday soon established that the magnet poles instead try to move in circles round the track of the current. He also designed an apparatus to demonstrate how a magnet pole revolves round a current, and vice versa. The design is of great historical interest; with all its deficiencies it is nevertheless the first example of an electric motor. It was, however, still too early to utilize electricity as a driving power, as long as galvanic elements were the only known sources of current; that current was far too expensive.

In 1825 Faraday became a member of the Committee appointed by the Royal Society to investigate the possibility of manufacturing glass for optical purposes. For four years he worked very hard at this task but did not succeed in attaining any results of practical value. A kind of glass produced by Faraday in these experiments, a heavy lead glass made by fusing boric acid, silica and lead oxide, and having a refractive index of up to 1.9 for violet light, later became of great importance, however, in his discovery of the influence of magnetism on light.

However busy Faraday was with these labours and with his work at the Royal Institution, he found time for other investigations also. During 1823 he succeeded in liquefying certain gases which had not previously been produced in liquid form e. g. chlorine, carbon dioxide, ammonia, ethylene, and others. In 1825 he discovered the new carbohydrate benzene and experimented with naphthalene sulphonic acid. During this work his thoughts were again and again attracted by the electromagnetic phenomena. Intuitively he felt that there was more to be discovered. It was a well known fact that static electric charges produced charges in adjacent conductors by induction, why then should not electric currents have a similar effect? He also reasoned in another way: "It appeared very extraordinary, that as every electric current was accompanied by a corresponding intensity of magnetic action at right angles to the current, good conductors of electricity, when placed within the sphere of this action, should not have any current induced through them, or some sensible effect produced equivalent in force to such a current."

Such reflections caused Faraday to make a number of experiments. Although one after another gave negative results, he did not tire, but continued with undiminished energy, while varying the conditions under which they were made. Finally his labours of years were rewarded. At an experiment made on August 29th 1831, he observed for the first time that an electric current was caused by magnetic influence. He had wound two coils of insulated copper wire on a cast iron ring, the ends of one being connected to a galvanometer, of the other to a battery of 10 galvanic cells. By accident he observed the galvanometer at the moment when the circuit was closed and found that the needle was strongly deflected, though it soon resumed its original position. The effect was thus not, as Faraday had expected, a permanent effect of the primary current on the secondary circuit, but a momentary reaction which, as Faraday writes, "... partook more of the nature of the electrical wave passed through from the shock of a common Leyden jar than of the current from a voltaic battery".

The idea given to Faraday by this observation he followed untiringly. He repeated old experiments where no effect had before been noticed, and determined the cause of his previous failure. As he had always looked for permanent effects, the sudden and quickly disappearing swing of the galvanometer needle had so far eluded his attention. By numerous experiments he thus in the autumn of 1831 discovered the conditions of electromagnetic induction, both that observed in electric currents—he called this to begin with volta-electric induction—and that caused by magnets, which he called magneto-electric induction.

This fresh discovery assisted Faraday to explain a mysterious fact which had caused much perplexity, viz. the so-called rotation magnetism discovered by Arago in 1824. Arago's phenomenon consists in a magnet suspended close above a horizontal copper disc swinging when the disc is rotated. By turning the copper disc fast enough it is even possible to make the magnet follow the movement and turn round. Poisson had written a theoretical treatise on the phenomenon, and other attempts at explanation had been made by John Herschel and Babbage, who attributed the effect to a kind of induced magnetism; nobody, however, had satisfactorily explained the curious fact that the disc was magnetic when it moved, but not at all when it was at rest.

As soon as Faraday had discovered electromagnetic induction he saw, however, that Arago's phenomenon might be caused by electric currents induced in the metal by the motion of the disc. He also succeeded in producing a continuous electric current by rotating a copper disc in a magnetic field. The edge of the disc was placed between the poles of a large and powerful horseshoe magnet, a galvanometer was connected by one lead to the centre of the disc and by the other to a brush contact touching its edge. When the disc was rotated rapidly about an axis at right angles through its centre, the galvanometer was deflected an amount which depended on the speed of rotation. Regarding this experiment Faraday wrote in a letter to a friend: "The new state has enabled me to make out and explain all Arago's phenomena of the rotating magnet or copper plate ... I am even half afraid to tell you what it is. You will think I am hoaxing you, or else in your compassion you may conclude I am deceiving myself. However you may do neither, but had better laugh, as I did most heartily, when I found that it was neither attraction nor repulsion, but just one of my old rotations in a new form. It is quite comfortable to me to find that experiment need not quail before mathematics, but is quite competent to rival it in discovery ..."

Faraday's mathematical training was of course very slight, but, although he was unable to build up his theories by the help of mathematics, he acquired a very clear conception of the forces of nature. To explain the phenomena of induction he assumed at first that the conductors were put into a peculiar state of tension which he called "electrotonic", but when he stated the laws for the genesis of the current he made use of a new expression "magnetic curves". He says: "By magnetic curves, I mean the lines of magnetic force, which would be depicted by iron filings; or those to which a very small magnetic needle would form a tangent".

These lines of force were soon to play a very important role in Faraday's theoretical speculations. He became convinced that the lines of force were something palpable and actually existing, an opinion which was in direct conflict with the generally accepted belief in an action at a distance without any intermediary. As early as January 1832 Faraday deserted the theory of the electrotonic condition, and put forward the hypothesis that induction currents are set up in every conductor which cuts magnetic lines of force: "This law, by rendering a perfect reason for the effects produced, take away any for supposing that peculiar condition, which I ventured to call the electrotonic state", he writes. The lines of force may be cut if the conductor is moved in the magnetic field, or if the conductor is stationary and the lines of force are assumed to move. This latter occurs if the induction is caused by variable currents; when the current increases the lines of force spread in ever-widening circles round the conductor; when it decreases, they contract and return towards the disappearing electric current.

Faraday pointed out that the phenomenon of induction makes it possible to build a new kind of electrical machine. "It is quite true that the force of the current thus evolved has not as yet been increased so as to render it available in any of our ordinary applications of this power; but there appears every reasonable expectation that this may hereafter be effected; and probably by several arrangements.—I have rather, however, been desirous of discovering new facts and new relations dependent on magneto-electric induction, than of exalting the force of those already obtained; being assured that the latter would find their full development hereafter."

Faraday could hardly have imagined how powerful and imposing these electrical machines of the future were to become, even though he was thus foretelling them. As soon as his discovery became known, inventors tried to make use of it. Pixii in 1831 designed an alternating current machine in which a permanent horse shoe magnet was rotated in front of a couple of wire coils, the "armature". The next year he added a commutator to rectify the current. In 1833 Saxton invented an electromagnetic machine, where the armature was rotated in front of the poles of a fixed magnet.

But progress was slow. The induced currents were at first used only for medical and physiological purposes; they were also employed in telegraphy, e. g. in the Gauss and Weber electrical telegraph of 1833. The Siemens cylinder inductor was also originally intended for telegraphy; it is now used for working small bells in telephones. As long as permanent steel magnets were used to produce the magnetic field, it was, however, impossible to obtain strong enough currents for practical technical use. In 1851 Sinsteden suggested that electromagnets should be employed instead, but as these were fed by current from galvanic cells they were still costly to use. Brett had already in 1848 thrown out the suggestion that the current generated in the armature might be passed through a coil wrapped round the steel magnet in order to increase the effect of the latter. Siemens was the first to grasp that the magnets could be entirely driven by the auto-generated currents, and in January 1867 he published an account of his new invention, the dynamo machine. Simultaneously Wheatstone had got more or less the same idea; his invention was announced a month later. The dynamo had, as Siemens said, "provided a cheap and convenient means of producing electric current of unlimited strength wherever power is available", a prediction which has proved remarkably true.

But it is not only the powerful induction currents which have become of importance. The weak currents which serve modern telephone communication are of equal consequence. The American artist Morse, who had earlier devoted his life to painting, was informed of Faraday's invention during a journey to Europe, 1829—1832. Already interested in the practical use of electricity, he now had another reason for pondering the possibilities of the electric current, and is supposed once to have said: "If the presence of electricity can be made visible in any part of the circuit, I see no reason why intelligence may not be transmitted instantaneously by electricity". Nor was it long before he produced his electromagnetic telegraph instrument. Direct transmission of the spoken word was, however, long delayed, and it was not until 1876 that Bell patented his telephone. After Hughes invented his microphone in 1878 progress was rapid, and the telephone has since made great strides towards perfection. The weak induction currents not only spread news in a fraction of a second, but are also capable of reproducing most admirably the human voice with all its accents and nuances.

While applied science thus took charge of Faraday's discovery and harnessed it for practical use, he himself continued his researches and his efforts to make further discoveries. His investigations of electromagnetic induction, which were carried out in a few months of the autumn of 1831, deal with the newly observed phenomena so thoroughly and exhaustively that nobody has since added anything of importance, with a single exception, namely, the discovery of self-induction. An announcement "On the influence by induction of an Electric Current on itself", was published by Faraday in January 1835. The impulse to this investigation was given by a young man, William Jenkin, who had noticed that a powerful shock may be received from a single galvanic cell when the circuit is closed through a wire wound round an electromagnet. Faraday confirmed the truth of Jenkin's observation, and made a series of experiments on self-induction and the extra current.

When Faraday had thus thoroughly studied electromagnetic induction, he began to investigate whether induction currents might not be of the same nature as galvanic currents. For this purpose he studied thoroughly electricity produced in various ways, e. g. by friction and galvanic elements, and even procured electric fishes to test whether the electricity they develop is similar to that obtained from other sources. The result convinced him that all electricity is of the same nature. His attention had during these experiments been especially directed to the chemical effects of the electrical current, and these were the objects of his next investigation, published in 1833 and 1834. Faraday first states that certain substances only conduct electricity in a fluid state; they must first be either melted or dissolved in water. These substances, which are chemically decomposed by the passing of the current, Faraday called electrolytes; the process he called electrolysis. He further introduced the now generally accepted terms electrode, cathode, and anode; when he wanted a name for the substances moving to a particular electrode he did not wish to call them electro-positive or negative, as he considered that these expressions involved an unproved hypothesis. He suggested instead the names anion and cation, with the term "ion" including them both. Numerous exhaustive experiments resulted in Faraday formulating his well-known laws of electrolysis, and the publication of a first table of ions and their electrochemical equivalent weights. His work strongly convinced him of the close connexion between chemical affinity and electrical effect, and he concluded that every atom was associated with an electric charge which, judging by the amount of electricity required to set free quite small quantities by weight of chemically combined matter, must be enormous.

He next approached the theory of galvanic cells, and attempted to solve the problem of the origin of their electricity. On this point divergent opinions were held and the waves of battle ran high between those scientists who, with Volta, explained the effect of the cell as depending only on contact electricity, and those who assumed that chemical forces cause the current. Faraday considered it most natural to seek the origin of the current in chemical changes in the cell, and proved this by numerous experiments. This did not convince the adherents of the contact theory, however, and Faraday was compelled to deal with the question once more, in a paper published in 1839. In this are described new experiments, and finally an argument produced, which should really have been decisive if only his opponents had been capable of grasping its full significance. He points out that the contact theory involves a creation of force, unlike every other experience. "Were it otherwise than it is, and were the contact theory true, then, as it appears to me, the equality of cause and effect must be denied. Then would the perpetual motion also be true; and it would not be at all difficult, upon the first given case of an electric current by contact alone, to produce an electro-magnetic arrangement, which, as to its principle, would go on producing mechanical effects for ever". This was published three years before Robert Mayer propounded his theory of the conservation of energy, and before Joule had carried out his celebrated experiments. The conviction that a perpetuum mobile is impossible and contrary to all experience was thus held earlier by Faraday. It is therefore all the more curious that later on he never completely grasped the significance of this principle of energy. In 1857 he published a paper "On the Conservation of Force"; although in this he quotes Helmholtz's work of the same title, the ideas propounded in the latter are obviously partly strange to him. This must be partly ascribed to the unfortunate nomenclature, "force" still being used to mean "energy". Faraday asked how the fact that the force of gravity varies inversely as the square of the distance can be reconciled to the principle of the conservation of force. In his opinion, part of the force of gravitation must, when the distance between the masses is increased, be changed into another force of whose existence he was convinced but which he sought in vain.

His labours on electrolysis and galvanic cells led Faraday to investigate the distribution of the electric force in insulators. He had already maintained in his theory of electrolysis that the electric force is not confined to the poles alone, but occurs at every point of the electrolyte, the particles of which are polarized before being split up. In Faraday's opinion, corresponding conditions obtain in insulators. In these also electric tension will cause polarization of the molecules, although no breaking down occurs. He was then led to think that all induction occurs only between neighbouring particles, and that electric action at a distance is always indirect, through some intervening medium. This theory was in conflict with current opinion, according to which electric charges exercise direct influence on distant bodies without the participation of any intervening medium. Faraday himself says that he hesitated long before breaking with the old opinions, but numerous experiments had confirmed his own ideas. As decisive in favour of the latter he considered the experiments showing that influence can be transmitted along curves —which he called "lines of inductive force"—as he had found that he could by induction electrify an insulated ball, even if it were placed behind an earthed conductor and was thus protected against direct effects.

Faraday then continued his experiments on the course of electric lines of force in various substances, and also examined whether different dielectrics had any specific effect on the induction which they transmit. For this purpose he used a spherical condenser which could be provided with various dielectrics such as shellac, glass, and sulphur, and discovered that each substance has a specific inductive capacity.

These experiments of Faraday's on electric lines of force are also connected with those made by him to find out whether electricity can occur as a separate fluidum without the presence of matter, or whether it is only to be regarded as a mere power of matter, like gravitation. His attempts to prove the independent existence of electricity by giving an independent charge —either positive or negative—to some substance, failed completely. These results made him consider electric induction and electric force as an effect of the particles of matter, in which positive and negative electricity is always developed in exactly equal quantities. Every insulated conductor, e. g. a small ball in the centre of a room, was regarded by Faraday as the inner coating of a Leyden jar, the walls of the room as the outer coating, and the lines of force as passing through the air from the electrified ball to the induced charge on the walls. Faraday made a series of experiments, trying to produce in an insulator an independent space charge. For these experiments his celebrated cage was built—a cube of copper net with a 12 ft. edge, in which he shut himself up with his measuring instruments. All attempts to charge the air in this cage were vain; the most sensitive electrometer inside it was not deflected, although the outside of the cage was strongly charged and emitted strong sparks and brush discharges. These investigations led Faraday to the conclusion that induction is the essential part of electrical phenomena, and seems to be chiefly an effect between adjacent particles, which are polarized so that parts of them become positive and parts negative. The induction effect may be regarded as though exercised along lines connecting the charged boundary surfaces. With the assistance of these lines of force, Faraday explained all the power effects of static electricity. Interest is thus transferred from the charged objects to the phenomena occurring in the intervening media, endowing them with the greater importance. The actual charges are of only secondary importance, being merely the terminal points of the lines of force.

In Faraday's opinion the force of gravitation also is exercised along lines of force, and he considered every material particle a centre from which such lines emanate to the most distant parts of space. He even suggested that these lines transmitted vibrations; light and other radiation would thus be a wave motion of the lines of force, which are a substitute for the ether, and are conceived as penetrating all bodies and all space. These ideas, which he himself calls but "the shadow of a speculation", are to a certain extent reminiscent of some modern theories.

Faraday's hypothesis of magnetic lines of force led to further fruitful experiments. He had long sought in vain for any effect of electromagnetic forces on light. Numerous unsuccessful experiments could not disturb his conviction that light and electromagnetic force were connected, and he persisted in his investigations until they were finally crowned with success. In November 1845 Faraday submitted to the Royal Society a remarkable paper with the title "On the magnetization of light and the illumination of magnetic lines of force". In this he describes his discovery that magnetic forces are able to rotate the plane of polarization of light. In his experiments the light of an Argand lamp was polarized by reflection in a slab of glass and analysed by a nicol prism. Between the polariser and the analyser a magnetic field was produced by means of electromagnets, and the lines of force of this field were nearly parallel to the ray of light.

What helped Faraday to make his discovery was a piece of glass of the kind which he had obtained 16 years before when trying to make optical glass. Under the influence of the magnetic field, the plane of polarization of the light was strongly rotated by this heavy lead glass. Faraday studied the phenomenon with his usual care, established the connexion between the direction of the lines of force and the direction of rotation of the plane of polarization, and compared the effects of various substances.

The new discovery confirmed Faraday's opinion of the nature of the lines of force; "there is no doubt", he writes, "that the magnetic forces affect the structure of matter".

It is but natural that, when such thoughts had once been started, he should be driven to examine the behaviour of various substances when subjected to strong magnetic forces. It was not long before his next work followed, in December 1845: "On new magnetic actions, and the magnetic condition of all matter". Here he describes diamagnetism, and demonstrates that practically all substances are affected by magnets. After examining the heavy lead glass, and finding that it was repelled by a strong magnet, he tested quite a number of other substances. His first list of diamagnetic bodies contained a variegated collection of substances, ranging from certain elements and salts to mutton, beef, blood, apple and bread. A large number of metals was also examined, and Faraday found amongst them the most diamagnetic substance known, namely bismuth. Several metals and even a few other substances were, on the other hand, attracted by magnets; these he called paramagnetic.

The following years were devoted to investigations on magnetism in crystals, and on the magnetic properties of gases—he found that oxygen was paramagnetic, while others, e. g. ethylene and cyanogen, were diamagnetic.

Faraday's investigations threw fresh light on magnetic phenomena. With justifiable pride he could end one of his papers with the following words: "A few years ago magnetism was to us an occult power, affecting only a few bodies; now it is found to influence all bodies, and to possess the most intimate relations with electricity, heat, chemical action, light, crystallization, and, through it, with the forces concerned in cohesion; and we may, in the present stage of things, well feel urged to continue in our labours, encouraged by the hope of bringing it into a bond of union with gravity itself".

Speculations on the force of gravity occupied Faraday's thoughts a great deal. Following his opinion that all natural forces have a common origin, or may be regarded as manifestations of one and the same cause, he attempted to find a connexion between gravitation and other physical phenomena. With this goal before him he made numerous experiments, and one of these series is described in a paper of 1850, where he gives an account of his vain efforts to produce induced currents by the effect of the force of gravity, e. g. in solenoids allowed to fall freely. The labour devoted by him to these and other similar experiments was considerable and, although the results were negative, he never abandoned his firm belief in the connexion of all natural forces, just as he never doubted that gravitation was transmitted along lines of force in the same way as electromagnetic forces. It is not surprising that he held so faithfully to an opinion which had led him to so many remarkable discoveries. And yet it was always clear to his critical mind that all hypotheses must be regarded as doubtful—"it is better to be aware, or even to suspect, we are wrong, than to be unconsciously or easily led to accept an error as right". He writes: "It is not to be supposed for a moment that speculations are useless, or necessarily hurtful. They should ever be held as doubtful, and liable to error and to change; but they are wonderful aids in the hands of the experimentalist and mathematician... They lead on, by deduction and correction, to the discovery of new phenomena, and so cause an increase and advance of real physical truth, which, unlike the hypothesis that led to it, becomes fundamental knowledge not subject to change".

This statement has been verified again and again, especially as regards Faraday's conception of the electromagnetic field, which has left its mark on the opinions of later times. Although his contemporaries hesitated to accept his theory of the electric and magnetic lines of force, this nevertheless began to spread when Maxwell gave mathematical form to Faraday's hypothesis, and soon ruled science. It formed the basis of Hertz' celebrated experiments of 1887, when long electromagnetic waves were for the first time produced and examined. Hertz himself considered that the significance of this experiment was only to give strong additional support to the Faraday-Maxwell theory. The future soon showed that practical use could be made of these waves; in our days, wireless telegraphy and broadcasting bear evidence of their great significance to intercommunication. In this sphere also the work of Faraday has borne rich fruit. Not only his experimental work but also his theoretical speculations have had enormous influence on both pure and applied science, an influence which cannot be overestimated.

Faraday's scientific work was of imposing grandeur, so comprehensive that it might have sufficed to fill his life completely. Yet he found time for many other things besides. Foremost among these activities outside his researches was that of being adviser to Trinity House, the association which supervises and takes care of the lighthouses of England. This is not run by the State, but by a private corporation which has since the time of Queen Elizabeth had the privilege of organizing lighthouses, beacons and buoys. In 1836 Faraday agreed to act as scientific adviser to this association, and kept the position for nearly 30 years. He undertook a great many very comprehensive and conscientious investigations for Trinity House, tested various kinds of lamps, reflectors, and lens systems, examined oils, and even compared various kinds of cotton for wicks. But his investigations were not restricted to the sources of light alone; we find for instance among his reports also analyses of paints and drinking water.—In 1854 electric light generated by Faraday's induction currents was first proposed for lighthouses; in 1858 the "magneto-electric" light was tested at South Foreland; it was at that time not yet able to stand comparison with oil lamps, but by 1859 the devices had been improved, and Faraday had the satisfaction of being able to report the superiority of electric light. In 1860 it was installed at Dungeness. The greater part of Faraday's last reports to Trinity House contained exact account of the new lighthouse light. Even at 70 years of age he undertook repeated trying and troublesome journeys to convince himself on the spot of the superiority of electric light. The highest reward for his self-sacrificing activity in the interest of navigation was surely the knowledge that his own great discovery could be used for "the great object of guiding the mariner across the dark and dreary waste of waters".

An account of Faraday that does not include at least a short account of his personality and character, cannot give a true picture of him. "Not half his greatness was incorporate in his science, for science could not reveal the bravery and delicacy of his heart", writes Tyndall, Faraday's successor and friend, who was very closely associated with him.

His contemporaries are unanimous in their opinion that Faraday possessed rare personal charm. As an example we will quote a statement by the German doctor and scientist Helmholtz, who had met Faraday several times. He praises his courteous helpfulness and charming social manner, and says: "Die vollkommene Einfachheit, Bescheidenheit und ungetrübte Reinheit seiner Gesinnung hatte etwas Bezauberndes, wie ich es bei keinem andern Manne je wieder kennen gelernt habe."

By all accounts Helmholtz's opinion seems to have been common to all who were brought into contact with Faraday. His friend Tyndall relates, however, that beneath his meekness and gentle mildness a volcano was smouldering. At bottom he was a fiery and easily moved nature. His wonderful spirit may have been inherited from his Irish ancestors, for according to the family tradition the Faradays were descended from Ireland. By great self-control he had made his inner fire the driving force of his life instead of wasting it in useless passion, and he seldom lost his temper, or even his calm.

His uncommon orderliness was highly characteristic. Even the most intricate questions were cleared up astonishingly easily under his guidance. His exceptionally methodical mind has stamped in particular all his scientific work. When he planned an investigation he used to employ a kind of card index to assist his memory. He wrote down on slips of paper the various problems which he hoped to solve by his experiments. These slips were arranged in the same order as that in which he intended to make his experiments. When the question on one of the slips had been answered he took it away, and others were added in the course of the investigation. From the answers he composed his manuscripts. He has left no less than eight volumes of these, containing 15 389 paragraphs. Guided by them, Faraday wrote his accounts for the Royal Society, which were printed in the Philosophical Transactions and subsequently published, collected into one book. His "Experimental Researches" are so well planned and so logically and accurately carried out that the total effect is good, even though it is really only collected accounts of one experiment after another. This is all the more remarkable as the discoveries described in them were absolutely new.

This peculiar method was partly a consequence of Faraday's early failing memory. When only 40, he began seriously to complain of loss of memory; afterwards he had indeed largely his sense of order to thank for his successes. When his memory failed him, he substituted for it his system of registration, and was thus able to maintain order in his investigations and carry them to a successful issue.

About 1830 Faraday became aware that his strength was not enough for both science and other occupations. Towards the end of the year 1830 he was increasingly called upon for analyses and other practical work, and could easily have earned a very large income, but he saw clearly that in that case he would have to sacrifice his research work. With the alternatives of wealth and science before him, he chose the latter, to the lasting benefit of mankind, but he never became wealthy. His additional income, which in 1831 amounted to £1 090, dropped the following year to £155, and subsequently never rose above a few tens of pounds a year.

And not only did Faraday give up making money, but he also relinquished social life, and after 1834 he consistently refused invitations to dinner, thus saving up as far as possible the strength at his disposal. In scientific investigation alone he did not spare himself, even though he knew that writing a paper always caused him great mental exhaustion.

After such efforts Faraday needed complete rest. He then liked to leave London for the seaside or some other place where he could enjoy wide views and the beauty of nature. On these occasions he was frequently so tired that he could do nothing but sit at his open window, gazing at the sea and sky. On such occasions he was ever accompanied by his wife, who took loving care of him. His marriage had taken place when he was 30, and was an exceptionally happy one.

When Faraday was nearly 50 he became so seriously troubled by loss of memory and vertigo that he thought he would be incapable of doing any more work. His wife then took him for a holiday to Switzerland. During this trying time, when Faraday feared that his strength was leaving him for ever, his character showed up in the most beautiful light. He was neither dejected nor impatient, he found no reason to complain, but only expressed his gratitude for all the kindness and affection he received. It was several years before he recovered his health, and he was only gradually able to resume his work. But in 1845 his discovery of the influence of magnetism on light showed that his investigations still bore the stamp of genius, and another period of fresh exertions followed. During later years his memory deteriorated still more; it even happened once that he worked for six weeks to obtain results which he had already established nine months earlier—his notes showed this fact, but he himself did not have the faintest recollection of it.

Faraday's lecturing work, which had in his early years been a source of joy to him, later became a burden, and in 1862 he completely dropped it. He worked for Trinity House until 1865, when his failing strength compelled him to discontinue his work as its scientific adviser.

He had written to the Royal Institution already in 1861, expressing a wish to resign his onerous duties there. In that letter he said amongst other things: "My life has been a happy one, and all I desired. During its progress I have tried to make a fitting return for it to the Royal Institution, and through it to science. But the progress of years (now amounting in numbers to threescore and ten) having brought forth first the period of development, and then that of maturity, have ultimately produced for me that of gentle decay. This has taken place in such a manner as to make the evening of life a blessing; for whilst increasing physical weakness occurs, a full share of health free from pain is granted whith it, and whilst memory and certain other faculties of the mind diminish, my good spirits and cheerfulness do not diminish with them."

SARAH AND MICHAEL FARADAY.

Faraday spent his last years quietly and calmly under the loving care of his wife. The end came on August 25th 1867. Quietly he met eternal rest; his death was a calm falling asleep.

Faraday had received rich and ample recognition during his life time. The Royal Institution had the primary advantage of his work, and on many occasions liberally acknowledged its value. Honours were showered upon him lavishly from all quarters; learned societies all over the world made him a member. He himself sought no distinctions or places of honour, although he was pleased at all the sympathy and goodwill so abundantly extended to him.

Faraday was an exceptional personality, serene and well balanced in mind as well as in work. Any task he accepted was carried out loyally and purposefully, and neither ambition nor desire of money tempted him to fall below the scientific ideal he had set up. His whole life gives an impression of great and tranquil harmony.

Faraday's life-work filled his contemporaries with admiration. Posterity is reaping the rich harvest of his effort, and has still more reason to recall with gratitude this great scientist, whose discoveries have founded modern electrotechnics and made possible the mighty progress of industry and culture.

The Ericsson Standard Two-Wire Repeater.

Communication from the Research and Development Department.

By *Torbern Laurent.*

1. Introduction.

In long distance telephony two different systems of lines with repeaters are used, called 2- and 4-wire circuits. With 4-wire circuits, a much greater range can be obtained than with 2-wire circuits, but on the other hand 4-wire lines are more expensive to build per km. than 2-wire lines. 4-wire circuits are therefore usually employed only at distances exceeding the maximum range of 2-wire circuits, while the cheaper 2-wire circuits dominate at shorter distances. As there are many more short lines than long ones, the aggregate length of 2-wire lines is at least equal to that of the 4-wire lines. The relation of 4- to 2-wire circuits will obviously be a function of the maximum range of the latter, as any increase of range will make telephony by 2-wire circuits possible at greater distances, for which the building costs may thus be accordingly reduced. An improvement of 2-wire circuits as regards increase of maximum range without appreciable increase of costs of construction will therefore always be valuable, even though it may not be possible to attain the same range as with 4-wire circuits, which at the present stage of technical progress seems fairly hopeless.

The phenomena primarily limiting the range of a 2-wire circuit are, that reflections occur in the lines, chiefly because the inductances of the loading coils are not exactly alike, the line-capacities between the loading points are not exactly alike, and the impedances of lines and repeaters are imperfectly matched.

The Ericsson standard 2-wire repeater is designed to comply with the demands necessarily made on 2-wire circuits when their range is utilized to the utmost limit. One feature is thus a special filter design, allowing very exact matching of line and repeater impedances. The use of Ericsson standard 2-wire repeaters, and improved compensation of capacity deviation in the lines, may very likely treble the present range of 2-wire circuits without any appreciable increase of cost for their construction.

A particularly interesting novelty in the Ericsson 2-wire repeater is a device for amplification adjustments, by which the amplification of the repeater can be adjusted while working to within $\pm$ 0.01 neper by a few simple manipulations without the assistance of measuring devices or the like. This is particularly valuable in lines with many repeaters, where summation effects may be troublesome.

This article begins with a short discussion of the range problem, the various solutions of the problem on which the Ericsson standard 2-wire repeater is based are then outlined, and the principles and design of the Ericsson system are finally described.

Patents have been applied for in most countries for the devices used in the Ericsson 2-wire system, and these applications refer to the following Swedish patents granted or applied for:

Swedish patent No.	66958
" " "	66516
Swedish patent application No.	1465/28
" " " "	3046/29
" " " "	3449/29
" " " "	5107/29
" " " "	1835/30
" " " "	4509/30
" " " "	5259/30
" " " "	1046/31
" " " "	1186/31
" " " "	2035/31
" " " "	2858/31

Among treatises which may usefully be studied in conjunction with this paper, we may mention *"On Cross-Talk and other problems of a kindred nature"*, *"The Svenska Radioaktiebolaget Valve Testing Set"* and *"The Swedish Voice-Frequency*

Signalling System", published in the L. M. Ericsson Review in *1928*, *1930* and *1931* respectively.

2. The Influence of Echo Attenuation on the Range of Two-Wire Circuits.

S in fig. 1 is what in the following will be regarded as a repeater section, consisting, as we see, of a line joining two repeaters, with half a repeater at each end. *D* signifies differential transformers, and *B* line balances. *A* 2-wire line is assumed to consist of *n* repeater sections, in all of which

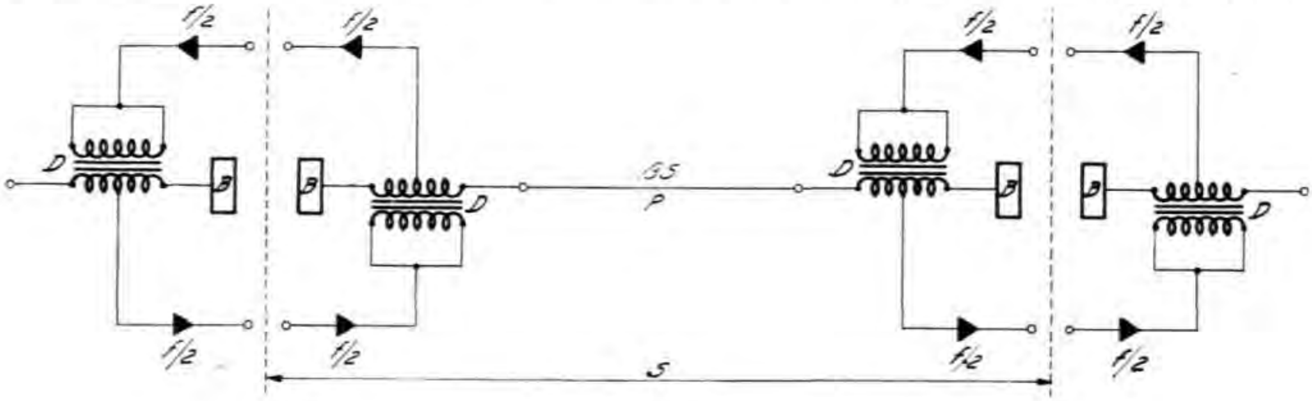

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Fig. 1.

βs = the attenuation between the repeaters.

f = the effective amplification of the repeaters (measured between their line terminals).

p = the echo attenuation in the line of the repeater section, measured from one end of the line when the other is terminated by half a repeater (in which obviously no singing can occur).

We will now compute the resulting echo attenuation *P*, measured from one end of the line, and for that purpose introduce the expressions

$$\left.\begin{aligned} p_0 &= p - f \\ b &= \beta s - f \end{aligned}\right\} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; \text{(a)}$$

b is obviously the over-all line equivalent attenuation of each repeater section.

Echo current arise by single, triple, quintuple etc. reflections of the current sent out on the line. We assume, however, that echo currents caused by multiple reflections can be disregarded by the side of those caused by single reflections, which is permissible as long as the equivalent of a 2-wire circuit is not appreciably affected by the currents circulating in the 2-wire repeaters or, in other words, as long as the 2-wire circuit can be considered perfectly stable. This assumption is thus valid when the 2-wire circuit is perfectly stable. The echo attenuation caused in each separate repeater section will be

$$\left.\begin{aligned} & p_0 \\ & p_0 + 2b \\ & p_0 + 4b \\ & \dots \\ & \dots \\ & p_0 + 2\,(n-1)\,b \end{aligned}\right\} \quad . \; . \; . \; . \; . \; . \; . \; \text{(b)}$$

These echo attenuations represent echo currents which are all assumed to be deflected in phase + or − φ from the resulting echo current. The resulting echo attenuation *P* can then be computed from the equation

$$e^{-P} = e^{-p_0}(1 + e^{-2b} + e^{-4b} + e^{-6b} + \\ + \dots . e^{-2(n-1)b}) \cos \varphi \quad . \; . \; . \; . \; . \; . \; . \; \text{(c)}$$

Now we get

$$e^{-P} = \frac{1 - e^{-2nb}}{1 - e^{-2b}} e^{-p_0} \cos \varphi \quad . \; . \; \text{(1)}$$

By solving *P*, we get the equation

$$P = p_0 - ln \frac{1 - e^{-2nb}}{1 - e^{-2nb}} \cos \varphi \quad . \; . \; \text{(2)}$$

We will now determine which of the repeaters is most liable to sing.

The permissible echo attenuation on one side of a repeater is

$$P_1 = p_0 - ln \frac{1 - e^{-2nb\alpha}}{1 - e^{-2b}} \cos \varphi$$

and on the other side

$$P_2 = p_0 - ln \frac{1 - e^{-2nb(1-\alpha)}}{1 - e^{-2b}} \cos \varphi \quad \text{(d)}$$

where α is dependent on the position of the repeater in the circuit.

The reflections caused by bad matching between the line and the lines or instruments connected to it are assumed to be equal at both ends of the line. The same reflections are assumed to be obtainable by extending the line at both ends by a certain number of repeater sections, i. e. by increasing n.

The most sensitive repeater is that in which $P_1 + P_2$ is smallest.

We have

$$P_1 + P_2 = 2\left(p_o - ln\,\frac{\cos\varphi}{1-e^{-2b}}\right) - ln\,(1-e^{-2nba})\,(1-e^{-2nb\,(1-a)}) \quad . \quad . \quad (e)$$

By differentiating with respect to a we get

$$\frac{d\,(P_1+P_2)}{da} = \frac{-2nbe^{-2nba} + 2nbe^{-2nba\,(1-a)}}{(1-e^{-2nba})\,(1-e^{-2nb\,(1-a)})} = 0$$

which makes $a = 1 - a$ or $a = {}^1/_2$ . . . . . (2)

$$\text{if } a < {}^1/_2, \frac{d\,(P_1+P_2)}{da} \text{ will be} < 0$$

$$\text{if } a > {}^1/_2, \frac{d\,(P_1+P_2)}{da} \text{ will be} > 0$$

Consequently

$P_1 + P_2$ is a minimum when $a = {}^1/_2$. (3)

This means that the middle repeater is most liable to sing. When appraising the stability of a line, the echo attenuations at the middle repeater should therefore be studied.

We introduce the symbols:

P_m = the resulting echo attenuation at the middle repeater.

g = the effective reflection, considering the phase conditions, between the line and the lines or instruments connected to it, expressed in nepers, and

B = the line equivalent.

The line equivalent will obviously be

$B = n\,.\,b,$ . . . . (f)

and according to equation (1) we get

$$e^{-P_m} = \frac{1-e^{-B}}{1-e^{-2b}}\,e^{-p_o}\cos\varphi + e^{-g-B} \quad . \quad . \quad . \quad (g)$$

By solving e^{-2b}, we get the equation

$$e^{-2b} = 1 - \frac{1-e^{-B}}{e^{-P_m} - e^{-g-B}} \cdot e^{-p_o}\cos\varphi \quad . \quad . \quad (4)$$

If $P_m > 0$ the system is stable.

When $P_m < 0$ singing will occur. The line cannot, however, be considered perfectly stable unless

$$P_m \geq +0.5 \text{ nepers,}$$

and according to the above this must also be considered a condition for the validity of equation (4).

We will illustrate equation (4) by an example, and assume that

$P_m = 0.5$ neper,

$g = 1$ neper and

$B = 1$ neper.

Equation (4) will then give us

$$e^{-2b} = 1 - 1.34\,e^{-p_o}\cos\varphi \quad . \quad . \quad . \quad (h)$$

In the most unfavourable case, φ will be $= 0°$. A probable value is $\varphi = 45°$.

When $f = 1.5$ neper we get

$$p_o = p - 1.5 \text{ neper} \quad . \quad . \quad . \quad . \quad . \quad . \quad (i)$$

According to equation (j), the number of repeater sections is

$$n = \frac{B}{b} = \frac{1}{b} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (j)$$

and at a distance between the repeater stations $= 60$ km. the range will be

$$S = n \cdot 60 \text{ km} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (k)$$

The values in the following Table have been computed from equations (h), (i), (j), and (k).

If the echo attenuation is increased from 3 to 4 nepers, the range will be 3 to 3.4 times longer, with stability retained in the line. This clearly proves the range to be very dependent on echo attenuation. Echo attenuation, on the other hand, depends partly on the matching of lines and repeaters, and partly on inhomogeneities in the lines, and, to increase the echo attenuation value, both lines and repeaters must, therefore, be tackled.

If the echo attenuation is measured from one end of the line, the far end of which is terminated by an impedance equal to the mathematical characteristic impedance of the line, the echo attenuation value obtained will be solely dependent on inhomogeneities in the line. This echo attenuation value will in the following be symbolized P_L.

If the line is perfectly homogeneous, and terminated by half a repeater instead of the above impedance, the measured echo attenuation will be dependent on the input impedance of the repeater.

Making

p_F = this last echo attenuation,

Echo attenuation p in nepers		2.5	3.0	3.5	4.0	4.5
$p_0 = p - f$ in nepers		1.0	1.5	2.0	2.5	3.0
The line equivalent of the first section b in nepers	$q = 0°$	0.3395	0.1775	0.100	0.058	0.0345
	$q = 45°$	0.214	0.119	0.0685	0.0405	0.02415
Number of repeater sections, n	$q = 0°$	3	5	10	17	29
	$q = 45°$	4	8	14	24	41
Range S in km	$q = 0°$	180	300	600	1020	1720
	$q = 45°$	240	480	840	1440	2460

W = the input impedance of the repeater, obviously depending on the grid and anode impedances alone,

Z = the characteristic impedance of the line, and

βS = the line attenuation, we get

$$p_F = 2\beta S + ln\frac{Z+W}{Z-W} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

By superposing the echo currents caused by reflections at inhomogeneities of the line and at the repeater, the actual echo attenuation p at the frequency giving the most unfavourable phase conditions may be computed from the following equation:

$$e^{-p} = e^{-p_L} + e^{-p_F} \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

Assuming for instance $\beta S = 1.3$ nepers and $\frac{Z+W}{Z-W} = 5$, which are normal values, we get, according to equation (5),

$p_F = 2 \cdot 1.3 + 1.6 = 4.2$ nepers.

$p_L = 3.8$ nepers is also a normal value.

According to equation (6), these p_F and p_L values give us

$p = 3.3$ nepers.

If p_F were infinite large,

p would be $= p_L = 3.8$ nepers.

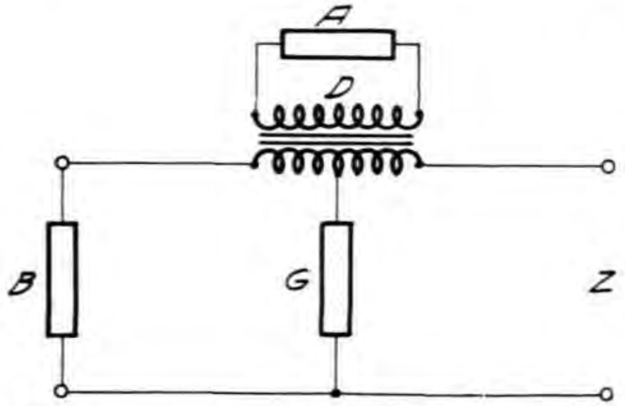
The echo attenuation will thus be depressed by 0.5 nepers by reflections from the repeater. As we have shown above, reduced echo attenuation involves a reduction of the range of a 2-wire line, and it is therefore clear that the input impedances of the 2-wire repeaters have a certain influence on the range of 2-wire lines. This influence will increase with p_L, i. e. with the homogeneity of the lines.

A paper was published not long ago, in which the author had computed the repeater impedance by applying the quadripole theory to the 2-wire repeater, and found it approximately equal to the line balance impedance, which led him to the conclusion that reflections at the repeaters may be disregarded. This, however, is not correct, as the results of this computation only tell us that if unbalance between lines and balances is produced in a certain way, the consequent reflection currents may compensate the reflections at the repeater. It is very doubtful if this procedure is a practical solution of the problem under discussion.

3. A Filter Arrangement with Input Impedance Independent of Frequency.

To reduce the difficulties of balancing, filters which cut off all frequencies unnecessary for speech are introduced in the 2-wire repeaters. Little or no balance will consequently be required for these frequencies.

In balancing loaded lines in particular it is very difficult to balance frequencies very near to the cut-off frequency of the lines. The filter image impedances of the usual types of filter depend on the frequency, and this dependence is especially prominent close to the cut-off frequencies of the filters. The input impedance of a 2-wire repeater, on the other hand, depends on the image impedance of its filter, and the frequency-dependence of the input impedance will therefore not correspond to that of the lines connected to the repeater. Relatively strong reflections between the lines and the repeaters will then be unavoidable, which, according to the previous chapter, will reduce the eventual range of the 2-wire line. Attempts have been made to improve the matching of repeaters and lines in present 2-wire repeaters by selecting filters which, at least at frequencies below the cut-off frequency and not too near this, has an image impedance practically independent of the frequency. But these filters are very highly dependent on the frequency in the immediate proximity of their cut-off frequency, and this frequency-dependence will affect the input impendance of the repeater before any effective attenuation can be introduced by the filters. As the stability of a 2-wire repeater requires all frequencies transmitted by it to be dealt



R 3035 Fig. 2.

with, it is not sufficient to neutralize the reflections of only the lower frequencies transmitted. The selection of such filters for a 2-wire repeater can therefore not be acknowledged to be a solution of the problem, even though they may improve the properties of the repeater somewhat.

The preliminary work on the new Ericsson 2-wire repeater therefore included efforts to design a filter which does not introduce frequency-dependence in the input impedance of the repeater, and already during the mathematical treatment of the problem a very interesting and perfectly satisfactory solution was found.

By introducing filters in both the anode and grid circuits of the repeater, it proved possible to eliminate entirely the frequency-dependence of the filters in the repeater input impedance at all frequencies both below and in the immediate proximity of the cut-off frequency. The mathematical proof of this is as follows.

Fig. 2 is a diagram of one of the differential transformers of the 2-wire repeater and the impedances connected to this.

D signifies the differential transformer,
A the input impedance of the anode filter,
G the input impedance of the grid filter,
B the line-balance impedance, and
Z the input impedance of the repeater.

We assume the differential transformer to be ideal, i. e. without losses, leakages, unbalances, etc., and with infinite mutual inductance. The ratio of its windings is further assumed to be 1 : 1.

The input impendance will then be

$$Z = \frac{4G\,(A + B) + AB}{4\,(G + B) + A} \quad . \ . \ . \ . \ . \ . \ (7)$$

The input impedance Z should be equal to the characteristic impedance of the line connected to the repeater, which is practically equal to the impedance B. The impedances A and G should consequently be dimensioned so that

$$Z = B \quad . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ (a)$$

By substituting this condition in equation (7) we find the dimensional condition

$$\sqrt{G \cdot A} = B \quad . \ . \ . \ . \ . \ . \ . \ . \ (8)$$

i. e. the geometrical mean of the anode and grid impedances must be equal to the line balance impedance.

We will now deal with the special instance when the impedance B is real and frequency-independent. Obviously, the impedances G and A may consist of two resistances, e. g. R_A and R_G (see fig. 3), the geometrical mean of which is equal to the resistance B. Let for instance R_A represent the anode resistance of the valve, and R_G the resistance of a grid potentiometer. Our anode and grid filters must then be successively built up in front of these resistances.

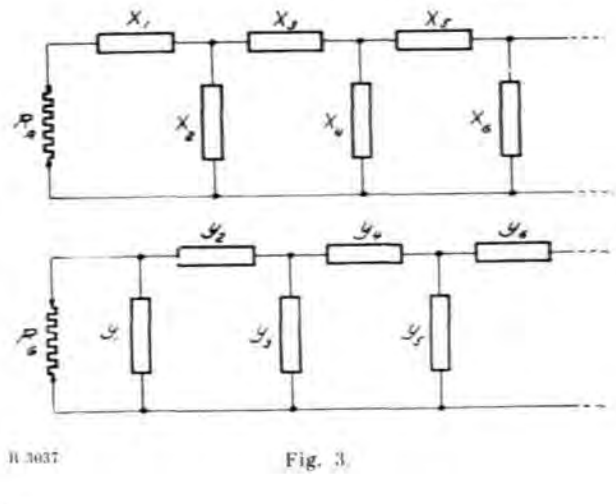
As an experiment, we introduce an impedance X_1 in series with the resistance R_A, and an impedance Y_1, in parallel with the resistance R_G. What must then be the nature of these impedances in order to maintain the condition of equation (8)? The reply to this question will obviously be obtained from

$$\sqrt{\left(R_A + X_1\right)\frac{R_G \cdot Y_1}{R_G + Y_1}} = B \quad . \ . \ (b)$$

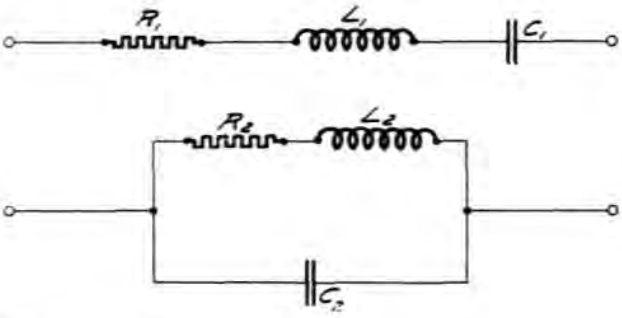
which when transformed becomes

$$\sqrt{X_1 \cdot Y_1} = B \ . \quad . \ . \ . \ . \ . \ . \ . \ . \ (c)$$

The geometrical mean of the impedances X_1



R 3037 Fig. 3.



R 3034

Fig. 4.

and Y_1 must thus be equal to the resistance B. If an impedance X_2 is now introduced in parallel with the impedance $(R_A + X_1)$, and an impedance Y_2 in series with the impedance $\frac{R_G \cdot Y_1}{R_G + Y_1}$, the impendances X_2, Y_2 being dimensioned so that the condition of equation (8) is still complied with, this problem is clearly exactly the same as the previous one, and the dimensioning condition consequently must be

$$\sqrt{X_2 \cdot Y_2} = B \quad \ldots \ldots \ldots \ldots \quad \text{(d)}$$

If we continue to build up the two impedance networks as shown in fig. 3, these must thus be dimensioned so that

$$B = \sqrt{R_A \cdot R_B} = \sqrt{X_1 Y_1} = \sqrt{X_2 Y_2} = \sqrt{X_3 Y_3} = \text{etc.} \quad (9)$$

if the geometrical mean of their input impedances is to remain equal to the resistance B.

If we now proceed to examine what the impedances X and Y must be like to satisfy the dimensioning equations (9), we find as before that the impedances X and Y may consist of two resistances, R_x and R_y respectively, so dimensioned that

$$\sqrt{R_x \cdot R_y} = B \quad \ldots \ldots \ldots \quad (10)$$

Another possibility is that one of the impedances is an induction L, and the other a capacity C, which should be dimensioned to make

$$\sqrt{\frac{L}{C}} = B \quad \ldots \ldots \ldots \ldots \quad (11)$$

Naturally, the impedances X and Y may of course also be complex impedances, built up in the same way as the impedance networks of fig. 3, and dimensioned in accordance with equations (9) and (10) or (11).

In this way impedance networks of any complexity may obviously be built up to fulfil the condition of equation (8).

A particularly interesting case occurs when one of the impedances X and Y is a series resonance circuit $(R_1\ L_1\ C_1)$ and the other a parallel resonance circuit $(R_2\ L_2\ C_2)$ as in fig. 4. If the resistances R_1 and R_2, representing the loss resistances of the coils L_1 and L_2, are zero, the dimensioning conditions will, according to the above, be

$$\sqrt{\frac{L_1}{C_2}} = \sqrt{\frac{L_2}{C_1}} = B \quad \ldots \quad (12)$$

If the resistances R_1 and R_2 have finite values, there is no exact solution of the problem.

In practice, however, it is possible to make coils with negligible resistances except at the natural frequencies of the resonance circuits. The dimensioning condition of equation (12) indicates that the series resonance circuit $(R_1\ L_1\ C_1)$ must have the same natural frequency as the parallel resonance circuit $(R_2\ L_2\ C_2)$.

For this frequency the impedance of the series resonance circuit is

$$= R_1 \quad \ldots \ldots \ldots \ldots \quad \text{(e)}$$

and that of the parallel resonance circuit

$$= \frac{L_2}{C_2 R_2} \quad \ldots \ldots \ldots \ldots \quad \text{(f)}$$

To fulfil the dimensioning condition of equation (9) for the natural frequency also, it is obvious that, beyond the dimensioning condition of equation (12), we must also have

$$\sqrt{R_1 \frac{L_2}{C_2 R_2}} = B \quad \ldots \ldots \quad \text{(g)}$$

or

$$\frac{R_1}{L_1} = \frac{R_2}{L_2} \quad \ldots \ldots \ldots \ldots \quad (13)$$

Verbally, this result means that the losses of the coils must be equal. This must obviously also be the case for any losses in the condensers.

The impedances X and Y may thus consist of a series and a parallel resonance circuit, provided that the losses of coils and condensers are comparatively small, and that they are dimensioned with due consideration to equations (12) and (13).

Fig. 5 is a diagram of a type of 2-wire repeater filter designed on the above principles.

F are the actual amplifying units,

T the anode transformers,

D the differential transformers, and

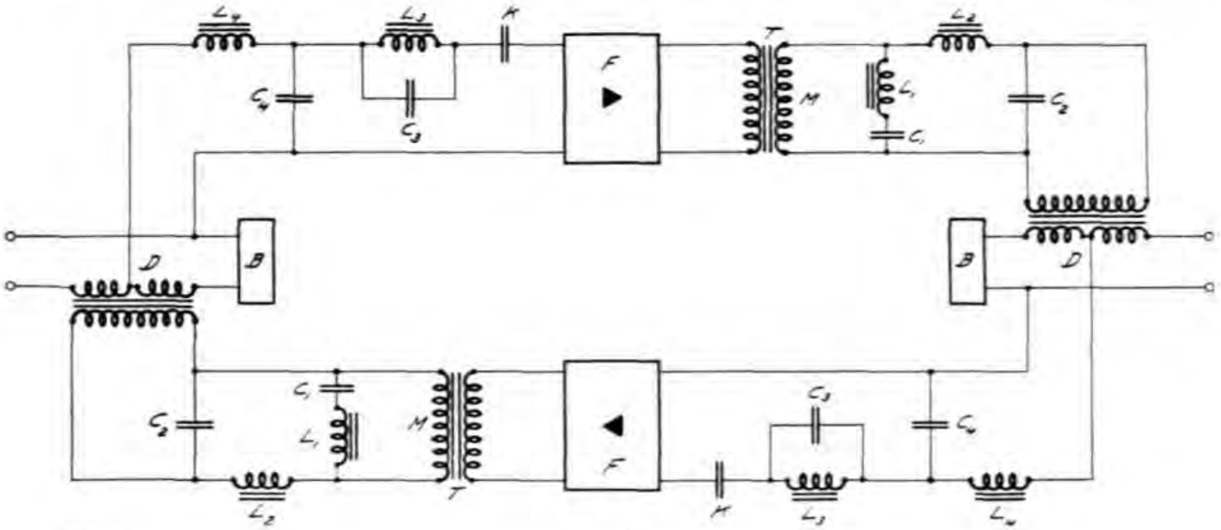
B the line balances.

The anode filters consist of the condensers
C_1 and C_2, and the inductance coils
L_1 and L_2. The grid filters consist of the condensers,
C_3 and C_4, and the inductance coils
L_3 and L_4.
K is a blocking condenser, and
M the secondary inductance of the anode transformer.

and to have as few types of coils and condensers as possible, in order to facilitate manufacture. Experience shows that satisfactory filter designs are obtained with

$$\left.\begin{array}{l} L_1 = L_2 = L_3 = L_4 \\ C_1 = C_2 = C_3 = C_4 \end{array}\right\} \quad \text{and} \quad \ldots \ldots (16)$$

whereby the dimensioning conditions of equation (13) are also satisfied in the best possible manner.



R 3040

Fig. 5.

We further introduce the symbols
R_G = the grid resistances (e. g. potentiometer resistances).
R_A = anode resistances of the valves, re-transformed to the secondary side of the transformer T, and
N = the winding ratio of the differential transformer (from the anode side to the line balance side).

The dimensioning conditions of equations (9), (10), (11), and (12) will then be

$$\sqrt{R_A \cdot R_G} = \sqrt{\frac{M}{K}} = \sqrt{\frac{L_1}{C_3}} = \sqrt{\frac{L_3}{C_1}} = $$
$$= \sqrt{\frac{L_2}{C_4}} = \sqrt{\frac{L_4}{C_2}} = B \cdot N \quad \ldots \ldots (14)$$

Other aspects of the design are: to obtain suitable cut-off frequencies, which are determined by the products

$$L_1 C_1 = L_3 C_3 \text{ and } L_2 C_2 = L_4 C_4 \quad \ldots \quad (n)$$

to match the anode and grid circuits so that they become as free from reflections as possible, which is done by making

$$R_g = \frac{Ra}{4 N^2} \quad \ldots \ldots (15)$$

Fig. 6 shows the input impedance measured in a repeater provided with a filter of this kind.

Curves I and II give the amplitude of the impedance divided by 800 ohm and the phase angle of the impedance expressed in radians, each as a function of the frequency f in cycles per second. The small deviations from a pure resistance of the impedance represented by the curves I and II, are chiefly caused by the differential transformer.

The lowest speech frequencies as a rule give larger and more capacitive line characteristics than the next higher ones, but corresponding properties can be obtained in the input impedance of 2-wire repeaters by under-dimensioning the condenser K. This condenser has also other objects to fulfil, which will be discussed in subsequent chapters.

The dot-and-dash vertical line III marks the position of the cut-off frequency of the filters, which, as we see, leaves the impedance fairly unaffected.

By this filter design, the problem of 2-wire circuits consisting of lines with practically real

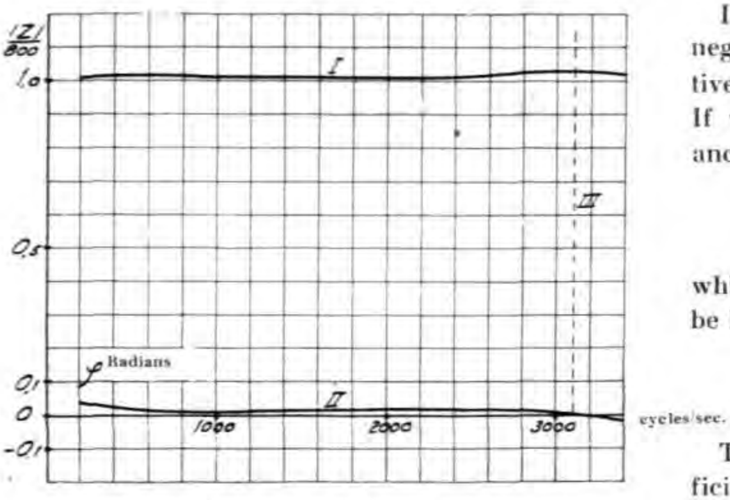


Fig. 6. The input impedance of the 2-wire repeater as a function of the frequency. Curve I is the amplitude of the impedance divided by 800 ohms, curve II its phase angle in radians. Line III marks the cut-off frequency of the filters.

and frequency-independent characteristic impedances, e. g. non-loaded overhead lines, may be considered solved. The most important 2-wire circuits consist of coil loaded cable lines, the characteristic impedances of which are frequency-dependent. We shall show later, however, how the characteristic impedance of a coil loaded line may by relatively simple means be changed into a real and frequency-independent impedance for all frequencies passed by the repeater, and this filter design may therefore be considered a solution for coil loaded lines also.

The Ericsson double filter design may be used for every type of filter. Dr. M. Vos has designed high frequency band pass filters on the double filter principle, and replacing the differential transformer by elements common to both filters, but as these are not used in 2-wire repeaters a detailed description will be left to another occasion.

4. Line Balance for Homogenous Lines.

The characteristic impedance of a homogeneous line is

$$Z = \sqrt{\frac{r + j\omega L}{a - j\omega C}} \quad . \; . \; . \; . \; . \; . \; . \quad \text{(a)}$$

where

r = line resistance per km of loop,
a = leakage „ „ „ „
L = self-inductance „ „ „ „
C = capacity „ „ „ „

In overhead trunk lines, r and a are usually negligible in comparison to ωL and ωC respectively, except for the lowest speech frequencies. If we disregard these, the characteristic impedance may obviously be written,

$$Z \simeq \sqrt{\frac{L}{C}} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad \text{(b)}$$

which on the other hand means that the line can be balanced by one resistance.

$$R = \sqrt{\frac{L}{C}} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad \text{(c)}$$

The lowest speech frequencies are usually sufficiently satisfactorily dealt with by connecting a condenser K of suitable size in series with the resistance R. This may be mathematically expressed by the equation

$$R + \frac{1}{j\omega K} \simeq \sqrt{\frac{r + j\omega L}{a + j\omega C}} \quad . \; . \; . \quad \text{(d)}$$

As a first approximation we may write

$$R^2 + \frac{2R}{j\omega K} - \frac{1}{\omega^2 K^2} \simeq \frac{L}{C}\left(1 + \frac{r}{j\omega L} - \frac{a}{j\omega C}\right) \quad . \quad \text{(e)}$$

$\frac{1}{\omega K}$ is small compared to R, and its square might therefore be disregarded in relation to R^2. Consequently

$$R^2 + \frac{2R}{j\omega K} = \frac{L}{C} + \frac{L}{j\omega c}\left[\frac{r}{L} - \frac{a}{C}\right] \quad . \; . \quad \text{(f)}$$

or

$$\left.\begin{aligned} R &= \sqrt{\frac{L}{C}} \\ K &= \frac{2\sqrt{\frac{C}{L}}}{\frac{r}{L} - \frac{a}{C}} \end{aligned}\right\} \quad . \; . \; . \; . \; . \; . \; . \; . \quad (17)$$

Usually $\frac{r}{L} \gg \frac{a}{C}$ which makes

$$\left.\begin{aligned} R &= \sqrt{\frac{L}{C}} \\ K &= \frac{2}{r}\sqrt{LC} \end{aligned}\right\} \quad . \; . \; . \; . \; . \; . \; . \; . \quad (18)$$

The characteristic impedances of loaded lines have practically the same properties as those of homogeneous lines at the lowest speech frequencies, and the same balancing method is therefore adopted at these frequencies, viz. a resistance and a condenser dimensioned according to equation (17).

5. Line Balance for Extra-Light Loaded Lines.

Fig. 7 is a diagram of one of the differential transformers in a 2-wire repeater, with the impedances connected to it for line balancing on the Ericsson method for extra-light loaded cables.

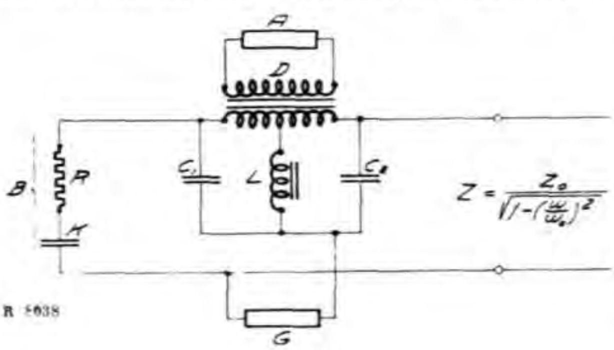


Fig. 7.

D is the differential transformer,

A the anode impedance,

G the grid impedance,

$B = R + \frac{1}{j\omega K}$ the balance impedance,

L a self-inductance, and

C_1 and C_2 two capacities.

The impedance of the loaded circuit is

$$Z = \frac{Z_0}{\sqrt{1-\left(\frac{\omega}{\omega_0}\right)^2}} \quad \ldots \ldots \quad (19)$$

where ω_0 is the impedance of a homogeneous circuit with the same resistance, induction, capacity, and leakage per km. as the loaded circuit, and ω_0 is the cut-off frequency (in radians per second) of the loaded line.

The capacities C_1 and C_2, and the inductance L form, together with the differential transformer, a ratio arm which, on the assumption that the differential transformer is ideal, will be

$$\frac{1-\omega^2 2LC_2}{1-\omega^2 2LC_1} \quad \ldots \ldots \ldots \quad (a)$$

The condition for perfect balance will thus be

$$\frac{B}{Z} = \frac{1-\omega^2 2LC_2}{1-\omega^2 2LC_1} \quad \ldots \ldots \quad (b)$$

If the expression for Z according to equation (19) is substituted in equation *(b)* we get

$$\frac{B}{Z_0} \sqrt{1-\left(\frac{\omega}{\omega_0}\right)^2} = \frac{1-\omega^2 2LC_2}{1-\omega^2 2LC_1} \quad (20)$$

The frequency $\omega = 0$ gives the relation

$$B = Z_0 \quad \ldots \ldots \ldots \ldots \quad (21)$$

which is obtained by dimensioning the resistance R and the condenser K according to equation (17). A further condition for balance of equation (19) must thus be

$$\sqrt{1-\left(\frac{\omega}{\omega_0}\right)^2} = \frac{1-\omega^2 2LC_2}{1-\omega^2 2LC_1} \quad \ldots \quad (22)$$

which can only be approximately complied with for frequencies below the cut-off frequency. For frequencies ω considerably below the cut-off frequency ω_0, $\left(\frac{\omega}{\omega_0}\right)^2$ will be $\ll 1$, and consequently $\omega^2 2LC_1$ will also be $\ll 1$ and $\omega^2 2LC_2 \ll 1$. For frequencies ω near to the cut-off frequency ω_0, $\left(\frac{\omega}{\omega_0}\right)^2$ will be relatively large, and $2\omega^2 LC_2$ should therefore also be relatively large, while $2\omega^2 LC_1$, which is more in the nature of a correction, still remains small. We may therefore assume that higher powers than 2 in the expression $2\omega^2 LC_1$, may be disregarded by the side of 1, and we then obtain by a series expansion

$$1 - 4\omega^2 L(C_2 - C_1) + 4\omega^4 L^2 (C_2^2 - 4C_1C_2 + 3C_1^2) + 16\omega^6 L^3 C_1 C_2 (C_2 - 3C_1) + 48\omega^8 L^4 C_2^2 C_1^2 \cong 1 - \left(\frac{\omega}{\omega_0}\right)^2 \quad \ldots \quad (c)$$

The following condition for the best possible approximation for the lower frequencies below the cut-off frequency ω_0 may then be made

$$\left.\begin{array}{ll} \text{I.} & 4\omega^2 L(C_2 - C_1) = \left(\frac{\omega}{\omega_0}\right)^2 \text{ or } \omega_0^2 = \frac{1}{4L(C_2 - C_1)} \\ \text{II.} & C_2^2 - 4C_1C_2 + 3C_1^2 = 0 \text{ or } C_2 = \begin{cases} +3C_1 \\ +C_1 \end{cases} \\ \text{III.} & C_2 - 3C_1 = 0 \text{ or } C_2 = +3C_1 \\ \text{IV.} & 48\omega^8 L^4 C_2^2 C_1^2 = 0 \text{ cannot be realized.} \end{array}\right\} \quad (d)$$

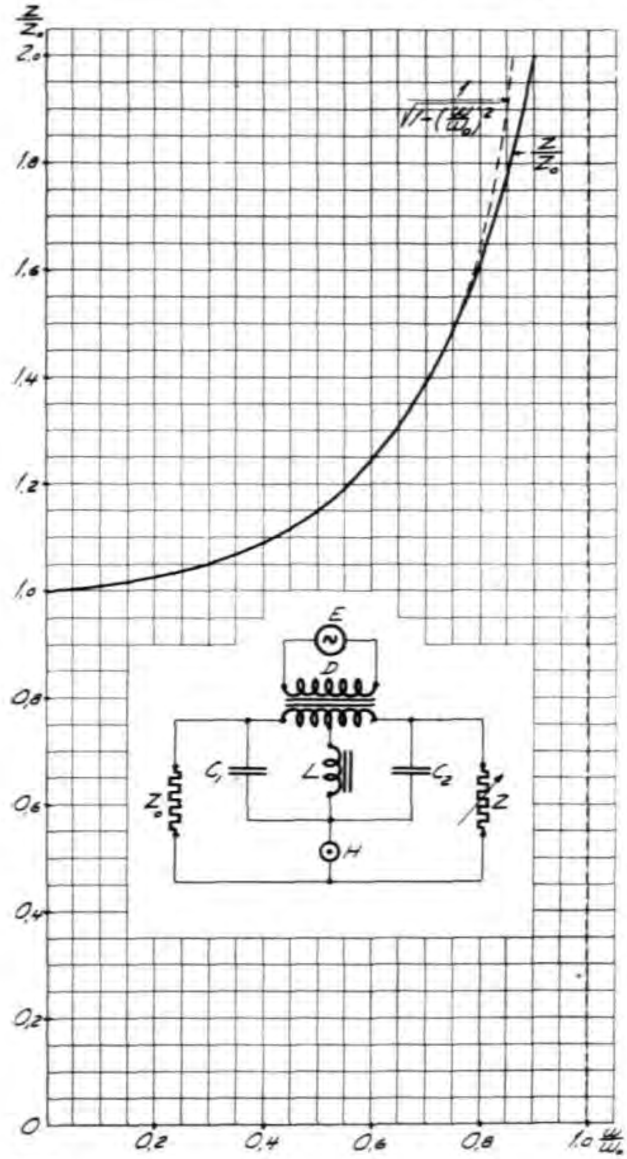
The value $C_2 = 3C_1$ will, according to condition I, make

$$\left.\begin{array}{l} C_1 = \frac{1}{8L\omega_0^2} \\ C_2 = \frac{1}{8L\omega_0^2} \end{array}\right\} \quad \ldots \ldots \ldots \quad (23)$$

For $\omega < \omega_0$, this will give approximately

$$\frac{1-\omega^2 LC_2}{1-\omega^2 LC_1} = \sqrt{1-\left(\frac{\omega}{\omega_0}\right)^2 + 0.105\left(\frac{\omega}{\omega_0}\right)^8} \quad . \quad (24)$$

As the undesirable term under the root sign is the 8th power of $\frac{\omega}{\omega_0}$, it might with fair exactitude be disregarded when $\omega \ll \omega_0$.



R 3021

Fig. 8. Experimental results showing the excellence of the Ericsson method of the line balance in extra light loaded lines.

Fig. 8 shows the results obtained confirmed experimentally.

The differential transformer D with the condensers C_1 and C_2 and the coil L, all dimensioned according to equation (23), formed the ratio arms of a bridge in which Z_0 and Z are represented by a fixed and a variable resistance respectively, and the anode and grid circuits by a voice-frequency generator E and a telephone receiver H respectively. For various frequencies, the resistance Z was varied until a minimum of sound could be heard in the telephone receiver H. The solid curve in fig. 8 gives the results of the measurements, with $\frac{Z}{Z_0}$ as a function of $\frac{\omega}{\omega_0}$. For comparison, $\frac{1}{\sqrt{1-\left(\frac{\omega}{\omega_0}\right)^2}}$ is plotted in the dotted curve as a function of $\frac{\omega}{\omega_0}$. We note that these curves agree practically completely up to $\frac{\omega}{\omega_0}=0.8$, and separate afterwards.

The capacities C_1 and C_2 and the inductance L will naturally affect the input impedance of the repeater.

If the ratio of the differential transformer is 1: 1 (from the anode side to the line balance side) and the mutual impedance between the two halves of the differential transformer M, the input impedance may be computed by the following equation: (The symbols are as in fig. 7).

$$\left.\begin{aligned}
Z_a &= 4j\omega M \frac{1-\omega^2 L(C_1+C_2)}{1-\omega^2(C_1+C_2)(M+L)+\omega^4 C_1 C_2\, 4LM}\\
A' &= \frac{Za\,.\,A}{Za+A}\\
S &= G+\frac{j\omega L}{1-\omega^2 L(C_1+C_2)}\\
\eta &= \frac{1-\omega^2\, 2LC_2}{1-\omega^2\, 2LC_1}
\end{aligned}\right\}\quad (25)$$

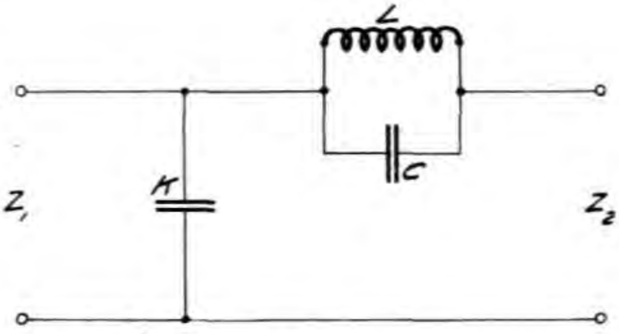
Consequently the input impendance

$$Z_1=\frac{S(A'+B)(1+\eta)^2+A'B}{(S+B)(1+\eta)^2+A'\eta^2}$$

An examination of these equations shows that although the input impedance increases with rising frequency just as the characteristic impedance of a loaded circuit, it does not increase as much as the latter. For light loaded lines, the variations of the characteristic at the speech frequencies transmitted by the repeaters are relatively small, and lines and repeaters can therefore be relatively well matched without special precautions. The capacities C_1 and C_2 will be so small that they have no effect on the other properties of the repeater. This method thus gives an extremely simple and effective line balance in light loaded circuits.

6. Line Balance for Medium Heavy Loaded Circuits.

A filter section which plays an important part in the line balance of loaded lines is that shown in fig. 9, consisting of two condensers K and C and a selfinductance coil L. As this section is



B 3036 Fig. 9.

asymmetric, the image impedances must be different at its input and output terminals. We will call these impedances Z_1 and Z_2 at the left and right hand pair of terminals respectively (see fig. 9).

According to the calculations

$$\left.\begin{aligned} Z_1 &= \frac{\sqrt{\dfrac{L}{K}}}{\sqrt{1-\omega^2 L(C-K)}} \\ Z_2 &= \sqrt{\frac{L}{K}\frac{\sqrt{1-\omega^2 L(C+K)}}{1-\omega^2 LC}} \end{aligned}\right\} \quad (26)$$

The image impedance Z_1 is apparently that of a loaded line, which, according to equation (19), may be written

$$Z = \frac{Z_0}{\sqrt{1-\left(\dfrac{\omega}{\omega_0}\right)^2}} \quad \ldots\ldots (19)$$

If we make

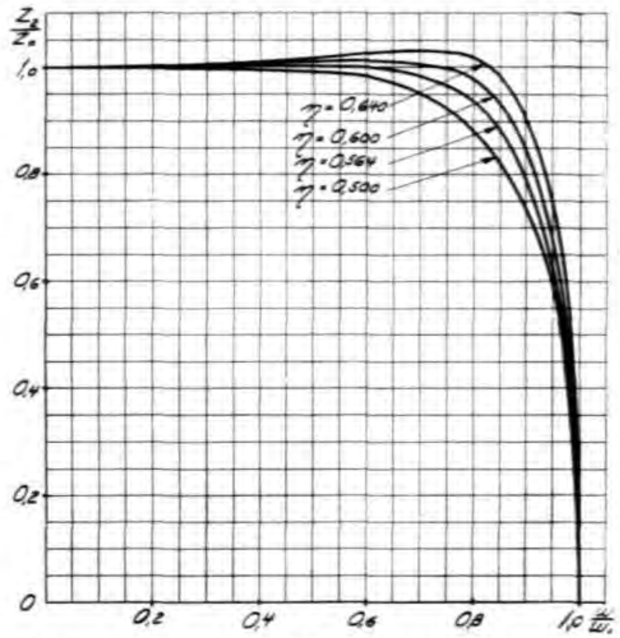
$$\left.\begin{aligned} Z_0 &= \sqrt{\frac{L}{K}} \\ \text{and} \quad \omega_0 &= \frac{1}{\sqrt{L(C+K)}} \end{aligned}\right\} \quad \ldots\ldots (27)$$

the Z_1-side of the filter section can be connected free of reflections to the loaded line. The image impedance its Z_2-side will then be

$$Z = Z_0 \cdot \frac{\sqrt{1-\left(\dfrac{\omega}{\omega_0}\right)^2}}{1-\dfrac{C}{C+K}\left(\dfrac{\omega}{\omega_0}\right)^2} \quad \ldots (a)$$

or

$$\left.\begin{aligned} Z_2 &= Z_0 \frac{\sqrt{1-\left(\dfrac{\omega}{\omega_0}\right)^2}}{1-\eta\left(\dfrac{\omega}{\omega_0}\right)^2} \\ \text{where} \quad \eta &= \frac{C}{C+K} \end{aligned}\right\} \quad \ldots (28)$$



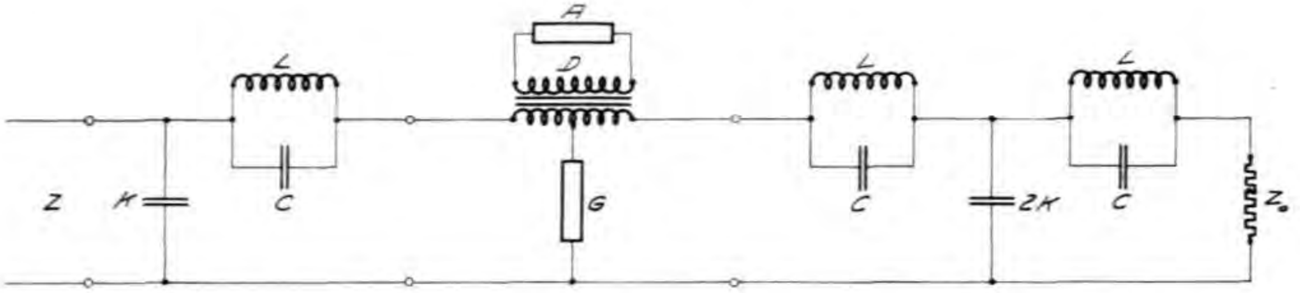
B 3022 Fig. 10.

Fig. 10 gives $\frac{Z_2}{Z_0}$ as a function of $\frac{\omega}{\omega_0}$ for various values of η. These curves show that by choosing a suitable value of η, the function Z_2 may be made practically independent of the frequency ω when $\omega < \omega_0$ and not very close to ω_0. By a filter section of this kind, Küpfmüller has made characteristic impedance of the cable real and frequency-independent, so that the line balance could consist of a resistance of the magnitude Z_0. Küpfmüller improved the quality of the balance by means of a small coil in series with the resonance circuit *(LC)*.

Hoyt uses the filter section to make a balance for a loaded line. By terminating its Z_2-side by a resistance of the magnitude Z_0, he obtains on the Z_1-side an image impedance which is practically equal to the characteristic impedance of the loaded line.

Both these methods have advantages as well as drawbacks. Küpfmüller's arrangement will match the loaded line better to the repeater then Hoyt's, which, however, gives better balance near and beyond the cut-off frequency than Küpfmüller's. The reason for the comparatively good balancing properties of the Hoyt balance at these frequencies is that the reflections between the filter section and the resistance connected to it are removed by the greater attenuation of these frequencies in the filter section.

The Ericsson balance for loaded lines will both



R 3039

Fig. 11.

match the loaded line well to the repeater, and provide good balance near and beyond the cut-off frequency.

Its functioning is shown in fig. 11, where D is a differential transformer, and A and G the anode and grid impedances connected to it. The characteristic impedance Z of the loaded line is changed into Z_2 by a line extension (K, C, L), and the line balance consists of a symmetrical quadripole (K, C, L) with the image impedance Z_2, the quadripole being terminated by a resistance Z_0. Obviously, this balance device possesses both the good matching properties of the Küpfmüller balance and the good balancing properties of the Hoyt balance.

In fig. 11, the quadripole is a T-network consisting of two filter sections as in fig. 9. Quadripoles with the same properties as this one may, however, be composed in many different ways, e. g. by bridged T or lattice type networks etc.

Fig. 12 shows the line balance which has proved most expedient. The quadripole here consists of a kind of lattice type filter section with mutual inductance between the branches. The object of the resistance r is to increased the attenuation of the filter, thus reducing the effect of the reflections at the resistance Z_0.

To obtain a better balance at frequencies where

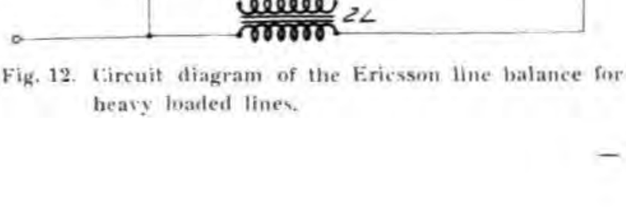


Fig. 12. Circuit diagram of the Ericsson line balance for heavy loaded lines.

the attenuation of the filter is relatively slight, the balance is designed with a slightly higher cut-off frequency and a slightly larger value of η than in the line extension.

Fig. 13 shows the agreement between the image

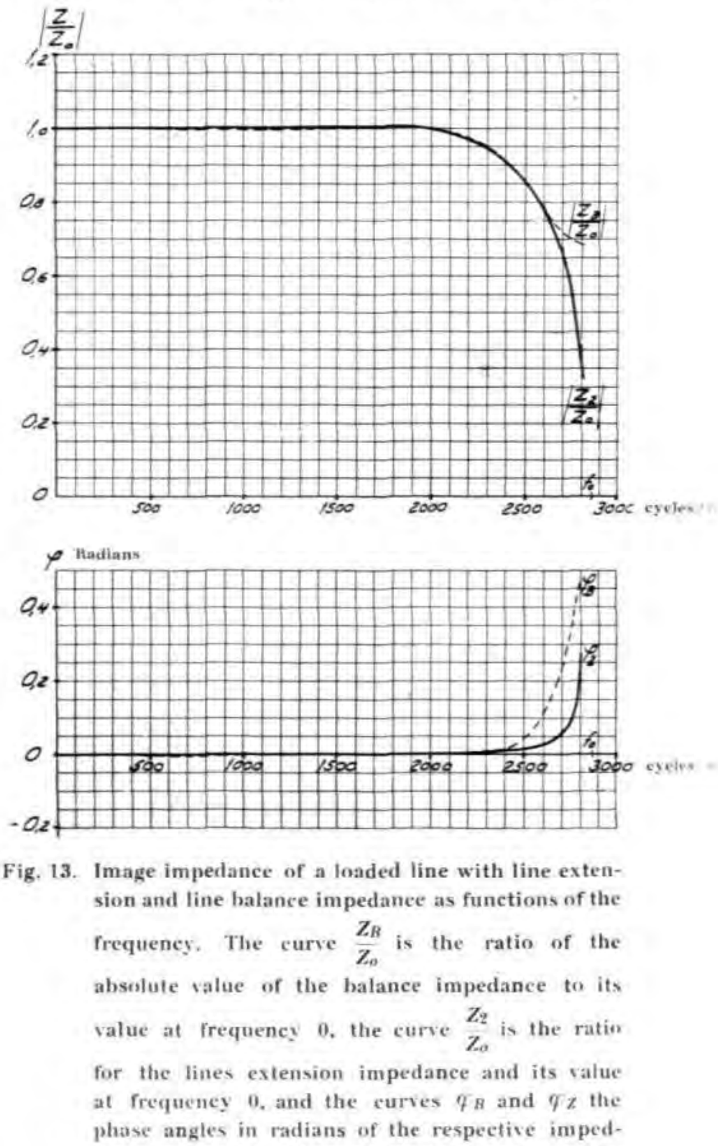
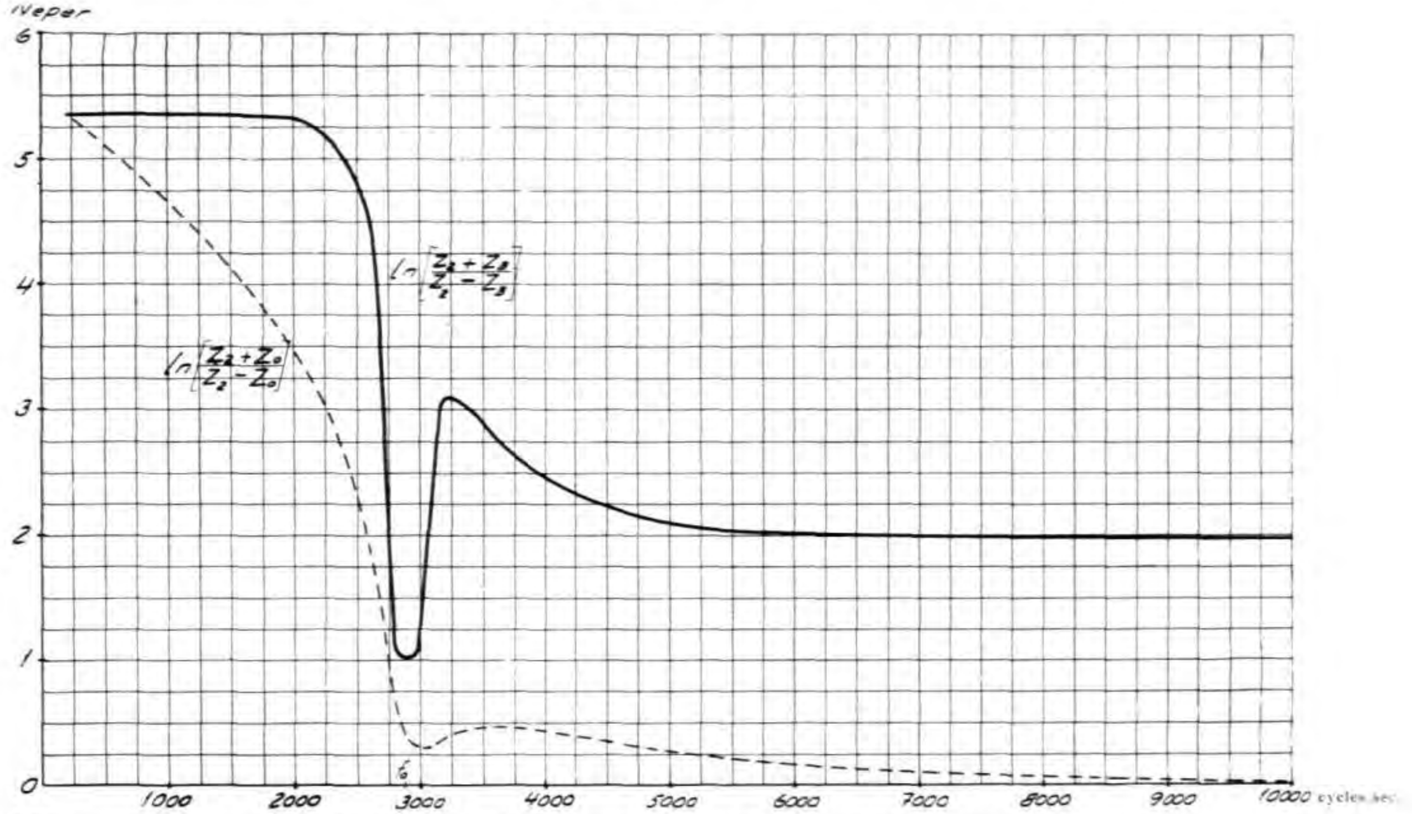


Fig. 13. Image impedance of a loaded line with line extension and line balance impedance as functions of the frequency. The curve $\frac{Z_B}{Z_0}$ is the ratio of the absolute value of the balance impedance to its value at frequency 0, the curve $\frac{Z_2}{Z_0}$ is the ratio for the lines extension impedance and its value at frequency 0, and the curves φ_B and φ_Z the phase angles in radians of the respective impedances. f_0 marks the cut-off frequency of the loaded line.



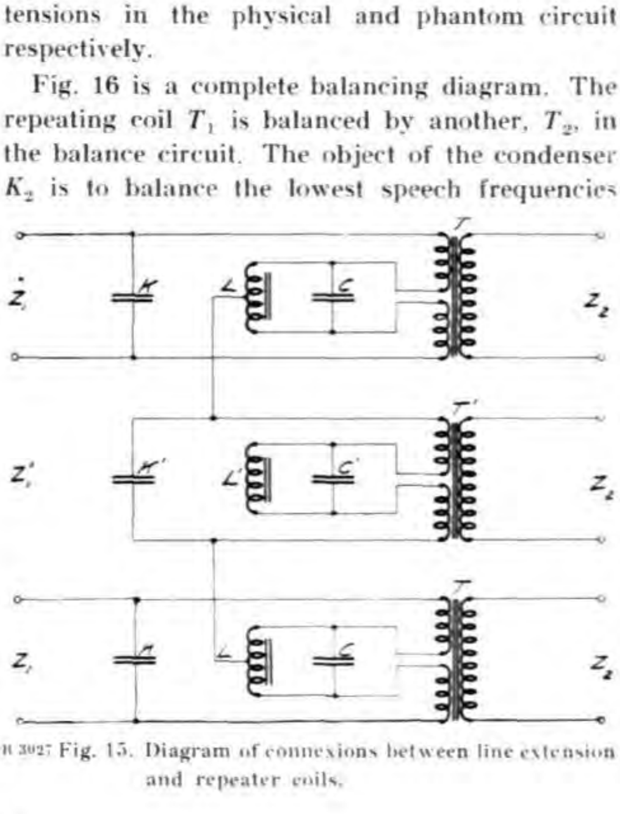
R 3045 Fig. 14. Observed echo attenuation as a function of the frequency.

impedance of the line extension and the impedance of the line balance. The dotted curves give the absolute value of the line balance impedance Z_B relatively to Z_0, and the line balance phase angle φ_B in radians.

The solid curves show the same thing for the line extension impedance Z_2. The cut-off frequency is $f_0 = 2870$ cycles. The solid curve of fig. 14 shows echo attenuation, obtained by direct measurements, as a function of the frequency when the balance impedance Z_B balances the impedance Z_2. The dotted curve shows measured echo attenuation as a function of the frequency when the impedance Z_2 is balanced by a resistance Z_0. For frequencies below the cut-off frequency, the echo attenuation is somewhat sensitive to small individual differences in the balanced impedances, and in this range of frequencies the echo attenuation curves of fig. 14 are in a way mean value curves. These echo attenuation curves distinctly show that the Ericsson line balance quadripole gives good balance at the cut-off frequency also, which is not the case when a resistance is used for balancing. Less will consequently be demanded from the repeater filters, which can be made simpler and cheaper.

Fig. 15 shows how line extensions are best arranged in phantomed circuits. T and T_1 are the repeater coils $(K\ L\ C)$ and $(K'\ L'\ C')$ the line extensions in the physical and phantom circuit respectively.

Fig. 16 is a complete balancing diagram. The repeating coil T_1 is balanced by another, T_2, in the balance circuit. The object of the condenser K_2 is to balance the lowest speech frequencies

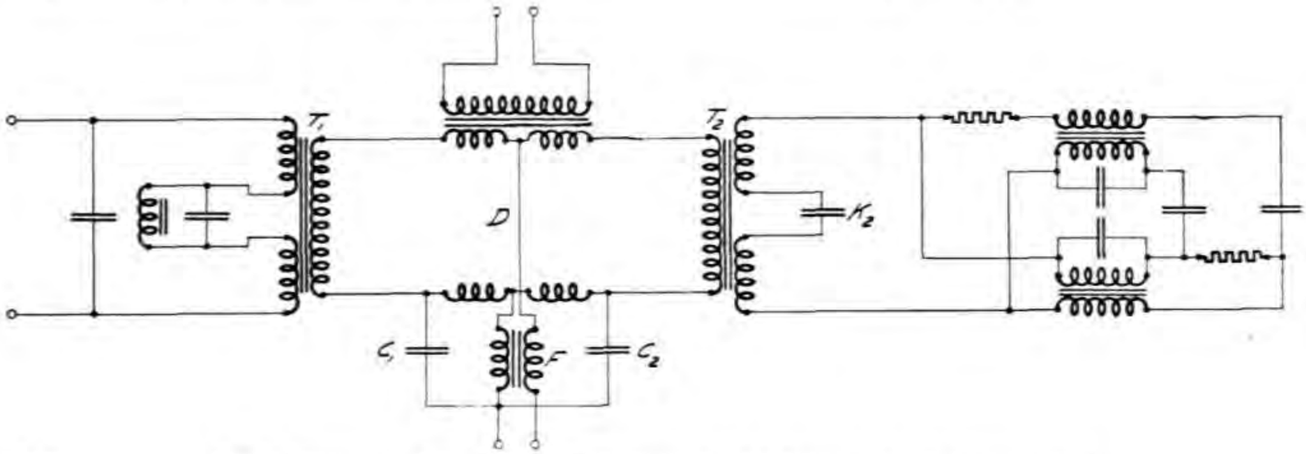


R 3027 Fig. 15. Diagram of connexions between line extension and repeater coils.

(see chapter 4). The condensers C_1 and C_2, together with the filter coil F (see chapter 5), may serve as exact balance when such is required. The other arrangements are described above.

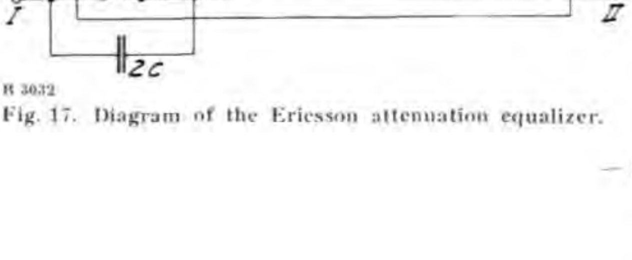
7. Attenuation Equalizer.

The fact that in a telephone line the higher frequencies are more attenuated than the lower,



R 3042 Fig. 16. Diagram of line balancing in heavy loaded lines on the Ericsson system.

will distort the speech transmitted and make it harder to understand. At an early stage of long distance telephony, attempts were made to neutralize this distortion by letting the speech current pass through an artificial line attenuating the lower frequencies more than the higher ones. These artificial lines have been gradually improved, and fig. 17 shows the special Ericsson design for an attenuation equalizer, which fulfils all modern requirements. It consists of a transformer T with four equal, close-coupled windings, two of which form the primary and two the secondary winding. The primary and secondary windings are symmetrically bridged by two condensers $2C$, and the input terminals of one or more cascade-connected distortion-free atten-



R 3032
Fig. 17. Diagram of the Ericsson attenuation equalizer.

uation network (b_1 b_2) are connected to the free centre point of the primary winding, while their output terminals are connected to the also free centre point of the secondary winding.

If we introduce the symbols

$2C$ = the capacity of the bridge condensers.

L = the self-inductance of the primary and secondary windings.

Z = the image impedance of the equalizer.

b = the attenuation of the equalizer.

Z_0 = the image impedance of the attenuation network ($b_1 b_2$).

b_0 = the total attenuation of the attenuation network,

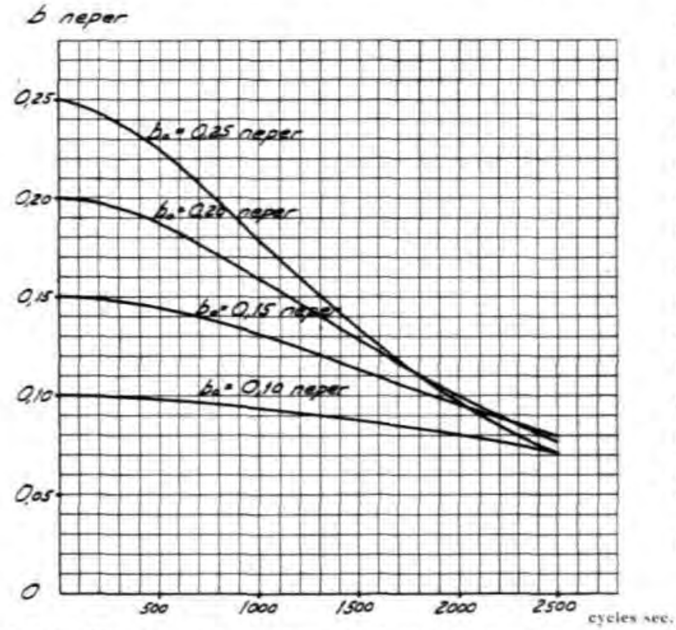
we find that the image impedance Z will be wholly real and frequency-independent if

$$Z_0 = \sqrt{\frac{L}{C}} = Z \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (29)$$

This property is of course desirable, since as a rule it enables the attenuation equalizer to be connected free of reflections in telephone circuits, and the equalizer is therefore dimensioned according to equation (29). The following argument proves that the attenuation b of the equalizer decreases with rising frequency:

At the frequency O, the bridge condensers will act as open circuits, and the transformer windings, the $D.\ C.$ resistance of which we disregard, as short-circuits. The attenuation network (b_1 b_2) will then be connected to the terminals I and II of the equalizer, and at the frequency O the attenuation in the equalizer will thus be $b = b_0$. For the frequency ∞, bridge condensers will act as short-circuits and the transformer windings as open circuits. The terminals I and II will consequently be directly connected in pairs, and all shunting disappears. The attenuation b in the equalizer must then be O. As the frequency rises, the attenuation will thus change from the value $b = b_0$ to $b = O$ or, in other words, the attenuation network $(b_1\ b_2)$, the whole of which is connected in the circuit at the frequency O, will be gradually disconnected as the frequency rises.

The curves in fig. 18 show an observed atte-



R 3025 Fig. 18. The attenuation b of the equalizer as a function of the frequency at various b_0-values.

nuation b as a function of the frequency for different values of b_0. The effect of the equalizer may obviously be adjusted by giving the attenuation b_0 a suitable value. In practice, this is done either by selecting for connexion in the equalizer an attenuation network from a large series of networks of different attenuation values, or by connecting in cascade a number of attenuation networks selected from a series containing only a few different attenuation values. The connexion of attenuation networks of certain desired attenuation values has long been practised for regulating the line equivalent of a circuit or the amplification of a repeater, and the system would therefore be simplified if the same method can be used for correcting the attenuation.

As appears from fig. 17, the equalizer is symmetrical in respect of its line branches as well as of input and output terminals. The former is important from the point of view of cross talk and disturbances, the latter from that of reflections.

8. Devices for Setting and Adjusting the Gain.

In long cable circuits, the number of repeaters in each circuit may be fairly large. The line equivalent, being the difference between the total attenuation and the total gain in the line, will then be a small difference between two large values. A small rate of change in the total gain or total attenuation will thus result in a very large rate of change in the equivalent. If for instance the gain in each of 20 repeaters in a telephone circuit drop 0.1 nepers, the equivalent will obviously be increased by $20 \times 0.1 = 2$ nepers, which in most cases will suffice to put the line out of action. It is thus of great importance that the gain of the repeaters be kept constant, and a special device is therefore introduced in the Ericsson repeater by which the gain can be controlled and adjusted in a moment, even while the repeater is working. The theory of this adjusting device is described in the author's paper, the "Svenska Radioaktiebolaget Valve Testing Set", published in the "L. M. Ericsson Review" of 1930.

Fig. 19 is a circuit diagram of the Ericsson device for setting and adjusting gain. The unamplified speech currents enter by the terminals II, pass the attenuation network B, the setting potentiometer P, arriving in the grid transformer T_g via the key O. The speech currents are amplified by the valve A, and the amplified currents pass the anode transformer T_a and leave by the terminals V.

The object of the attenuation network B, interchangeably connected in the repeater, is to give the correct amount of gain. In view of the mode of working of the grid transformer T_g the potentiometer P, which sets the gain in steps of 0.1 nepers, must have a constant internal resistance at the terminals IV. This is obtained by the potentiometer shown in fig. 19, which, in contradistinction to those previously known, consists of only a few sizes of resistances, which makes the potentiometer fairly easy to make. The ratio of the grid transformer T_g is adjustable by means of secondary taps connected to the adjustment and fine-setting potentiometer S, which can further adjust the gain in steps of 0.02 nepers.

The gain is controlled and adjusted as follows: The head phone *H* is put on, the plug *T* is plugged into the jack, *J*, and any conversation on the line is listened to in the repeater. During a break in the conversation, the key *O* is depressed and the potentiometer *S* turned to the highest position in which no singing tone from the repeater is heard in the phone *H*. The gain between the terminals IV and V is then fixed, within ± 0.01 nepers, at a certain value depending solely on the attenuation in the network *K* back-coupling the repeater at the moment of adjusting. The measuring frequency, which is obviously equal to the singing frequency, is mainly determined by the resonance of the condenser *C* with the secondary inductance of the anode transformer T_a, and it is thus possible to select the measuring frequency by designing the condenser *C* in a certain way.

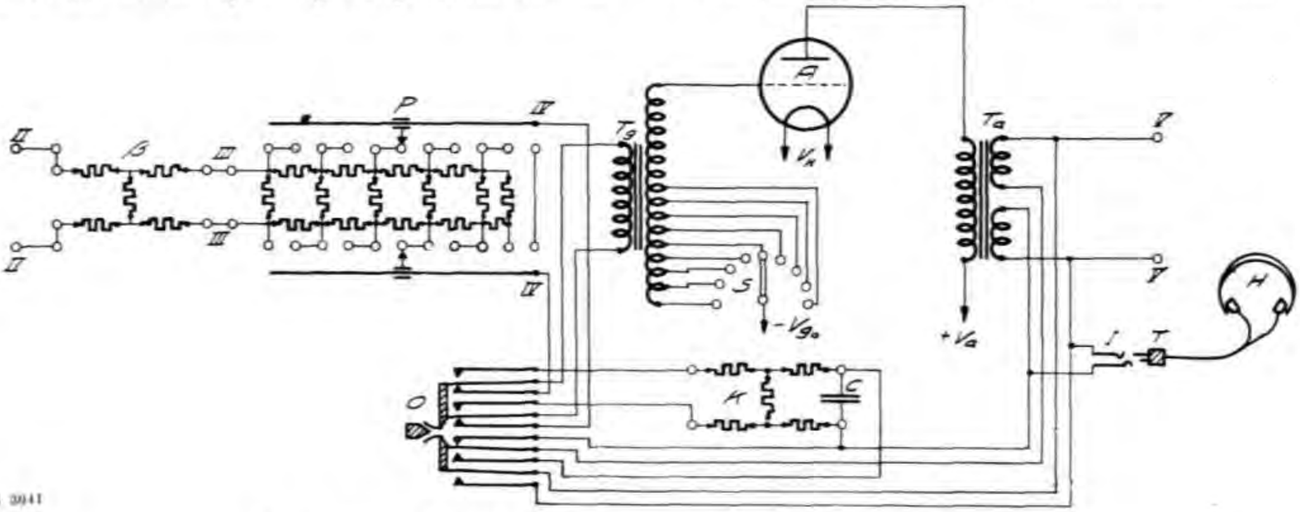


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Fig. 19. Circuit diagram of the gain-setting and gain-adjustment devices.

The position in which the potentiometer *S* is set after the gain adjustment, will serve as zero-position when using it for fine adjustment of the gain. As will be shown later, the potentiometer *S* is in practice provided with a movable scale, the zero point of which is set to the position of the potentiometer after the gain adjustment. This scale is subsequently used for the fine adjustments.

Alteration of gain may obviously be caused by the amplifying valve, the amplification of which depends on fluctuations in anode and filament voltages and in grid bias, aging phenomena etc. and varies sightly in different valves, so that the gain will change when a new valve is put in.

With the gain adjustment just described, however, it is possible, in spite of these variations, to maintain the gain set (by means of β, *P* and *S*) within ± 0.01 nepers.

The attenuation in telephone lines is also exposed to certain variations from temperature, and the aggregate effect of these may be noticeable in working. In underground cables these variations are very slow, however, and regularly follow the changes of the seasons. If the setting of the gain is sufficiently accurate, these variations can therefore be neutralized by changing the setting about twice a year.

9. Current Supply.

All the valves in a repeater station naturally obtain their filament, anode, and grid voltages from common batteries. The filament battery is of either 6 or 24 volt. In the latter case, the valves are divided in groups of four, the filaments of which are connected in series. The anode battery is of 120—130 volt.

Certain devices, shown diagrammatically in fig. 20, must be introduced to prevent these common batteries from transmitting cross talk between the several speech circuits and from admitting to them any noise voltages from the batteries.

In fig. 20

A is the amplifying valve

T_g the grid transformer.

T_a the anode transformer,

K_1, K_2, C_1, and C_2 condensers,

R a leakage resistance, and

L a choke coil, also serving as an alarm relay.

The choke coil L and the condensers C_1 C_2 form a low pass filter, preventing the speech currents in the anode circuit entering the anode battery, and noise voltages in the anode battery entering the anode circuit. Any noise voltages occuring in the grid battery are prevented from entering the grid circuit by the filter formed by the leakage resistance R and the condensers K_1 K_2.

Noise voltages in the filament circuit may enter the anode as well as the grid circuits. By designing the condensers C_1, C_2, K_1 and K_2 in compliance with the following condition:

$$\mu \frac{K_1 - K_2}{K_1 + K_2} = \frac{C_1 - C_2}{C_1 + C_2} \quad \ldots \ldots \quad (30)$$

where μ is the amplification factor of the valve, the noise voltages entering the anode circuit will, however, compensate the anode voltages caused by noise voltages entering the grid circuit. In the Ericsson repeater, the following three conditions for the condensers C_1, C_2, K_1, and K_2 are in use:

$$C_1 = C_2 \quad K_1 = K_2 \quad \ldots \ldots \quad (31)$$

$$C_1 = 0 \quad \frac{K_2 + K_2}{K_2 - K_1} = \mu \quad \ldots \ldots \quad (32)$$

$$C_2 = 0 \quad \frac{K_1 + K_2}{K_1 - K_2} = \mu \quad \ldots \ldots \quad (33)$$

which obviously all comply with the condition of equation (30).

Fig. 21 is a circuit diagram for four amplifying valves, their filament circuits connected in series. These valves form part of two 2-wire repeaters, each with two valves, and the devices enclosed by the dotted squares I and II are mounted in the repeater panels of the respective repeaters.

In fig. 21

B_a is the anode battery,

B_k the filament battery,

B_g the grid batteries,

O key for switching on anode voltage and filament current,

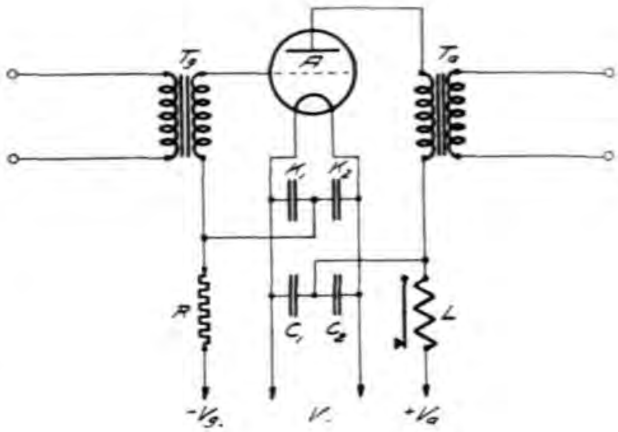
X fuses,

S protective resistances,

M_1 filament resistance with soldering-tab adjustment,

M_2 filament rheostat,

I_g test jack for measuring filament current,



R 3026

Fig. 20.

I_A test jack for measuring the total anode current of the group,

I_k test jacks for measuring the filament voltages of the valves,

I_a test jacks for measuring the anode current of the valves, and

r resistances, compensating changes in anode voltage caused by voltage drops in the filament circuit.

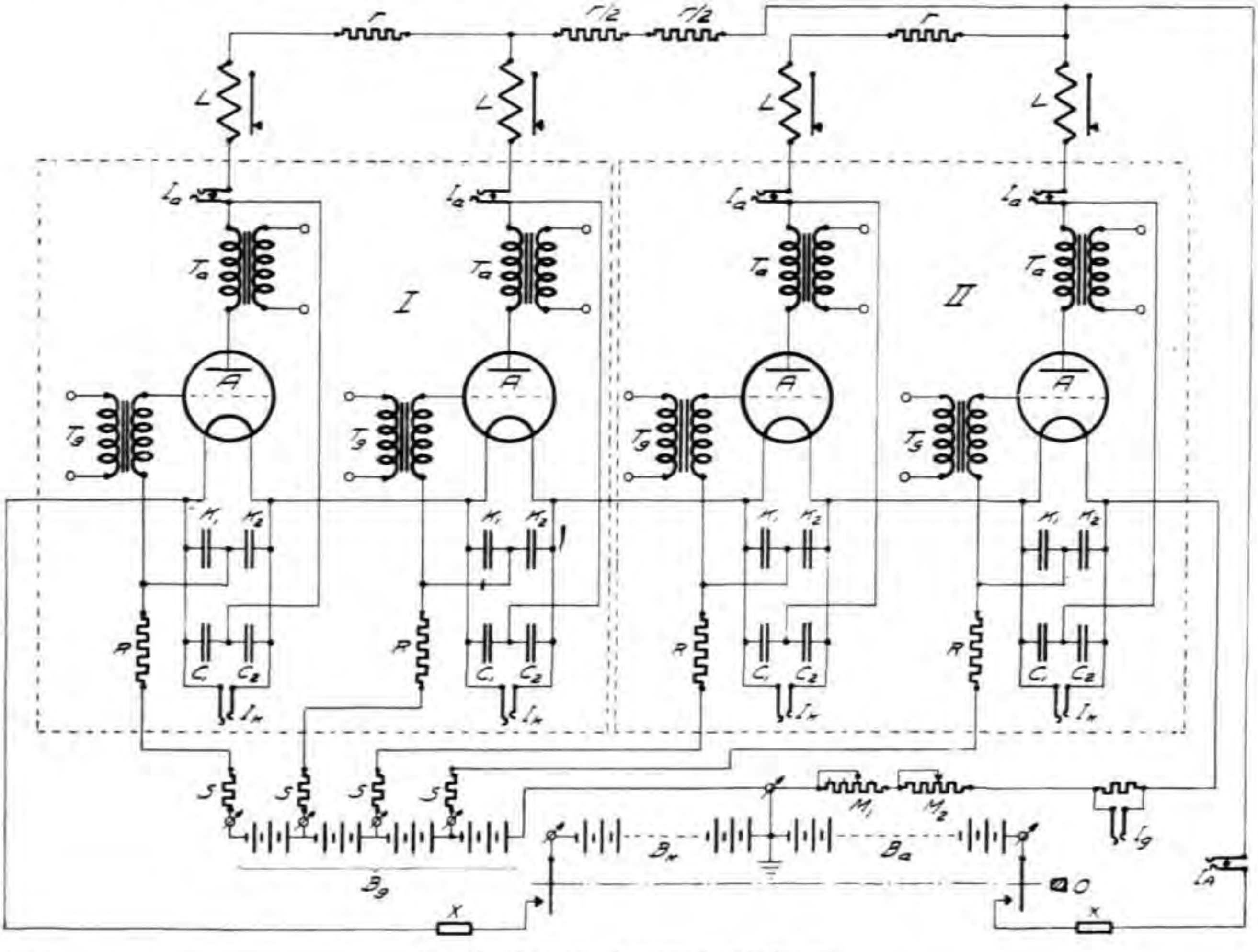
Other symbols as in fig. 20.

The measurements are made by D.C. instruments, connected to plugs by cords. Routine control measurements are made from the measuring jacks I_g and I_a, while the measuring jacks I_a and I_K are used for localization of faults. When, for instance, a filament breaks, the defective valve in the filament circuit is best found by means of a 24 volt telephone lamp fitted with a plug, which is in turn plugged into all the I_k jacks. The lamp will light in the jack of the defective valve. Blown fuses, de-energized alarm relays, etc. will cause alarms and lamp indications, which for the sake of simplicity have been left out of fig. 21.

10. Ringing Set.

20-cycle signal currents cannot be transmitted, nor amplified, by valves. Special signal currents, so-called voice frequency signal currents, which may be amplified in the valves in the same way as speech currents have lately been used in telephone lines with a large number of through repeaters. For a closer study of this system the reader is referred to the author's article "The Swedish Voice Frequency Signalling System" in "The L. M. Ericsson Review" no. 1—3, 1931. In cord-circuit repeaters, or in telephone circuits with one or two through repeaters, however, the simplest way is to retain the 20-cycle signal current and to provide each repeater with a ringer consisting of relays which, when actuated by signal currents arriving at one side of the repeater, send out another signal current on the line the other side of the repeater. This ringer must of course be able to transmit signal currents in both directions, and this causes a troublesome phenomenon necessitating certain precautions, as powerful currents originating from line capacities charged by the signal current may otherwise return to the sending end of a line immediately after a signal has been sent out. Immediately after having transmitted a signal in one direction, the ringer may thus be actuated by "back-kicks" to send out a signal current in the opposite direction. When this has ceased, the ringer will again be actuated by the resulting "kick" to send signal current in the first direction, and so on. A kind of self-tripping condition is set up in the ringing set, which puts the line out of action.

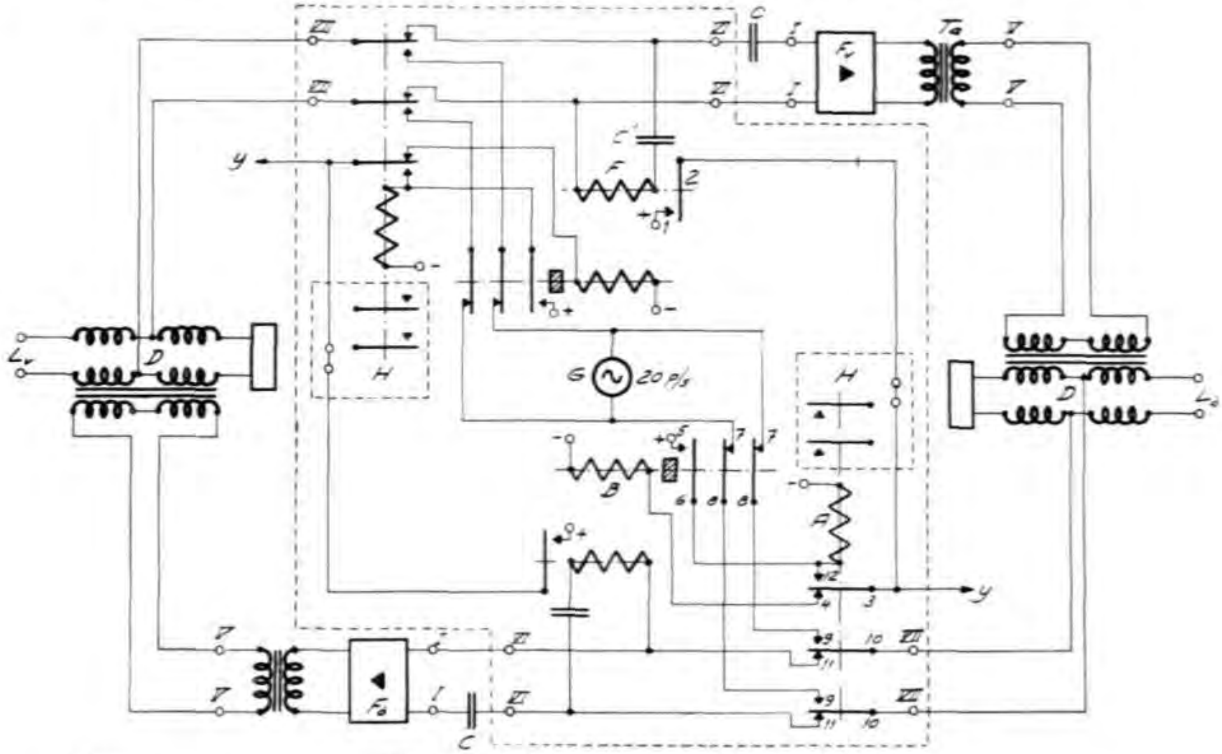
This phenomenon may, however, be avoided by introducing delayed action in the ringing. It must either be impossible to send a signal from the ringing set until a certain time has elapsed since this was last actuated, or else the ringer must be unable to transmit signals in one direction until a certain time has elapsed since it acted in the other direction. The delay must of course be sufficient to give the line capacities time to be discharged. The first method obviously introduces a longer delay in the signal transmission than the latter, and this is obviously a drawback, particularly when the line contains many ringing sets. On the other hand, by the first method the ringer will be insensitive not only to "back-kicks", but also to other disturbances, e. g. thunder claps, while the latter method will only remove the difficulties of back-discharges. If only one or at



R 3049 Fig. 21. Diagram of current distribution.

the most two ringing sets are used in each line — voice frequency signals being otherwise employed—the delay in signal transmission required by the former method need not interfere with the traffic. A circuit diagram of the Ericsson ringing set, which is based on this method, is shown in fig. 22. This ringer is connected to the line inside the differential transformers D, where the relay B to break slowly, and the delayed action required in the ringing set for protection against back-discharges and other similar disturbances is consequently obtained.

When the ringing stops, relay F is tripped, and breaks the circuit (+ 1, 2, 3, 12, A, —). This de-energizes relay A, which breaks the ringing current at the contacts (9, 10).



B 3048

Fig. 22. Circuit diagram of the ringing set.

the two directions of speech separate. According to the above, a 20-cycle ringing current from the line L_v cannot pass the repeater F_v, nor go the back way through the repeater $F_ö$. But it will actuate the relay F, the inductance of which, in series with the condenser C', gives current resonance at 20 cycles, closing the circuit (+ 1, 2, 3, 4, B, —). The relay B will thus be energized to close the circuit (+ 5, 6, A, —), and break the contacts (7, 8,). This energizes relay A, which locks over the circuit (1, 2, 3, 12, A, —), closing contacts (9, 10), and breaking the circuit (+ 1, 2, 3, 4, B —). The delayed-action relay B is slowly de-energized, and contacts (7, 8,) are then eventually closed. The ringing current generator G will then send out current on the line $L_ö$ over the connexions (7, 8, 9, 10).

Before the signal is sent, the relays F, B, and A must thus be actuated in their turn to close, and

The high ringing voltages, which affect the durability of the valves unfavourably, are neutralized by the condensers C and the anode transformers T_a. By means of the relay springs and taps in the circuit (2, 3) in the dotted square H, the ringing set may easily either be switched from its ringing function to affect only a supervisory lamp in the trunk position, or else pole changers operating only during the sending of the signal, may be started. The leads y end in the test jacks, and enable the station supervisor to use the ringing set for signals in either direction. We will return to this in chapter 11.

11. Supervisor's Telephone and Listening Set.

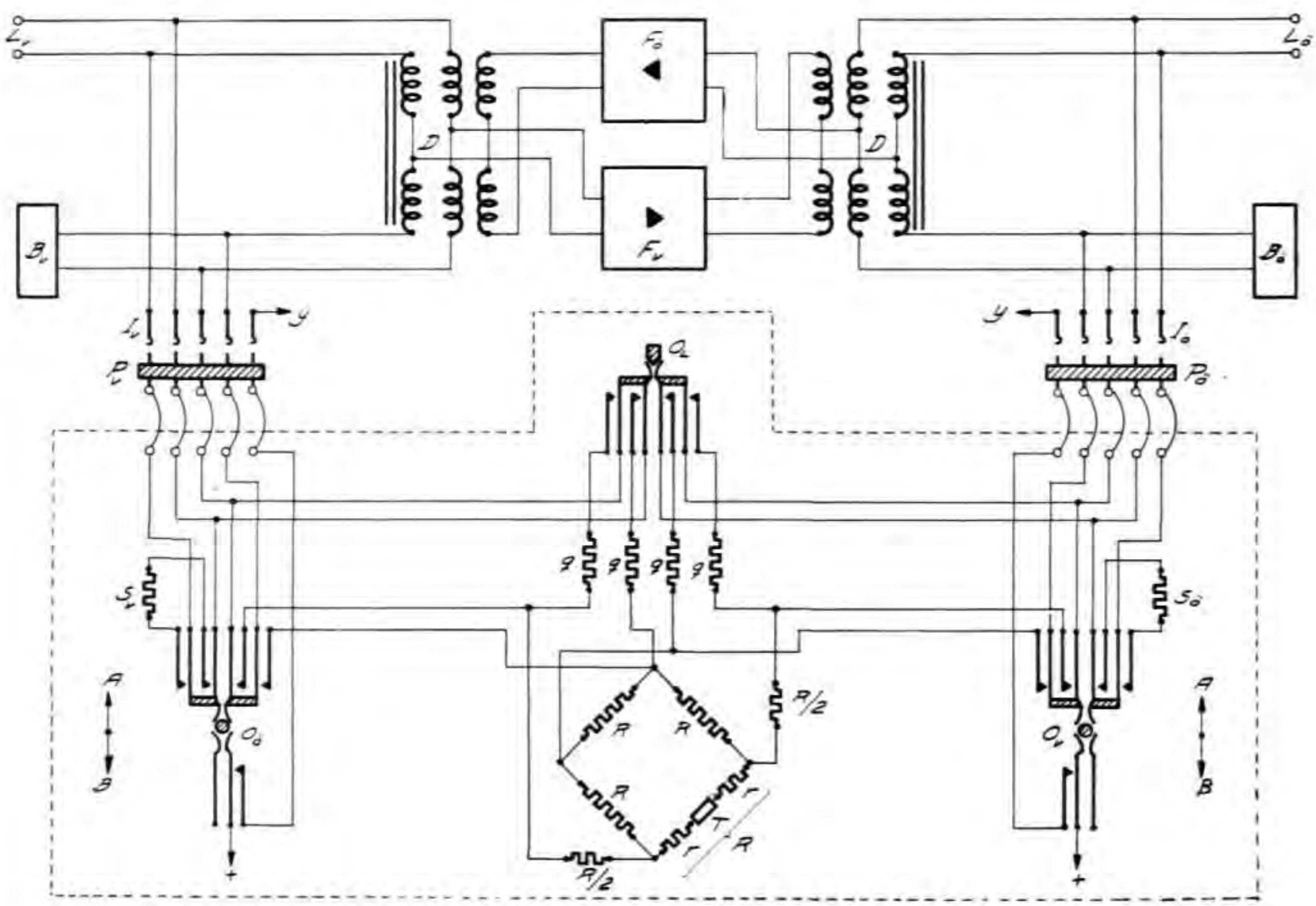
Fig. 23 is a diagram of a supervisor's telephone and listening set on the Ericsson system.

By this device it is possible to listen in — without disconnecting the line or balance circuits — without appreciable increase of attenuation in the circuit. The instrument also allows signals and conversation to one of the persons using the line at a time, or to both simultaneously.

R and r resistances, forming with the head set T a balanced bridge.

$\frac{R}{2}$ resistance for symmetrizing the head set with respect to earth,

q relatively large resistances,



R 3046 Fig. 23. Circuit diagram of speaking, ringing, and listening devices.

The speech currents from the line L_v to the line $L_ö$ are amplified in the repeater F_v, and those from the line $L_ö$ to the line L_v in the repeater $F_ö$. The line L_v is balanced by the line balance B_v, and the line $L_ö$ by the line balance $B_ö$.

All line and balance circuits are tapped for connexion to the test jacks I_v and $I_ö$.

The leads y from the test jacks end at the relay springs 3 (see fig. 22 of the 2-wire repeater ringing set).

The telephone and listening set consists of

O_L listening key.

$O_ö$ speaking and ringing key for the line $L_ö$.

O_v speaking and ringing key for the line L_v.

T supervisor's head set.

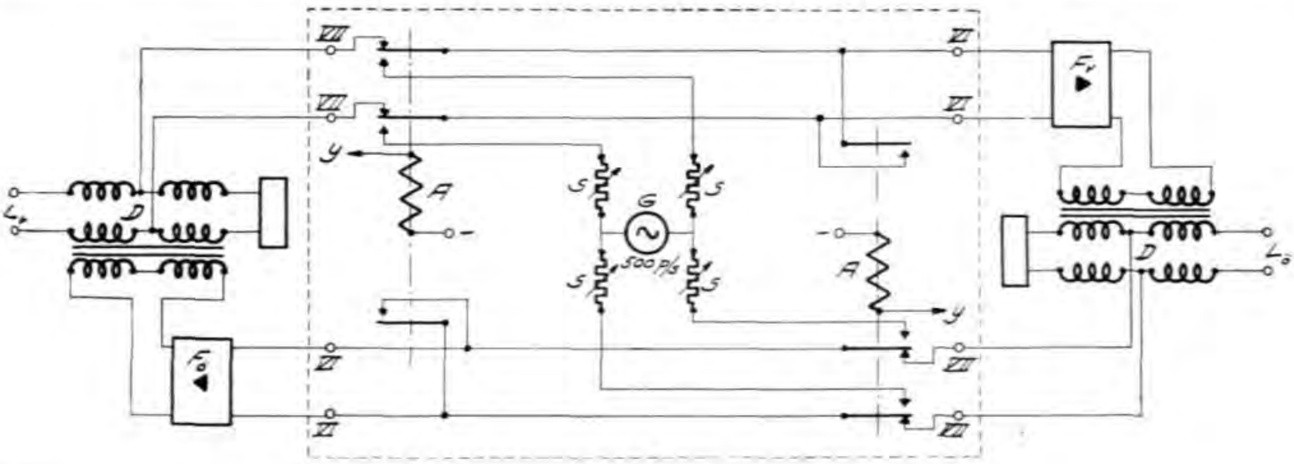
S_v and $S_ö$ balance resistances, and

P_v and $P_ö$ junction cords.

The key O_L is pressed down when listening. Each diagonal in the bridge (R, r, T), in series with two resistances q, will then shunt the anode sides of the repeaters, transformed by the differential transformers D. The speech currents arriving in the listening set being thus amplified, the resistances q may be made large enough to reduce the additional attenuation introduced in the circuit by the listening set to less than 0.05 nepers. Reaction is prevented by the bridge (R, r, T) being balanced.

For speaking on the line $L_ö$ the key $O_ö$ is put to position A, and for speaking on the line L_v the key O_v is put to position A.

In the first case, speech currents from the head set enter the circuit of the line balance B_v. For well known reasons these will not be admitted to the line L_v, but are amplified in the repeater F_v and sent out amplified in the line $L_ö$. The speech currents from the line $L_ö$ are amplified in re-



R 3044 Fig. 24. Arrangements for voice frequency signalling.

peater $F_ö$ and, though part of them go to the line L_v, enter the circuit of the line balance B_v also and are thus admitted to the head set. The line balance B_v, the resistances $(R, \frac{R}{2}, r)$, etc., absorb a large portion of the current, but this is amply compensated by both outgoing and incoming speech currents being amplified in the repeaters F_v and $F_ö$ respectively. To prevent the connexion of the head set in the circuit of the line balance B_v causing unbalance, a resistance S_v is simultaneously connected in shunt with the line L_v. The balance in the bridge (R, r, T) obviously enables the keys $O_ö$ and O_v to be put at the same time in the A-position without risk of singing or echo.

A calling signal is sent out on the line $L_ö$ or L_v by putting the key $O_ö$ or O_v to the B-position, which actuates the ringing set to send out a signal on the line $L_ö$ or L_v as required.

If voice frequency signals are to be used, the leads y from the test jacks may be connected to the relays A of fig. 24. These will then transmit the signals from the voice frequency generator G. S are protective resistances limiting the signal current suitably. The other symbols are the same as in fig. 22.

In repeater stations where only voice frequency signals are used, however, it is simpler to send the signal current from the telephone and listening set, in the same way as the speech currents, which makes the relays A superfluous. Certain alterations must of course then be made in the set described above.

These telephone- and listening sets are mounted in a special bay, which in the following will be called the Control Panel.

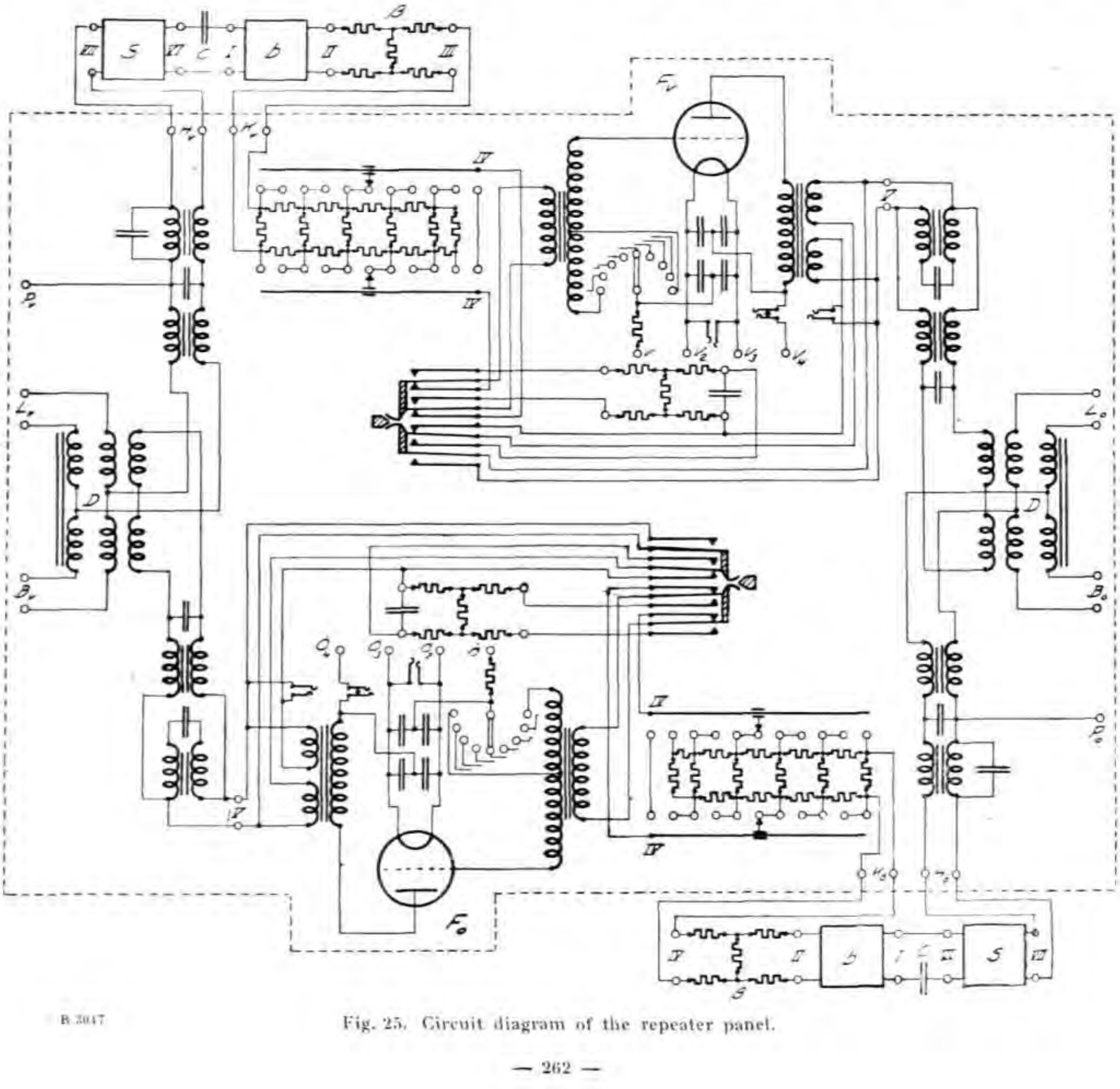
12. The Repeater Panel.

In the previous chapter the several parts of the Ericsson 2-wire repeater have been separately described. We will now see how these are combined into constructional units, and in this chapter the so-called Repeater Panel, in which the amplifying parts are mounted, will be specially described.

The only parts fitted in this Panel are those which are used in every 2-wire repeater, and can be designed to suit any local conditions without alterations of connexions or other arrangements in the Panel. The object has been to obtain a standard panel suitable for all occurring conditions and always used as a complete unit. In many standard designs certain alternative parts are included, generally increasing their cost unnecessarily. Parts which are not always necessary or have to be adapted in design and dimensions to local conditions, are in the Ericsson system mounted on relay rails or rack shelves, which increases the flexibility of the system.

The parts which on these principles can be fitted in the repeater panel are: amplifying valves with grid and anode transformers; gain-adjustment device; gain-setting potentiometer; differential transformers; and the filters. It is an open question whether the same filter design is suitable in every case. Filters with different cut-off frequencies are of course used for different types of circuits. But when the frequency range to be passed by a repeater for satisfactory speech transmission is once fixed, the repeater should obviously under all circumstances pass those frequencies and no more, as otherwise the stability of the line would be unnecessarily reduced. If the stability of any circuit should demand a further cutting down of the frequency range passed, it is better to try to increase the stability by other means than to lower the cut-off frequencies of the filters.

The parts which will be mounted outside the repeater panel will thus be: the attenuation equalizer, which will have to be adapted to local circumstances, is unnecessary in short lines and not required for all the repeaters in long lines; the ringing set, which is not required for voice frequency signals, and is sometimes replaced by the relay device of fig. 24; the attenuation network (see fig. 19), which is sometimes unnecessary, and the attenuation value of which must be adapted to local requirements; the condenser *C* (see fig. 22), which must also do the work of the condenser *K* of fig. 5, and therefore must have a capacity



B 3047

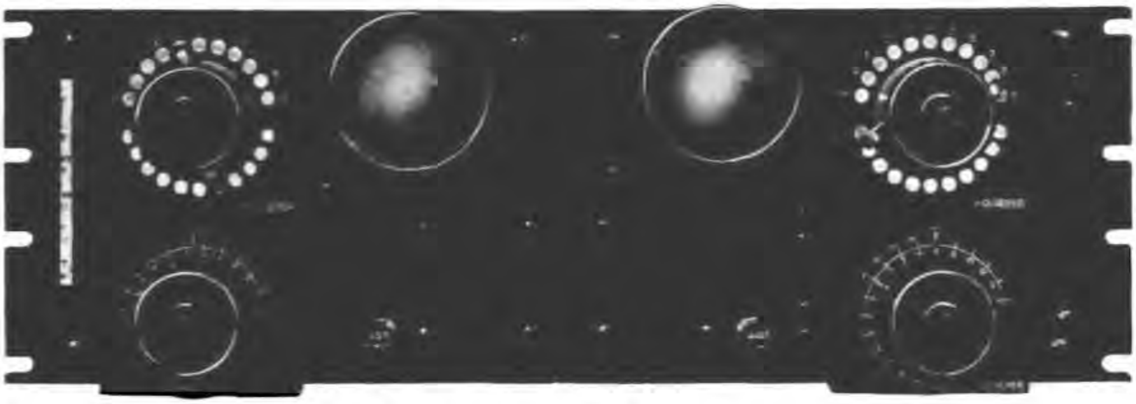
Fig. 25. Circuit diagram of the repeater panel.

selected with a view to local conditions (see chapter 3); anode alarm relays with resistances (see fig. 21, L and r respectively), which are more suitably mounted on relay rails; and the devices common to several repeater panels for current distribution, e. g. the filament current resistances M_1 and M_2, the measuring jacks I_g and I_a, the key O etc., of fig. 21. Line balances, line extensions, line transformers or the like, are of course also excluded from the repeater panel.

these the two grid transformers, and on either side the differential and anode transformers and the filter coils.

On either side of the condensers we see the back of the valve sockets and the grid leakage resistances, and furthest to the right the terminals of the measuring and headphone jacks. The condensers are easily loosened and removed for repairs if necessary.

Fig. 6 shows the input impedance of the repeat-



R 3050 Fig. 26. Front view of the repeater panel.

er as a function of the frequency at normal gain, and figs. 28, 29, 30, and 31 the gain as a function of the frequency. At maximum gain the impedance curve will be somewhat deformed by the capacity of the grid transformer windings. Curves I and II of fig. 28 show the gain when the latest and older designs respectively of repeater filters are used, and curve III is the echo attenuation curve of fig. 14, below which the gain curve must lie for stability. The gain curves in fig. 29 are obtained by measurements in various positions of the setting potentiometer, in fig. 30 for various settings of the adjustment- and fine setting potentiometers, and in fig. 31 for various values of the attenuation b_o (see chapter 7) when an attenuation equalizer was connected.

Fig. 25 is a diagram of the repeater panel, which includes everything within the dotted line. What has been said in the foregoing chapters will make a detailed description superfluous. To facilitate recognition, certain connecting points are marked by Roman numerals, referring to figs. 17, 19, 22, and 24.

D. C. supplies are connected to the terminals V_1, V_2, V_3, V_4, $\ddot{O}_1$, $\ddot{O}_2$, $\ddot{O}_3$, and $\ddot{O}_4$; lines and line balances to the terminals L_v, $L_{\ddot{o}}$, B_v, and $B_{\ddot{o}}$ respectively; and any condensers used for balancing coil loaded lines the terminals P_v and $P_{\ddot{o}}$.

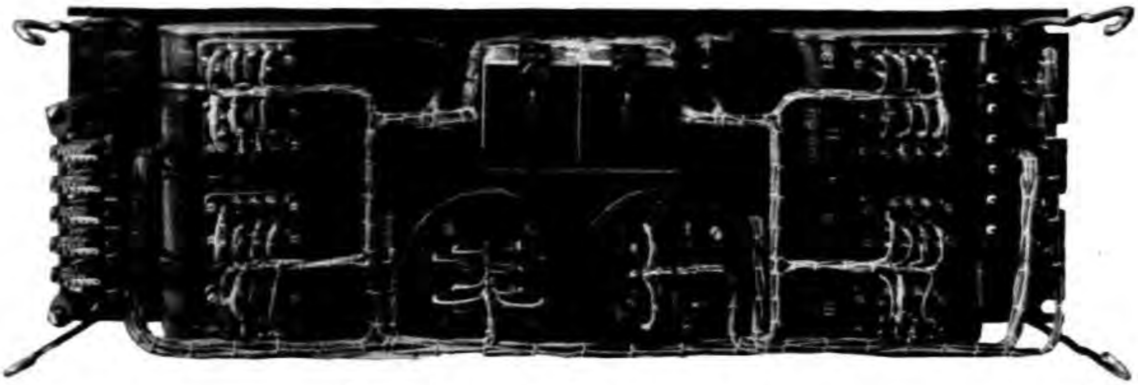
A ringing set S, condensers C, equalizers, attenuation networks B, etc. may be connected between the terminals H_v, $H_{\ddot{o}}$ and K_v, $K_{\ddot{o}}$ respectively.

Fig. 26 is a front view of a repeater panel. In the centre we see the two amplifying valves, and at the side of them the two setting potentiometers. Below the setting potentiometers are the adjustment potentiometers, below the valves the press buttons for the gain adjustment and furthest to the left the measuring and headphone jacks.

Fig. 27 is a back view of the repeater panel. Furthest to the left are the connecting terminals, in the centre the condensers at the top, below

13. The Repeater Bay.

The equipment of a station may suitably be divided into two groups, which we will call line termination equipment and repeater equipment. The line terminations include cable distributing boxes, lightning arrestors, fuses, repeating coils, line extensions, line balances, main distribution frames, and the like. Line terminations thus serve to protect the station from disturbing currents from the outside, to separate physical and phantom circuits, to transform the characteristic impedance of the lines to one which is practically frequency-independent and suitable for the repeaters (in the Ericsson system 800 ohm), and to supply the requisite line balance impedances to the repeaters. The reason why line balances are included in the line terminations is that these circuits have to be provided with repeating coils and are wired in the racks like the lines.



R 3052 Fig. 27. Back view of the repeater panel.

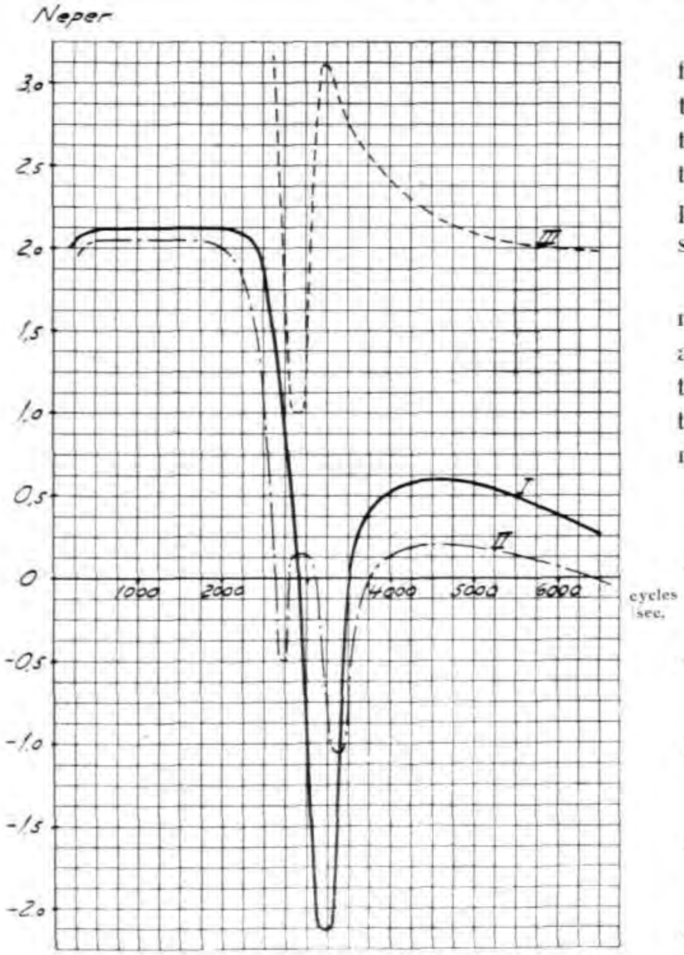
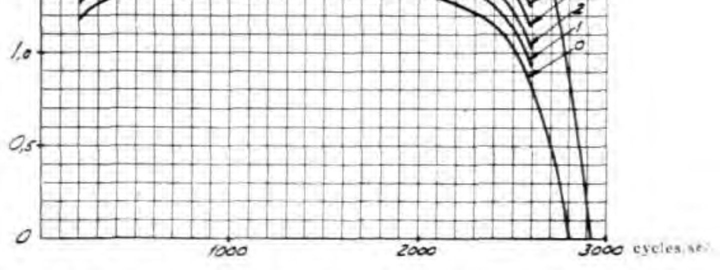


Fig. 28. Gain as a function of the frequency. The curves I and II show the gain in new and old designs respectively of the repeater filters, and curve III is the echo attenuation curve of fig. 14, below which the gain curves must lie.

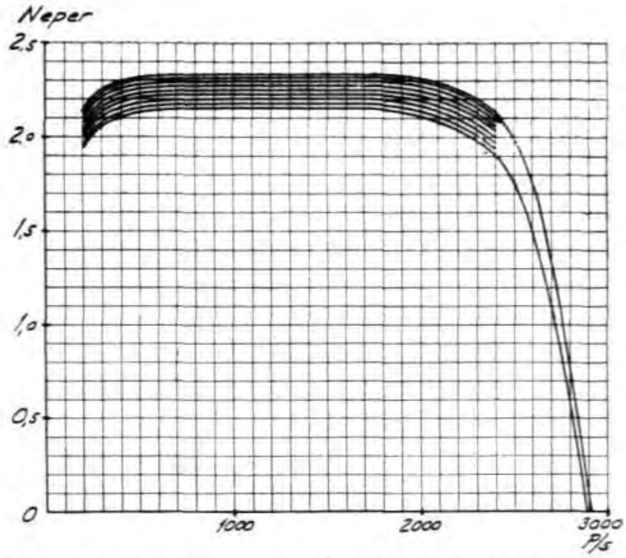
The object of the line terminations, to transfrom the individual characteristic impedances of the lines to a standard impedance suitable for the repeaters, is to get not only the above mentioned reflection-free matching of lines and repeaters, but also reflection-free connexion in the station of lines which need no repeaters.

The possibility of opening up for measurement reflection-free connecting points between lines and repeaters of frequency-independent characteristic impedances also greatly facilitates the determination of the operating qualities of lines and repeaters.

The repeater equipment, comprising everything



R 3028 Fig. 29. The gain as a function of the frequency for various settings of the gain adjustment.

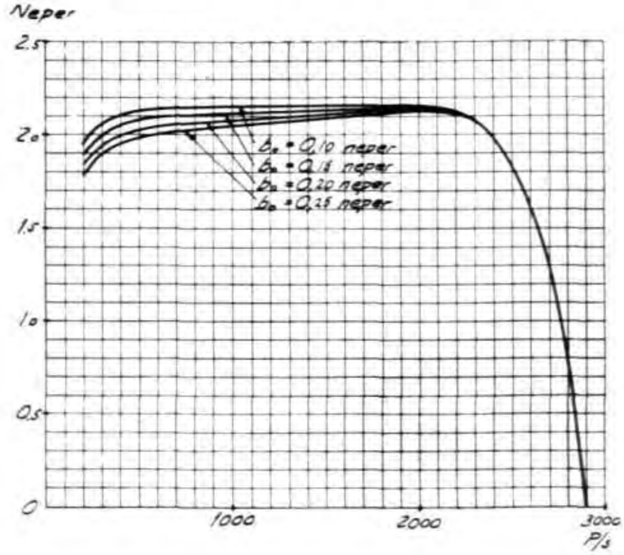


R 3024 Fig. 30. The gain as a function of the frequency for various steps of fine-setting and adjustment.

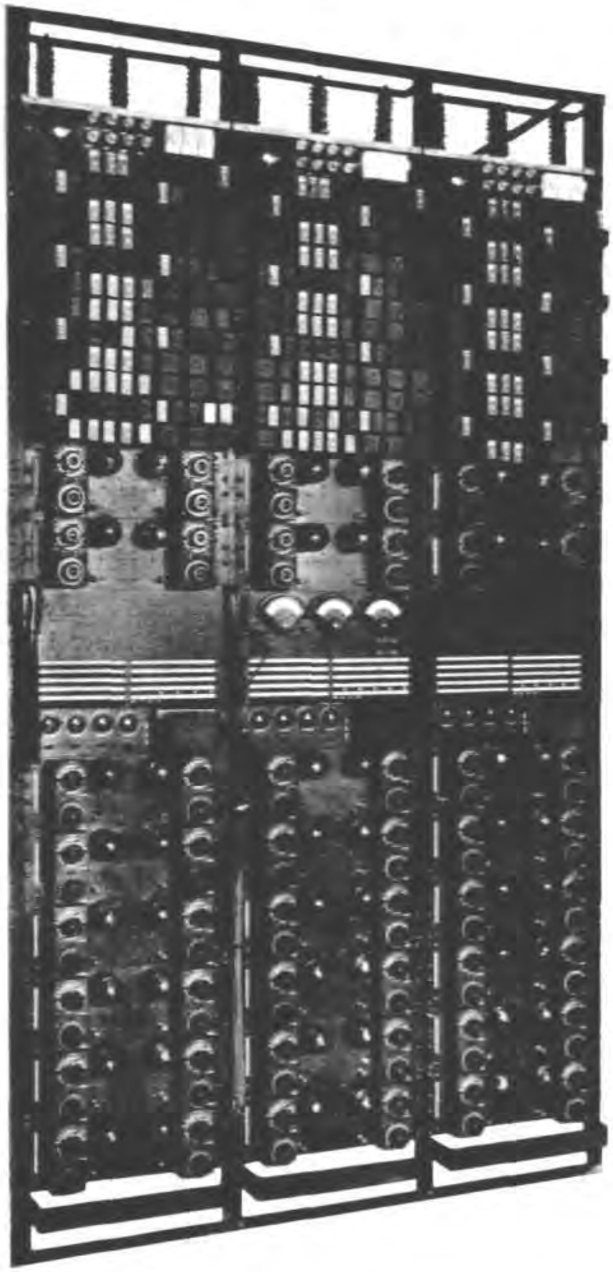
else, is in the Ericsson system collected in a bay unit, containing 8 complete repeater equipments per bay.

This unit system offers the advantage over the usual systems using separate bays for repeater panels, relays, current distribution devices, etc. that a repeater station can be planned with less regard to eventual extensions, and need not be encumbered with expensive, incompletely utilized bays.

Fig. 32 shows the Ericsson unit bay for 2-wire repeaters. At the bottom we note four repeater panels, and immediately above these the so-called



R 3029 Fig. 31. The gain as a function of the frequency for various b_o-values when an attenuation equalizer is connected.



R 3051 Fig. 32. Front view of the repeater bay.

current distribution panels. In the latter we see four dials for adjusting the filament current (M_2 in fig. 21), below these dials the respective keys (*O* in *fig.* 21), furthest to the right protective casings for the fuses, and to the left of these lamp indicators for blown fuses.

Above the current distribution panels are seen the jack panels, containing in- and out-jacks for line and balance circuits, parallel jacks for speaking and listening from the control panel (K_0 and L_0 in fig. 23), measuring jacks for measuring filament current and the resulting anode current of the groups (I_g and I_A in fig. 21), jacks for junction lines to test bays etc., connecting jacks to the control panel, indicator lamps for disconnected anode alarm relays and no-voltage alarms etc., etc.

Above the jack panel of the middle bay, the control panel is seen, with the listening key (O_L in fig. 23) and the speaking and ringing keys (O_v and O_5 in fig. 23) furthest to the right, and a head set jack furthest to the left. Above the control panel we see the so-called measuring panel, principally consisting of three *D. C.* instruments with connecting cords and plugs, by which battery voltages, filament currents, anode current, and filament voltages may be measured in the measuring jacks in the jack- and repeater-panels.

Both control and measuring panels may be common to several bays, and in the other bays the corresponding panels are then either filled in with blind panels as shown in the side bays of fig. 31, or else used for measuring instruments, e. g. for gain measuring, balance testing, or the like.

Above the measuring panel another two repeater panels are seen, and the greater part of the space above them is taken up by relay rails. On these relay rails ringing sets, blocking condensers, attenuation equalizers, attenuation networks (*S, C, b* and *s* respectively in fig. 25), and anode alarm relays (*L* in fig. 21) are mounted.

The bays shown in fig. 31 are equipped with all the parts described, but obviously these are rarely all required in one bay. Devices for automatic compensation of variations in line attenuation, and remote control of gain adjustment, say from the operator's position, may for instance also be mounted on the relay rails. Above the relay rails a panel is finally seen carrying the main fuses to the right, the alarm bell to the left, and series lamps for the 20-cycle signal current in the centre.

The New Ericsson Subscriber's Automatic Telephone
1931 Model.

Thomas Alva Edison.

By *E. Herlin*, Ph. D.

Thomas Edison has to a whole generation been the great wizard always mentioned whenever a new, epoch-making invention startled the world. A son of the "land of great opportunities", he never let a favourable occasion pass, but carved for himself a career which was most unusual. Like so many other famous Americans, he began as a newsboy. It was not poverty, however, that drove him to this occupation, for the home in which Thomas Edison first saw the light of day on February 11th 1847—in Milan, Ohio—was not poor, and his parents could have kept him without difficulty if he had not demanded more of life than boys usually do. But Thomas Edison did demand more than usual, for he early developed an unquenchable and irresistible thirst for knowledge. The means provided by his parents were not sufficient to procure the scientific and technical books he wanted, nor were they enough for all the chemicals the boy used in the laboratory he had fitted up in the basement of his parent's house. He was therefore not satisfied until his parents gave him permission to become a newsboy on the Grand Trunk Railway.

THOMAS A. EDISON.

He was then 12 years old. Early each morning the train left his home town, Port Huron in Michigan, for Detroit and did not return till late at night. His whole time was of course not occupied in selling papers. The irresistible inclination to work which characterized his whole life was already apparent. In a luggage van on the train he arranged a laboratory to continue his experiments. He also set up a printing press there and himself published a paper, The Weekly Herald, the first newspaper ever printed on a moving train. When after some time several more trains were put on the line, Edison got a couple of other boys to help him sell his papers. Another couple of young assistants looked after the two shops he opened in Port Huron, one for newspapers and the other for farm produce bought in Detroit or from the farmers along the railway. Thus, even at 12, qualities were already apparent which later proved invaluable to the great inventor, i. e. the ability to put others to work, and to organize. In this way the young paper-boy earned a fairly good income, but all he made was spent on books and chemicals. Then as afterwards, the only value of money to him was that it made his experiments possible.

When Edison was 15 years old, an event occurred which was to be of enormous importance to his career. One day in August, 1862, he saw at a railway station a small child crawl across the rails in front of a shunting truck. He rushed up and pulled the child away. It was the station-master's daughter. The grateful father, Mackenzie by name, showed his gratitude to the lad for his presence of mind by letting him into the secrets of telegraphy, and Edison soon became a skilled telegraph operator.

This event became important to him from two points of view. It gave him a profession which paid better than that of selling newspapers, and therefore increased his opportunities for study, and also directed his interest, which had previously been taken up wholly by chemistry, to electricity instead, in which he was later to make his most important inventions.

Edison now became a telegraph operator in various places, and thanks to his wide reading he became particularly good at deciphering the press telegrams, which often were almost unintelligible, as the telegraph cables in those days were badly insulated, and disturbances were rather frequent. After five years as a telegraph operator, Edison was engaged as an engineer in the Western Union Telegraph Co. in 1868, and the next year in the Gold & Stock Telegraph Co. in New York. With these firms he had ample opportunities for experimenting, and his labours soon began to yield results in the shape of several inventions, chiefly relating to telegraphy. To allow better use to be made of the expensive telegraph lines, he worked out his "duplex" system, by which two telegrams could be sent on the same line. Later on he improved this into a quadruplex, and finally sextuplex, system.

Edison's first great financial success came in 1873 when, at 26 years of age, he received 40 000 dollars for a new stock exchange tape machine. This money enabled him to fit up a laboratory and an engineering workshop at Newark, which in 1876 were moved to Menlo Park in New Jersey. This was the year Bell patented his telephone, and one of the first problems tackled by Edison in his new laboratory was that of improving the Bell invention, and he succeeded in designing the first carbon microphone for practical use. He had great difficulty in obtaining absolutely pure carbon for this, but he overcame it by keeping a number of paraffin lamps burning in a separate room with wicks turned right up so that they smoked. Now and again the soot was scraped up and weighed out into suitable portions, compressed in a hand press into small thin discs, and taken to the telephone workshops.

The first microphones had very low resistance, and the variations in this resistance caused by speaking into the microphone were therefore also very small. The variations in current caused by them were consequently also minute, and still more reduced by the high resistance of the lines. Edison now made an invention improving these conditions considerably. He introduced in the telephone a transformer which changed the low tension current of the microphone circuit into alternating current of a higher voltage, better able to overcome the resistance of the lines.

The knowledge gained by Edison, through working on the telephone, of the connexion between sound vibrations and membrane oscillations, led him to another remarkable invention. The actual idea of this came to him, however, during some experiments to produce a method by which telegrams could be recorded automatically on a sheet of paper placed on a rotating metal disc. He then got the idea of investigating whether the oscillations of a microphone diaphragm could not be captured in the same way, and an apparatus thus obtained which could record as well as reproduce the human voice. The results were good right from the first attempt. The invention was then improved in the laboratory established by him at Fort Myers in Florida, and the phonograph soon carried Edison's name throughout the world. It was also in Menlo Park that, in 1879, Edison began his labours with the incandescent lamp. Although the German-American mechanic Heinrich Goebel and the Englishman Joseph Swan had both been occupied with the same problem for twenty years before it was tackled by Edison, it was nevertheless Edison who in this case, as in so many others, produced the first really practical solution.

The origin of Edison's incandescent lamp is characteristic of the methodical way in which he worked. The great difficulty was to find a suitable incandescent wire. After many expensive and unsuccessful experiments it was found that charred cotton thread could be kept incandescent in an evacuated glass bulb for a couple of days. This solved the principle of the problem. The practical incandescent lamp ought to contain a carbon filament in a high vacuum. To find a suitable and sufficiently durable carbon filament, Edison sent out expeditions to various parts of the world to collect vegetable substances, the fibres of which were charred in his laboratory and tested. Charred hair was tried too, and old Mackenzie, for whom Edison had found a place in his laboratory, made use of his fine red beard for this purpose. The lamp made from it gave a light which was, however,—according to Edison himself—far too rich in red rays! After an enormous number of experiments Edison finally came to the conclusion that charred bamboo fibres provided the best material for the incandescent filament, and so the carbon filament lamp came into being.

Edison, however, did not rest content with this. He also invented new, or improved existing, designs of such things as lamp holders, fuses, cables, dynamos, etc., in fact everything pertaining to an electric light plant, and he also took part personally in establishing factories for manufacturing incandescent lamps, electric machinery etc. The largest of these, the Edison Electric Works at Schenectady, was later merged with the Thomson-Houston Works into the well-known General Electric Co. Other electrotechnical inventions of his too, for instance an electric tramway system and a method of telegraphing to trains en route, contributed much to the foundation of the great electrical industries of our times.

After 10 years of fruitful work at Menlo Park, Edison moved his laboratories and workshops to West Orange in New Jersey. Here he invented among other things the kinetoscope, the predecessor of cinematographs, and a new storage battery of much the same design as the Nife battery patented a little earlier by the Swedish engineer Jungner.

Edison had never quite deserted his first love, chemistry, and at West Orange he devoted himself to several chemical problems. He invented, inter alia, a method of refining iron ore whereby poor ores could be made use of, he improved the process of cement making, and he set investigations on foot to ascertain whether any of the common and easily cultivated plants in the country could be used as raw material for the production of rubber.

In his research work Edison was in a class by himself, in that he always directed his attention to practical problems. He did not study science for science's sake alone, nor did he work at an invention simply because some idea had entered his head, but always selected problems which he realized would be of great practical importance, and set to work on these, usually empirically and with scientific accuracy. Naturally, he did not fail in the course of this work occasionally to make discoveries which at least at first seemed to be of only academic interest. One of these was the electric effect which bears his name, and which subsequently proved to be of enormous practical import, for on it is based the thermionic valve now used for many purposes, especially in wireless.

Edison knew how to gather round himself a staff of assistants and how to infuse in them his own burning enthusiasm for the work. In his first laboratories he had a clock as a reminder of the value of time, but that clock was never allowed to go, because he would not let time decide the rate of working. At times, his days and nights were therefore very irregular. When busy on an interesting problem, he forgot both food and sleep. Not until the problem was solved, or when he was so tired that his brain refused to work, did he seek rest—in bed or on a laboratory table—anywhere. His pupils and assistants followed his example as far as their endurance permitted. Entering his laboratory early in the morning, one often found them asleep here and there on the tables.

It is but natural that when, as in Edison, genius cooperates with intensity, the result should be brilliant. Edison's actively creative spirit has left its mark in many different spheres, and his name is coupled with a multitude of appliances and devices which have become indispensable to modern civilization. During the night of the 17th—18th October the devoted scientist and indefatigable worker entered his last rest.

Electrical Point Machine with Incorporated Point Lock.

Communication from the "Signalbolaget".

By *E. G. Windahl.*

The point machine, see fig. 1 a below, is fitted beside the points and has two tie rods, fixed to the tongues of the points. The driving power, fig. 1 b (p. 270), is supplied by an electric motor, 7, which may be either D. C. or A. C. By means of gears, 9 and 10, the driving power is transmitted to the tie rods, 3 and 4, which move at right angles to the longitudinal axis of the point machine and, being connected one to each tongue of the points, regulate the movements and positions of these. The tie rods, and the driving wheels 11 and 12 acting on them, are so arranged that they impart the correct combination of movement as well as locking the closed tongue in each position of the points. Fig. 2 shows how the movements and locking are effected. The two driving wheels, 11 and 12, which have teeth on one part of their circumference only, are fixed on the driving shaft, 17, and engage with the corresponding rods, 3 and 4, the interdependence of which is indicated at the bottom of the illustration. In fig. 2, I and I a, one of the end positions, is shown. The rod 3 is connected to the tongue which in this position is open, and rod 4 is connected to the closed tongue of the points, which latter is locked by rod 4 being locked by the blank part of driving wheel 12. When the points are thrown over to the other end position, the driving wheels are turned in the direction indicated by the arrow, when at first rod 3 (the open tongue) alone is moved to the right of the picture by the egaging teeth, while rod 4 (the closed tongue) remains locked. When the position shown in figs. II and II a is reached, the locking of rod 4 is released and it is moved to the right by rod 3, which is still actuated by its driving wheel 11 (both tongues are moved). Driving wheel 12 of rod 4, however, soon begins to take an active part in the driving, and the two driving wheels now cooperate in moving the rods. In the position shown in fig. 2, III and III a, the driving force on rod 3, which has then reached its end position, ceases (the tongue is close up against the rail), and the rod is locked by the blank part of driving wheel 11, which is now in a position preventing any return movement of the rod. During the remaining part of the throwing-over operation, rod 4 is only moved to the open tongue position, see fig. 2, IV and IV a, while rod 3, attached to the closed tongue, remains locked.

R 3059 Fig. 1 a.

In addition to the locking of the closed-tongue rod described above, the point machine is provided with a locking device 1, fig. 1 b, combined with the motor shaft, to prevent any vibration caused by the passing of trains or the like improperly affecting the setting of the mechanism when the throwing-over operation is completed. This locking device is automatically disconnected when the motor is started, and connected as soon as the motor power is cut off.

For the protection of the motor, the point machine is fitted with a friction-coupling, 2, fig. 1 b, which will also function in case of the points being forced. Should the points be forced, the open tongue, affected by the wheel pressure, will by its tie rod thrust the mechanism backwards, causing the friction-coupling to slip.

By the end of the point machine, where there is an intake, 16, for the electric wires, a contact device, 5, is arranged for switching the motor and control circuits required. This contact device is operated by two steering devices, 15, fixed on the extended shaft of the driving wheel.

If tongue control is required, the switching of the contact device is also made to be conditional on a couple of detector rods, 13 and 14, which run parallel to the tie rods and are, like these, connected one to each of the tongues of the points.

The point machine is also provided with a device, 6, for manoeuvring by hand by a special crank. All parts of the point machine are easily accessible for inspection and lubrication. The cogged wheels, 9, which move more rapidly, are

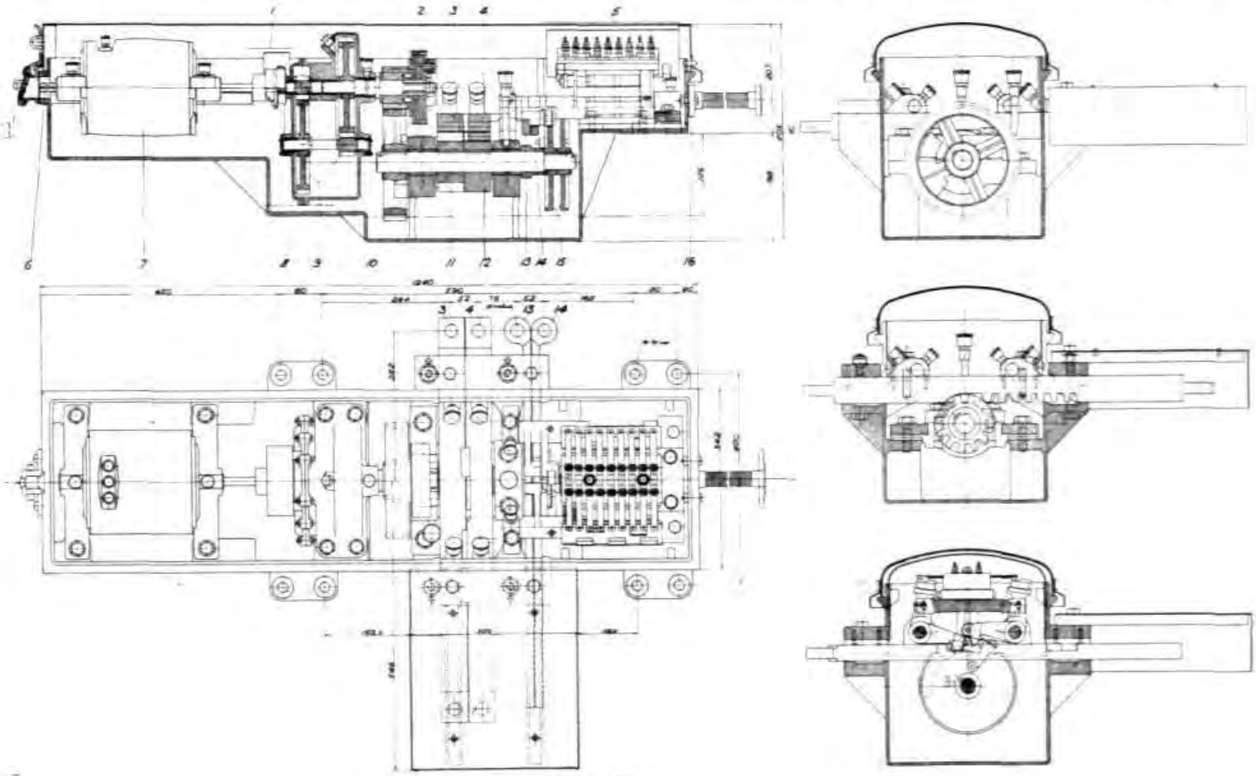


Fig. 1b.

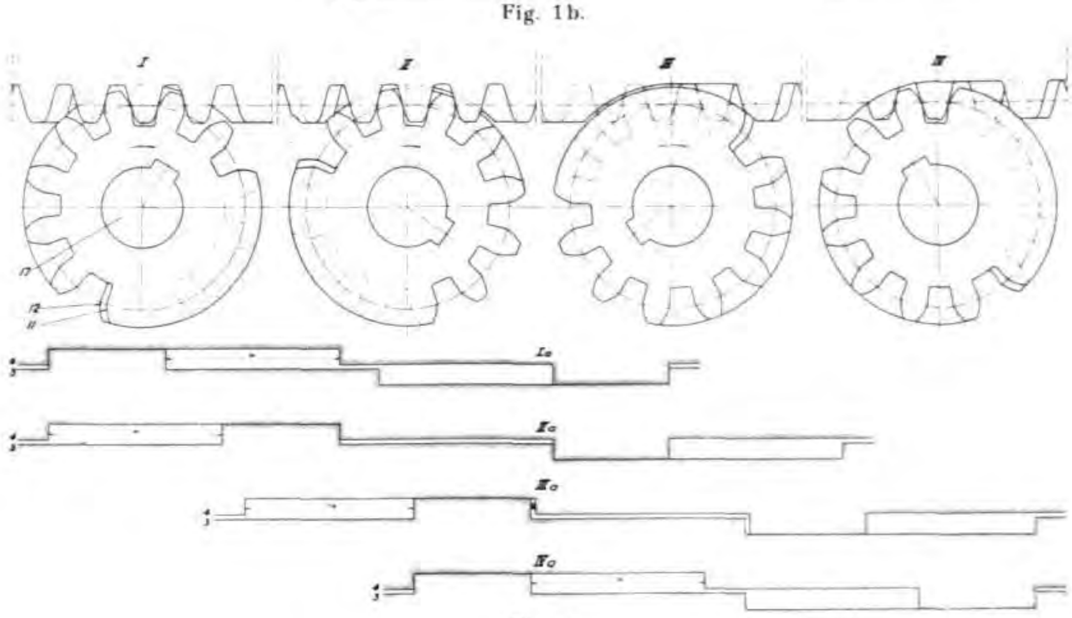


Fig. 2.

wholly enclosed in a cast iron casing, 8, filled with oil to a certain level so that the cogged wheels are partly running in oil, thus ensuring efficient lubrication.

Fig. 3 a shows a point machine fitted to single points, and fig. 3 b shows that the parts required for making the connexion are very simple. The two rods, 21 and 22 respectively, by which each tongue is joined to the corresponding tie rod (3, 4) and detector rod (13, 14) of the point machine, are thus of exactly the same pattern. To enable the point machine to be placed to either side of the points, the tie rods 3 and 4 are provided with holes at both ends for the connecting bolts. The detector rods 13 and 14 can be easily pulled out and moved to the side where the connexion is to be made. To protect the rods between the point machine and the points, a wooden casing with lid may suitably be put up. On the other side of the point machine the projecting rod ends are protected by the sheet metal casing, 18, provided for this purpose.

The cable box, 19, of the point machine, which is designed for the connexion of one or two cables, is mounted on a pole close to one end of the point machine and is connected to this by a flexible steel tube, 20, through which the connecting wires are led into the point machine.

The steel tube, 20, must when fitted be protected by a plate put up between the cable box, 19, and the point machine.

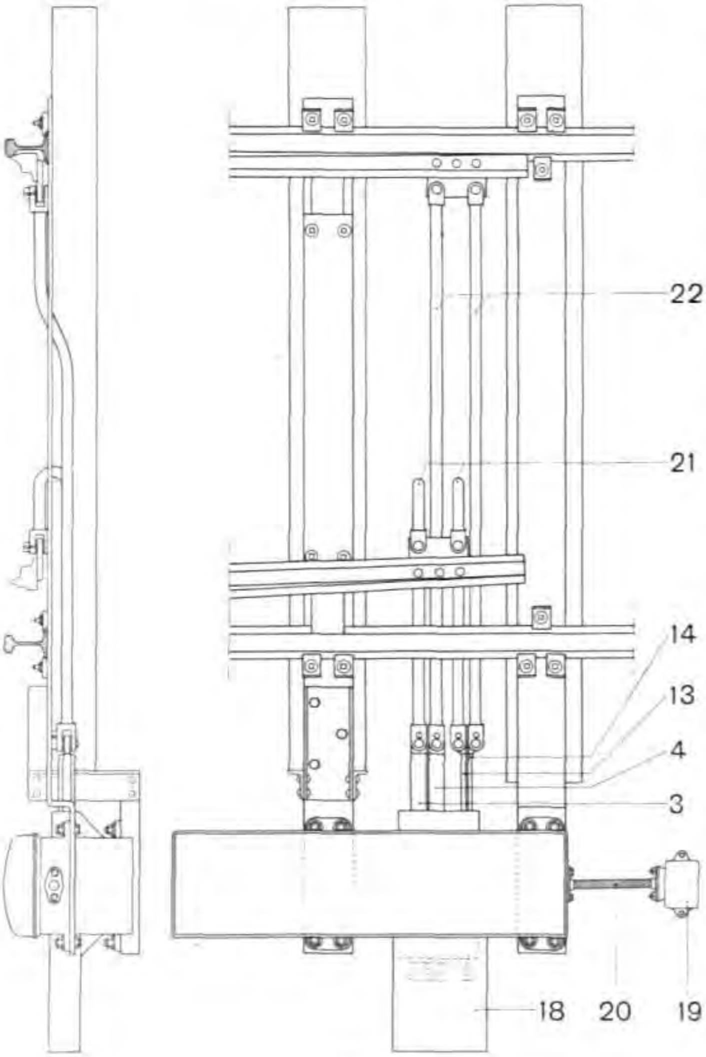


Fig. 3b.

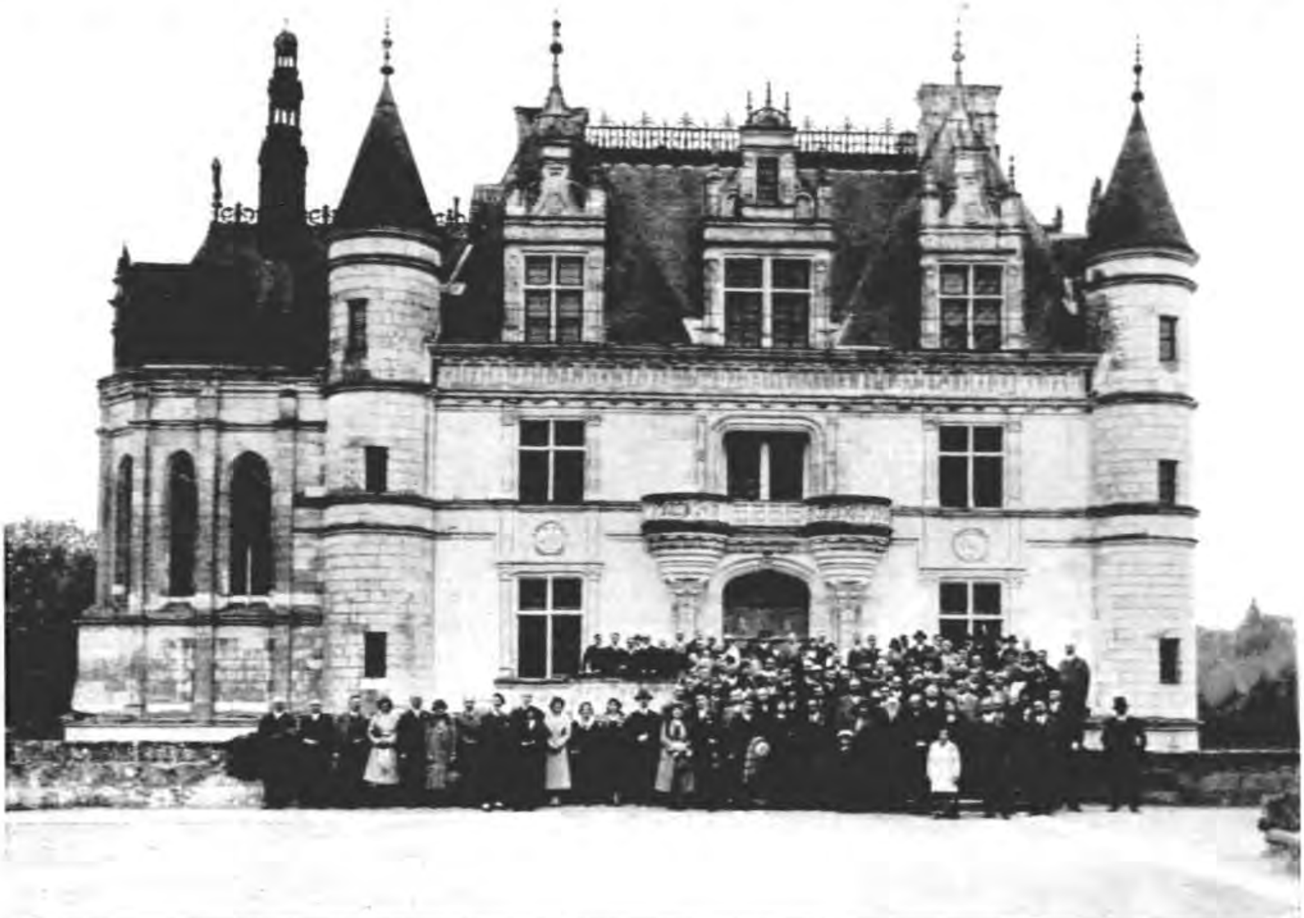
R 3058

Fig. 3a.

Comité consultatif international des communications téléphoniques à grande distance — C. C. I. — Plenary Session in Paris 1931.

By Dr. *M. Vos.*

The International Consultative Committee on Long Distance Telephony, the CCI, held its 8th plenary session in Paris from September 14th to 21st 1931. This meeting took place at the Sorbonne in la Salle du Conseil Académique, under the chairmanship of M. Lange, Directeur de l'Exploitation Téléphonique de France.



R 1003 Group of Delegates outside the Chateau Chenonceaux.

Since the preceding plenary meeting, the number of countries attached to the CCI had increased by 4, viz. the Dutch East Indies, the Union of South Africa, Chile, and Uruguay, making the present total number 36, of which 27 are European. 24 countries in all were represented at this session, namely Germany, Argentina, Austria, Belgium, Chile, Cuba, Denmark, Spain, U. S. A., France, Great Britain, Dutch

East Indies, Iceland, Italy, Luxembourg, Mexico, Norway, Holland, Roumania, Sweden, Switzerland, Czechoslovakia, U. S. S. R., and Yugoslavia.

The several countries were represented by delegates from the respective Government Telephone Administrations or from the Companies operating the telephones of the country. The last was the case with Mexico, which was represented by the Mexican Consul at Le Havre as Head of the delegation, Empresa de Teléfonos Ericsson which was represented by Dr. M. Vos and Messrs. F. Markman and H. Blomberg, and the Mexican Telephone and Telegraph Co., represented by Messrs. E. A. Brofos and S. M. Catterson.

By special invitation, the plenary session was also attended by representatives of the Japanese Telephone Administration, which country has not yet joined the CCI, and by representatives of the International Bureau of the Universal Telegraph Union and of the Technical Commission on Cummunication and of the League of Nations. Invitations had also been issued for certain of the meetings to representatives of the International Union of Railways and Tramways, certain International Power Organizations, the International Broadcasting Union, and others.

Between plenary sessions, the technical and traffic questions to be studied by the CCI are dealt with by the Commissions of Assessors (Rapporteurs) (CR), at present seven in number, which deal with questions concerning:

1. The Protection of Telephone Lines against the Disturbing Influence of Power installations.
2. The Protection of Telephone Cables against Corrosion due to Elektrolysis or to Chemical Oction.
3. Transmission, Maintenance and Supervision of Lines and Installations.
4. The Master Reference System for Telephone Transmission, Reference Systems and Working Standards.
5. The Co-ordination of Telephony and Radiotelephony.
6. Traffic and Operation.
7. Tariffs.

Empresa de Teléfonos Ericsson is represented in the 1st, 3rd, and 4th CR.

The Administrations and Operating companies having been given an opportunity of expressing their opinions on the questions recommended for examination by the last plenary session, these are discussed at meetings of the Commissions of Assessors. On account of the close connexion between some of the questions dealt with by certain commissions, it has been considered desirable for the 1st—5th CR to meet simultaneously in the same place, and similarly the 6th and 7th CR. This has also been done this year, the 1st to 5th commissions having met in Prague in June, and the two latter in London in April, 1931.

The questions on the agenda of the plenary sessions are divided into three groups, each discussed separately under the guidance of a Vice-Presidents. These groups are:

A. Questions of telephone transmission, and on maintenance and supervision of lines and installations (3rd—5th CR).

B. Questions relating to the protection of telephone lines against disturbances from power installations and against corrosion due to electrolysis or to chemical action. (1st and 2nd CR.)

At the 8th plenary meeting, the following were elected Vice-Presidents of the respective groups:

Colonel Sir Thomas Purves, the Engineer in Chief, British Post Office. (group A)

Mr. Muri, Head of the Technical Section, Swiss Administration of Telegraphs. (group B)

Professor Dr. Breissig, German Ministerial Counsellor. (group C)

General questions of organization are dealt with at joint plenary meetings of the Heads of the Delegations of the several countries, and the resolutions are confirmed at the concluding session. At this year's plenary session the classification of the countries belonging to the CCI was dealt with, primarily for distribution of the expenses incurred in the operation of the Secretariat and the Laboratory. It was resolved that every country should be given the choice between the classification table adopted by l'Union Télégraphique Universelle and a table made up on the basis of the populations of the several countries.

The arrangements made by the French reception committee this year were excellent, and allowed the delegates present to benefit greatly from the meeting, apart from the discussions pure and simple. On Monday, September 14th, the delegates thus visited the laboratory of Système Fondamental Européen de référence, SFERT, when interesting experiments were made on certain subjects at present being studied by the CCI. On Thursday, September 17th, the delegates with ladies were invited by le Ministre des Postes, Télégraphes et Téléphones to dinner in the permanent Colonial Museum of the International Colonial Exhibition. After dinner the guests were intertained by a display of exotic dancing etc. The whole concluded with a dance. On Saturday, September 19th, the delegates were invited to take part in an excursion to the Loire chateaux. The journey was made by special train from Paris to Blois and thence by bus to Tours, visiting the chateaux of Chambord, Blois, and Chenonceaux, returning to Paris by train. Lunch was served in the historical Hall of State in the Chateau de Blois, and dinner at the Grand Hôtel in Tours.

In the following paper by Mr. A. Lignell, Director of Telephones in Stockholm and Mr. A. Holmgren, Head of Department, Swedish Telegraph Administration, an account is given of the most important technical and traffic questions dealt with at the 8th plenary session.

R 4004 Group of Delegates in the "Grand Amphithéatre" of the Sorbonne.

Technical and Traffic Questions at the CCI:s Plenary Meeting in Paris 1931.

By *A. Lignell* and *A. Holmgren.*

The International Consultative Committee on Telephony, the CCI, held its 8th Plenary Session in Paris from September 14th to 21st 1931.

The questions on the agenda at the closing session are divided into three groups, each discussed at separate meetings, under the guidance of a Vice Chairman.

A. Questions of telephone transmission, and of maintenance and supervision of lines and installations;

B. Questions of traffic, operation and tariffs;

C. Questions relating to the protection of the lines against disturbances from power lines, and of cables against electrolysis and chemical corrosion.

Between plenary meetings, the questions are dealt with by "commissions rapporteurs" (CR), at present seven in number, dealing with the following groups of questions:

I. Protection of lines against the disturbing influence of power lines.

II. Protection of cables against electrolysis and chemical corrosion.

III. Transmission and maintenance questions.

IV. Electroacoustic questions.

V. Coordination of telephones and radio-telephony.

VI. Traffic and operation questions.

VII. Tariff questions.

At plenary meetings, questions prepared by nos.
I and II CR are dealt with under group C
III to V CR are dealt with under group A, and
VI and VII CR are dealt with under group B.

Some information on the most important questions dealt with is given below.

Transmission Questions.

The IIIrd CR had 23 items on its program, the IVth 9, and the Vth 3. Certain of these were common and led in several cases to joint proposals from all three commissions.

In view of the various uses of the term "*transmission level*", the following definitions were approved:

The *relative level* of the power, voltage or current at any point in a system is determined by the ratio of the value of the quantity in question (power, voltage or current) at that point to the corresponding value at the point chosen as origin.

This definition thus gives the transmission level in the sense used in ordinary level-diagrams for transmission lines. In determining, for instance, the properties of the amplifying valves in a line, it is essential to know the absolute value of the voltage etc. In order to get uniform treatment, it may however, be advantageous in this case also to use the term "level" (in nepers), which is then referred to a certain absolute value. For this reason the following definition was made:

The *absolute level* of power, voltage, or current is determined by the ratio of the value of the quantity in question to

1 milliwatt for power
775 millivolts for voltage and
1.29 milliamp. for current.

These values are, as we know, equivalent when the line impedance is 600 ohms. The scales of the usual transmission measuring instruments are thus divided to read absolute levels.

At any point in a line one can distinguish: relative level, absolute level, and volume. The first two refer to measurements, while the volume refers to the speaking current during the telephone conversation, or the strength of the impulse when the line is used otherwise (e. g. for telegraphy).

If, therefore, in measuring relative levels, it is desired to avoid corrections, the generator feeding the line should be adjusted to give the same power, voltage or current as would be given by a generator placed at the beginning of the line and feeding to it a power of 1 mW, a voltage of 775 mV, or a current of 1.29 mA.

Reference equivalent for calls on international lines.

In the earlier regulations of the CCI the limit of permissible attenuation in an international circuit including transformers was put at 1.3 nepers at 800 cycles/sec., and for continuing the circuit from the exchange serving the international circuit to the subscriber, including existing exchange equipment, 1.0 nepers. The maximum over-all line attenuation between two subscribers is therefore 3.3 nepers. A change was made at Brussels in 1930 restricting the application of the first of these 1.3 nepers to 2-wire circuits alone, while the corresponding value for 4-wire lines was fixed at 1.1 nepers. At the same time the desirability was expressed of reducing the values in the future to 1.0 and 0.8 nepers respectively for 2- and 4-wire circuits. These values, however, still only refer to lines and exchange equipment, while nothing was decided regarding the efficiency of the subscriber instruments. To be able to guarantee a certain quality of reception between two subscribers, regulations in this last respect also are obviously wanted. Now that the Master Reference System has been introduced in Paris (SFERT = Système Fondamental Européen de Référence pour la Transmission Téléphonique), we have a fixed and unchanging standard, by reference to which commercial sets can be calibrated. In practice this calibration will be done indirectly by means of working standards (système étalon de travail) already calibrated with reference to the standard instrument in Paris. We have thus, at given prescribed values for the instruments with reference to this latter standard, an opportunity to examine how far these demands are fulfilled by the instruments in use. The efficiency of telephone circuits having up to now been given in terms of their attenuation, it has been found best to go on doing so and express the reference equivalent of the whole circuit in terms of attenuation. This means that — when the neper is the unit — the equivalent of an instrument as a transmitter will be

$$b = {}^{n}\log \frac{V_n}{V_x}$$

where V_n is the voltage of the reference standard instrument at its output terminals and V_x the corresponding voltage of the tested set when both are affected by the same volume of sound and both connected to lines of 600 ohms impedance. By analogy with the attenuation in lines, the greater the equivalent of the instrument, the less its efficiency. The CCI has now for the first time introduced the efficiency of the instrument among the demands on an international telephone circuit. For the present, however, this has not been stated by itself but in conjunction with the other losses in the circuit between the end of the international circuit and the subscriber. On the basis of measurements made in several countries the CCI has thus, instead of the previous regulation for an attenuation of one neper between the end of the international circuit and the subscriber, fixed the following values for "système émetteur national" and "système récepteur national", which are below termed transmitter- and receiver-equivalents and comprise the same losses as in the old rule with the addition of the equivalent of the telephone instrument itself as a transmitter or receiver:

(1) in an international telephone circuit between any two subscribers on the same continent the national transmitter-equivalent should not exceed 2 nepers and the national receiver-equivalent should not exceed 1.3 nepers.

(2) in future building or alteration of telephone systems it is desirable that efforts should be made to surpass the demands in (1) so that for 90 per cent. of the subscribers the transmitter- and receiver-equivalents should not exceed 1.7 and 1.2 nepers respectively.

The total reference equivalent will from this, and with 1.3 nepers for the international line, be $2.0 + 1.3 + 1.3 = 4.6$ nepers, for a 4-wire line $2.0 + 1.1 + 1.3 = 4.4$ nepers. With the improvements considered desirable both in the international and in at any rate the majority of national circuits the equivalent will be

for 2-wire circuits: $1.7 + 1.0 + 1.2 = 3.9$ nepers.
for 4-wire circuits: $1.7 + 0.8 + 1.2 = 3.7$ nepers.

These values for the total reference equivalent can of course not be compared with former regulations concerning the highest permissible attenuation, as their size depends among other things on the zero-levels chosen once and for all for the SFERT. With the old regulations one might in two calls over circuits with the same reference equivalent receive quite different volumes of sound, that is, if the two calls were made on different instruments. According to the new regulations the same total reference equivalent in two conversations will also mean that there has been the same ratio of sent volume to received in both cases. It has thus not been possible to deduce the new values from the former ones; they are instead based on perfectly independent experiments made in the SFERT laboratory in Paris. The assumption gone on here has been, that these values should give satisfactory reception of speech when the circuit is at the same time affected by the maximum noise disturbances permitted in the CCI's "Directives". During the conference the delegates were given an opportunity of forming for themselves in the SFERT laboratory an opinion of the import of the new regulations.

The various telephone administrations are now at liberty to distribute the losses, within the limits of the stipulated transmitter and receiver equivalens, among the various elements of which the inland circuit is composed. As an example we will give the distribution assumed by the German administration:

Joint losses, *G*, in transmitter- or receiver-couplings:

attenuation in the subscriber's line	not to exceed 0.45 nepers
trunk lines	not to exceed 0.30 nepers
losses in exchanges	not to exceed 0.25 nepers
	Total *G* not to exceed 1.00 nepers

Transmitter equivalent.

Total *G* as above	not to exceed 1.00 nepers
current feed losses	not to exceed 0.25 nepers
equivalent of subscriber instrument	not to exceed 0.75 nepers
	Total sending losses not to exceed 2.00 nepers

Receiver equivalent.

Total *G* as above	not to exceed 1.00 nepers
equivalent of subscriber instrument	not to exceed 0.00 nepers
	Total receiving losses not to exceed 1.00 nepers

We note that the receiver-equivalent is here 0.3 nepers below the CCI value.

Measurements of intelligibility.

Except for the instrument values, which are compared with SFERT, the above attenuations or reference equivalents are for a definite measuring frequency, 800 cycles/sec. The calibration of the instruments, on the other hand, is done by means of voice tests, and the whole band of frequencies used in speech will influence it. It is expressly stated, however, that it is the total voice volume that is equalized in calibration[1]), and no regard is thus paid to the quality of the speech (its intelligibility).

This also, however, obviously much affects the actual results of a telephone conversation of a given duration and, in extreme cases, the possibility of carrying on a telephone conversation at all. The new stipulations of the CCI thus only guarantee a certain voice volume (properly speaking, the relation between sent and received acoustic effects), but for the present says nothing of articulation. There certainly are a number of other regulations intended to ensure a certain intelligibility in the transmitted speech, but the connexion between the factors controlling this, and the reference equivalent of the line, is not yet quite clear. Important quantitative investigations on the former have in recent years been made under the auspices of the 4th CR at the SFERT laboratory in Paris, as well as in the laboratories of the large telephone administrations and manufacturing companies. This problem is extremely far-reaching and complicated. So far the main result has now been that lines on which these investigations can be systematically conducted have been settled. Without going into details of this very complex subject, we will only mention here some of the difficulties to be overcome. As the experiments have to be made in the form of voice tests, many subjective factors come in which have to be counteracted, or else eliminated by arranging the experiments suitably. The effect of the microphone and receivers used in telephone conversations depends very much on the way in which they are applied to the mouth or ear. This manner of application must be fixed accurately if the experimental results obtained are to be made unambiguous and reproduceable. The stock of words used for the tests—syllables

[1]) For measurements which only refer to the voice volume as distinct from the test of intelligibility (see below) the term *telephonometry* has been reserved. Experiments are being made to replace "speech" and "listening" in these by electroacoustic instruments such as gramophone records and "artificial ears". No design, however, has yet been made that satisfies all the demands.

formed in a certain way (logatomes)—must in their component parts be representative of those most likely to occur in telephone conversations. To make the results of the experiments valid internationally it is further necessarry for this latter condition to be satisfied in several different languages. To deal with this question, a series of intelligibility tests have been made jointly between the telephone laboratories of various countries, using the international circuits. Measurements of intelligibility must be made by a whole staff of "experimental" persons, each of whom must use a large number of logatomes. In any one method the individual results may vary considerably, but the larger the number of experiments the more the average tends to approach a particular value.

To make the existing and expected results of intelligibility tests of use in the organization of international communications the CCI has resolved to include in its program of work for next year the question of estimating the importance of the various factors which influence the transmission, among which, apart from the attenuation at 800 cycles, we may mention: the attenuation distortion, the range of the band of frequencies transmitted, disturbing noises, the effect of one's own microphone on one's own receiver (side-tone), reflection losses, echo effects, cross-talk, cross-talk buzz (the confused unintelligible sound from many conversations, "babble"), phase distortion, transmission time and non-linear distortion. The idea is to make as many as possible of these factors "commensurable", so that if they are each known in the natural measurements ususally employed, their total reducing effect on the transmitting efficiency of a line might be obtained in the form of a single quantity characteristic of the line and called the "transmission effective". With the help of the intelligibility tests this will very likely be possible for at any rate a majority of the factors mentioned above.

The use of unloaded cables for whole repeater sections in international circuits.

This type of conductor, which has been used experimentally in Holland and elsewhere, has not been considered suitable for including amongst the designs recommended by the CCI. In special cases, however, (e. g. with some submarine cables) the advantages offered are considered so great that it should be permitted, provided special devices for attenuation equalization, etc., are used, to comply with the CCI's general demands on international circuits.

Transmission time.

Experiments made have proved it to be most expedient to fix the transmission time in a telephone circuit on one continent at $^1/_4$ second. With longer transmission times the conversation is disturbed, as the parties are no longer in the immediate contact with one another (in time) required for conversation. After some hesitation as to who should speak, both often begin together, nobody is understood, both hesitate again, and so on. The echo-suppressors necessary in long lines make the confusion worse confounded. A transmission time of $^1/_4$ second corresponds, in a lightly loaded cable line and with a transmission speed of 32 000 km. per second, to a line length of 8 000 km. For still longer lines, cables loaded even more lightly would thus be required. An over-head copper line will only reach the $^1/_4$ second limit with a length of 70 000 km.

For calls between two continents where the communication between the continents is by wireless, the CCI stipulates for the connecting line on each continent a maximum of $^1/_{10}$ second, corresponding to 3 000 km. in a lightly loaded cable.

Instruments for measuring impulses and voice volume.

For checking the voltages in lines, the telephone repeaters, or other devices, while being used for, for instance, calls, or transmission of broadcasting programs, direct-reading meters for voice volume and impulses are used.

The former, which has a certain inertia, measures the average voltage (r. m. s. value) during a certain time. Such a volume indicator (indicateur de volume) may be used as an observation instrument in adjusting the voltage in transmission lines during broadcasting, in telephonometric measurements, etc. According to the CCI the volume indicator should have an inertia such that the pointer will in 0.2" after connection with a sinusoidal voltage have reached 80 per cent. of the reading corresponding to continuous voltage (integration time), and also take 0.2" to return to zero (return time).

The peak indicator (indicateur de crête) is used to measure maximum voltages of very short duration. For this an integration time of 0.02″ and a return time of 2″ has been stipulated. If a peak indicator and a volume indicator are connected in the same circuit during a conversation the former will therefore show higher voltages than the latter. When it is said that at zero-level in a telephone circuit the maximum power during speech may rise to 5 mW, this means the reading on a peak indicator—the reading on a volume indicator might remain below 1 mW.

Voice frequency signalling.

In Europe 500 p:s. modulated by 20 to 25 p:s. is used for voice frequency signalling. Receiving instruments having now been designed, in Sweden for example, which work perfectly satisfactorily for a pure 500 p:s. frequency and even more reliably than for modulated frequencies, the CCI has now consented to this system being used by agreement for direct traffic between two countries, provided that no connexion is made to exchanges beyond which use the modulated system.

Lines used for transmitting broadcasting programs.

After a thorough investigation by the 3:rd CR in conjunction with representatives of the International Broadcasting Union, the CCI has revised important parts of the previous regulations for circuits used for transmtiting broadcasting programs.

The relative level at an arbitrary point in such a circuit should not exceed zero-level by more than 1.15 nepers, on the assumption that the absolute level at the zero-point is the same as in an ordinary telephone circuit, where it is estimated not to exceed 5 mW. The maximum power should thus at no point exceed $5 \cdot e^{2 \times 1.15}$ or 50 mW. The repeaters used must be able to reach this power output without noticeable distortion.

The reference equivalent of the whole transmitting line measured at 800 p:s. and reckoned from the output terminal of the first repeater to the output terminal of the last repeater, should be *zero* with a tolerance of at most ± 0.3 neper.

The repeaters should be provided with such means of regulating the amplification, that the variation in line attenuation and its dependence on the frequency caused by temperature changes can always be compensated.

To make perfectly certain of good transmission of both speech and music the line should effectively transmit the whole band of frequencies from 50 to 6 400 p:s. For any given frequency to be considered effectively transmitted its attenuation is presumed not to differ from the attenuation at 800 cycles/sec. by more than 0.5 neper. This is done by making the gain in the repeaters at various frequencies correspond to the attenuation in the respective line sections at these frequencies. Usually special equalizers have to be connected for this purpose at each repeater.

To facilitate supervision it is further recommended that the gain in all stations be adjusted so that a voltage V of arbitrary frequency (within the prescribed band) fed in at the beginning of a repeater section of the line will give the same voltage V at the beginning of every succeeding section in the line.

The cross talk attenuation between two lines used for broadcasting transmission should be at least 9 nepers in cable lines and at least 7 nepers in over-head lines.

At that point in the line where the working voltage (the relative level) is lowest, the disturbing noises, measured in mV, as directed by the CCI, shall be in cable lines at least 6.9 nepers ($^1/_{1000}$) and in over-head lines at least 6.0 nepers ($^1/_{400}$) lower than the maximum working voltage at that point.

To avoid saturation phenomena or disturbing modulation in the repeaters, it has been provisionally stipulated that the absolute value of outside voltages in the transmission line must not exceed $^1/_{100}$ of the maximum working voltage.

Similarly 2.3 nepers has been provisionally decided on as the limit of the non-linear distortion, when this is defined as the natural logarithm of the ratios of the r. m. s. value of the fundamental to the r. m. s. value of all harmonics. This value shall be applicable for one arbitrary frequency within the band transmitted and for the maximum working voltage.

Finally, the following maximum differences in transmission times for various frequencies have been considered permissible: between the highest frequency and 800 p:s not more than 10 millisecs., and between 800 and 50 p:s not more than 80 millisecs.

In order that the electrical properties specified above for international lines for transmitting broadcasting programs shall give the advantage intended, it is obviously essential that the lines between the end of the international line and the studio or wireless transmitter, should also be constructed to just as strict rules.

Terminal repeaters.

To avoid the increase of work involved by the use of cord-circuit repeaters, what are called terminal repeaters have been proposed, and in America even to some extent used. A circuit with terminal repeaters is at the end exchanges provided with extension lines to attain the requisite stability for service between these exchanges. But when such a circuit is connected to another similar one for a through call, the line extensions are automatically cut out, and the attenuation in the through circuit will then be less than the sum of the attenuations in the two circuits connected and may be kept down to the same order of magnitude as in one of the circuits.

Fitting of terminal repeaters must be done at the same time for a whole exchange, and therefore necessitates a considerable initial outlay. The CCI has therefore thought better not to recommend that existing equipments of cord-circuit repeaters should be replaced by terminal repeaters. It considers, however, that when new interurban exchanges are built the latter system should be installed whenever an economic investigation of all the relevant factors indicates that it would be better to use than the cord-circuit repeater system.

The maximum power in repeaters.

Although enough experiments have not yet been made to decide finally the maximum power occurring at zero-level in a telephone call, the CCI has nevertheless, in view of the need of regulations for the design of telephone repeaters, provisionally adopted a maximum power of 5 mW. In the same connexion the values given below have been fixed for the power which the different types of repeaters should supply without the non-linear distortion exceeding 5 per cent.

for 2-wire repeaters in cables or over-head lines 20 mW.

for 4-wire repeaters in cables, also those used for voice frequency telegraphy, 50 mW.

During these tests the repeaters should be terminated with 600 ohms, without line transformers.

New or revised specifications.

The CCI has adopted new specifications for *submarine cables* forming part of long international lines and for *two-band telephony*.

Amongst the instruments, a *recording level meter* has been specified provisionally on the lines of an instrument designed by Siemens & Halske (Pegelschreiber). This is driven by a clockwork which pushes forward continuously the paper on which the record is made. To the same clockwork is coupled a variable condenser which changes continuously the frequency of a heterodyne oscillator in which the power is constant for different frequencies and which serves as transmitter. The rate of feeding of the paper will thus become proportional to the measuring frequency, making the frequency the abscissa. The reading of the instrument which measures the incoming voltage at the various frequencies gives the ordinate. For measurements on lines two synchronized instruments are required. For joint measurements by two exchanges the same instrument will then be required in both, or, at any rate, to be able to cooperate, the apparatuses of both must fulfil certain common requirements.

For *transformers* the demand is introduced that the dielectric strength shall be 500 volts, or in exceptional cases 2 000, between the windings or between a winding and the metal case, by analogy with previous similar demands for cables and loading coils, in cases where the plant is exposed to induction from power lines. Regulations have also been made out for the efficiency of transformers. For speech frequencies this is measured as attenuation, as for lines, and must not exceed 0.08 nepers for any frequency within the range of speech when transmitting 1 to 50 mW. If the transformer also has to serve for transmitting low frequency current, of 16—25 cycles/sec., it must, when measured from the exchange side and loaded with a non-reactive resistance of 2 000 ohms, have an energy efficiency of at least 55 per cent. when the measuring voltage is 45 ± 3 volts. The measuring can here be done by, for instance, a wattmeter.

By theoretical investigations and measurements made by Svenska Radioaktiebolaget it has been shown that the far-end cross-talk between different lines could be largely avoided if the impedance of the transmitter and receiver and any amplifier used were well matched with that of the line. This could be made use of in *carrier current telephony* when several plants with the same carrier frequency use the same poles for their lines. For this reason the following specifications for carrier current telephone plants:

$2\frac{Z-W}{Z+W}=0.8$, where Z is the impedance of the line, and W that of the transmitter, receiver, or repeater.

Finally, a rule has been introduced fixing the highest permitted *additional resistance from hysteresis* in loading coils. If L represents the inductance of the coil in henries, the additional resistance, h, measured at 800 p:s and expressed in ohms per milliamp. of measuring current and per henry of coil inductance, must not exceed

$$h=12\ L\ \text{ohm/mA} \times \text{Henry}.$$

Other questions.

A proposal had been made by the Swedish representatives for the utilization of the frequency range between the speech range and the cut-off frequency for a voice frequency telegraph channel in lightly loaded circuits. It was decided that this should be further studied by the telegraph administrations, and in particular intelligibility tests should be made to see how the amplitude of the telegraph frequency would have to be regulated in order to avoid any unfavourable effect on the telephone transmission. In connexion with the investigation of this question, experiments giving favourable results had been made in France on three telegraph channels between the speech range and the cut-off frequency, without, it is stated, any accompanying bad effect on telephone traffic.

Certain parts of the CCI regulations concerning *periodic measurements* on international lines have been revised. Further, the time-table first drawn up in Brussels for making these periodic measurements has been supplemented and revised. A permanent sub-commission, on which England, France, Germany, Holland, Rumania, Sweden and Switzerland are represented, exists for dealing with any urgent questions arising between the CCI meetings.

Questions of traffic, operation and tariffs.

The following countries were represented on the 6th and 7th C. R.s:

Belgium, Denmark, England, France, Germany, Spain, Sweden, Switzerland, and the Soviet Republic; also the American Telephone and Telegraph Company.

The commissions had made a report on 24 questions.

The CCI resolutions are given below:

Calls with Préavis or Avis q'appel.

It was decided that the subscriber who has demanded a call should have the right, as long as he has not been rung up for the call, to make alterations without charge in the details of his demand, both as regards the telephone number and the person asked for within the same local system, as well as the time the call may have been booked for.

In the event of a change of an avis d'appel necessitating the sending of another message, another avis d'appel fee will be charged, and possibly also an express fee.

The motive for these concessions was a gratifying general wish to facilitate international personal calls. To conceed without charge such alterations may lead to many calls taking place which would otherwise have been cancelled.

It was further settled that a préavis can also be directed to a subscribers main station without stating as before a person or particular extension. This concession is of importance, as it is often a great advantage to the called number to know that a call is expected, so that they can, for instance, keep a good linguist or other specially qualified person in readiness.

As regards the service regulations for calls with préavis in force up to now, it was decided that the called exchange should repeat to the called station the desired person or extension number not only when preparing the call but also when it comes through.

Experience had shown that in large P. B. Xs it often took a considerable time before the call could be put through to the required person or extension if this procedure was not followed.

Changing the class of a demanded call.

It was decided that changing of a demanded ordinary call to an urgent call or vice versa should be done free of charge, but that the time of the change should be counted as a new order time in the class of call in question.

Subscription calls.

(conversations par abonnement)

During the heavy traffic period subscription calls are at present allowed—except during the hours of maximum traffic (to be determined by the Heads of the terminal exchanges concerned) —for the same changes as for ordinary calls, subject to certain conditions regarding the delays on the various circuits.

The average delays must not exceed:

15 minutes for circuits under 500 km.,
30 " " " between 500 and 1 000 km., and
45 " " " exceeding 1 000 km.

If the delays are longer, three times the normal rate will be charged.

As these regulations mean that the tariffs for subscription calls vary on different circuits and even on the same circuit according to the delays which can be held, Sweden has proposed the same method of charging as has been adopted among the Northern countries, i. e. single tariff plus the charge for an extra minute for every call—the same during the whole of the heavy-traffic period.

The reason for this was that users find it hard to understand these varying charges, and, besides, it is very difficult for the deciding frontier control exchanges to fix, with even fair approximation, the times at which the lower fee can be charged.

A majority for this proposal could not, however, be obtained. Instead, the resolution led to yet another tariff category for subscription calls being introduced—the double rate. Whether double or treble rate is to be used will depend on an agreement between the administrations of each separate traffic route concerned, that is, not only between those of the terminal countries but also of the one or perhaps more transit countries.

As, however, this resolution led to a reduction of the charges for subscription calls—though only conditional—it is to be hoped that in time a uniform reduced rate will be reached, or the same system as has been introduced in Northern traffic.

It will probably be found impossible in the long run to retain the varying tariff.

Occasional Fixed-Time Calls.

(conversation fortuites à heure fixe)

The regulations with regard to these calls are now as follows:

1. A fixed-time call must be demanded at least half an hour in advance. For calls necessitating changes in lines or installations a longer warning may be demanded.
2. A fixed-time call is put through at the time specified unless a conversation is already in progress, in which case the fixed-time call is delayed until this conversation is finished. If, however, lightning calls or urgent Government calls are waiting at the stated time these are put through before the fixed-time call. In the event of several fixed-time calls being booked for the same time, these are put through in turn according to the time of receipt of the demand at the directing exchange.
3. Fixed-time calls, except for those lasting an hour or more, which are put through during the light-traffic period and are charged for at half the rate for ordinary calls during the heavy traffic period, without additional fees—are charged for at a rate which is three times the fee for an ordinary call of the same duration during the same tariff period, with an additional fee of one minute during the same tariff period. The minimum additional fee is 0.50 frcs.
4. If the called or calling party refuses or if the calling party does not reply when the call is put through the usual rules for refusal and no reply are applied, i. e. only the fee for one minute of an ordinary call is debited that is, not the additional fee).
5. A fixed-time call can also be accompanied by préavis. In this case it is charged as an urgent call with préavis and the additional fee for a fixed-time call is not charged.
6. If a fixed-time call accompanied by préavis is cancelled after the transmission of the préavis has been commenced, only the préavis fee is charged.

If a fixed-time call without préavis is cancelled before being put through, no fee is debited.

The principal innovations in these regulations are:

1. that a fixed time call must be ordered at least half an hour instead of least one hour before the call is wanted,
2. that a fixed-time call may be in conjunction with préavis, in which case only the préavis fee is charged (not the additional fee for fixed-time calls),
3. that the additional fee for a fixed-time call without préavis is only charged if the call is actually put through.

Priority of International Calls over Internal Calls.

It was decided that calls on an international circuit 600 km. or more in length as the crow flies should be given priority over the private internal calls, ordinary and urgent, of the terminal countries.

So far international calls have only taken precedence of internal calls of the same class. This has, however, caused expensive delays on the longer international circuits. Another reason for this change in the regulations is, that the countries which have no urgent or lightning calls give priority, as they have pointed out, to incoming international calls over all private calls, and do not have the corresponding privilege for their own outgoing international calls; there is, besides, the consideration of extra-European communications.

Regulations for International Transit Traffic.

Concerning transit traffic the CCI has made the following statements:

1. The construction of direct circuits through the transit countries is recommended whenever the traffic density justifies it.
2. In the absence of permanent direct circuits it may in certain circumstances be of advantage to allocate circuits at definite times so as to allow direct connections temporarily according to the needs of the traffic.

This pronouncement is of course intended to avoid, by means of a direct service, an intermediate exchange, which is not only expensive in itself, but also inevitably means that less effective use is made of the circuits.

The delays must besides be considerably longer this way than by direct service.

With the present demands for short delays for calls the resort suggested in point 2, a time allotment, is hardly to be recommended, except perhaps in the long circuits where, on account of the great distance, the increase in delay for certain calls due to the connexion being only temporary is of slight importance. If, however, a time allotment should in some cases prove necessary, it might often be convenient to use an intermediate exchange during a certain part of the time when the direct connexion is not available.

By means of new circuits Sweden has now succeeded in getting rid of the previous time allotments on the Paris and Amsterdam routes and all our international circuits are now full hour connexions. In connexion with the discussion of the rules for transit traffic the following question was dealt with:

"Can the CCI recommend that telephone communications which need to engage more than two international circuits should not be allowed?

If not, on what conditions should such connexions allowed?"

The following principle was laid down.

Although it is desirable not to use too many international circuits for a telephone communication, there are already a number requiring more than two international circuits.

Nor could many of the proposed new routes be established if the use of more than two international circuits were forbidden.

As regards the service procedure the resolution will be found in the note below.

In cases where using an intermediate exchange is necessary the following service rules have been laid down:

1. It is essential that the transit exchange should be the directing exchange, that is, should give the orders for preparation and establishment of the circuit.
2. The demands for calls are forwarded as quickly as possible to the transit exchange. To avoid an accumulation of demands with the operator at that exchange, it is, however,

desirable that the frontier control exchange should not pass on too many demands for the same terminal exchange in the addressee country. The directing operator in the transit exchange has therefore the right to limit the number of demands handed in at the same time, in which case the exchange in the country of dispatch should state how many demands are waiting. Cancellations, préunavis, avis d'appel, and demands for bourse calls during the time the Bouse is open are passed on with right of priority.

3. Immediately after an international transit call, the frontier control exchanges in the terminal countries can put through further calls direct, even if the demands for those calls have not been handed in to the transit exchange. The direct connexion is allowed to remain as long as the transit exchange considers it advisable provided, however, that it has no call waiting higher in order of preference than the transit calls in question.

4. The tickets for demands for transit calls are arranged by the directing operator with other waiting demands according to the class of call and time of receipt at the transit exchange.

5. The first transit call in a series is necessarily the oldest call of the highest class, irrespective of the direction in which the next preceding call between the transit exchange and the co-operating frontier control exchanges has been put through. The other transit calls of the series are then put through alternately. When the direct communication is broken, the transit exchange resumes service alternately on each route.

6. Before the commencement of the last but one call which has to be passed between the transit exchange and the two terminal exchanges, the two corresponding positions at the transit exchange shall advise the two other exchanges to prepare the transit connexion. These will then prepare the calling and called parties. If either of the subscribers does not reply the transit exchange should be informed before the beginning of the call which is put through immediately before the transit call so as to avoid any unnecessary connexion of the two international circuits and make it possible to prepare for the next transit call before the end of the one before it.

7. The control exchanges should hold the internal circuits and subscriber lines ready for putting through the transit call as soon as its turn arrives.

8. When there is a difference of opinion between the frontier exchange in the country of dispatch and the transit exchange, the latter has the right of decision.

Note: In the event of more than two international circuits being used in a connexion, the administrations concerned will jointly appoint the directing exchange.

Lettering of difficult words.

(Système d'épellation.)

After protracted experiments the following words for lettering have now been approved by the CCI. to be used from September 1st 1931. A Amsterdam, B Baltimore, C Casablanca, D Danemark, E Edison, F Florida, G Gallipoli, H Havana, I Italia, J Jerusalem, K Kilogramme, L Liverpool, M Madagascar, N NewYork, O Oslo, P Paris, Q Quebec, R Roma, S Santiago, T Tripoli, U Upsala, V Valencia, W Washington, X Xantippe, Y Yokohama, Z Zürich.

List of Phrases to be used for the Operation of international circuits.

As it is necessary to avoid as far as possible losing time in operating international circuits through language difficulties, the CCI requests the administrations to direct international operators to employ the expressions in German, English and French collected in the pamphlet "Liste des phrases le plus fréquemment échangées dans le service téléphonique international".

Between countries which do not use any of the languages mentioned above it is desirable that the administrations should come to some mutual agreement as to which language to use, and that the above phrases should be translated into that language.

Charges for calls using a wireless route.

The CCI considers it desirable:

that each European country should only form one tariff zone for each wireless communication, and

that the terminal and transit charges for the wire communications should be fixed by agreement between the administrations concerned.

As regards a wire communication through one or more transit countries the sum of the terminal charge (which is received by the country of origin or destination) and of the transit charge or charges should in principle be the same for one wire communication as for another, between the terminal country and "le centre radio-émetteur".

Example. The total charge for the wire communication from London to Germany should be the same for a call from Germany to Australia, as for a call from Germany to the United States: London being the "centre radio-émetteur" for both these calls.

Radio-Broadcast Transmissions and their Tariffs.

At the meeting of the 6th Reporting Commission in London in April 1931 the regulations given below were prepared in conjunction with representatives of "L'Union Internationale de Radiodiffusion", and were approved at the plenary meeting in Paris; since they are perfectly new, they are here given in full.

These regulations must be regarded as provisional, as the experience in organizing these transmissions, which are strongly on the increase, cannot at present be considered sufficient.

The minimum time for ordering might be thought rather long, but it has been made ample so as to be able to ensure the connexion with certainty.

In practice the order is generally given later, but the connexion is of course arranged in these cases too, as long as no special arrangements requiring longer notice are involved.

"*Considering*

that experience to date of questions concerning radio-broadcast transmissions is insufficient for the drawing up of final rules regarding such transmissions, and *that* the orders for circuits for broadcast transmissions must still be given through the agency of the central administrations or to those "central bureaux" to which the administration telephone companies concerned may have transferred their rights in this respect, but

that on the other hand, particularly when the same program is relayed by several stations, it is desirable that the procedure of transmission should be made as simple as possible, the CCI advises,

that the following rules should until further notice apply to radio-broadcast transmissions:

1. Booking of Circuits.

A circuit for broadcast transmission shall be booked by the broadcasting organization in the country where the receiving microphone is put up, from the "Service Centralisateur" (central bureau) of that country.

A list of the central bureaux to which the broadcasting companies of the several countries have to apply when ordering a telephone circuit (giving also, the name, full address, and telegraphic address of each bureau) shall be sent by the CCI secretariat to all administrations and telephone companies which have joined the CCI, and these in their turn will forward this list to the broadcasting organization of their country.

A circuit for broadcast transmission should always be booked in good time, at least ten days in advance as a rule. The demand will be accepted as long as the telephone traffic is not inconvenienced thereby, and provided there are no technical obstacles.

In exceptional, or very simple, cases shorter warning may be allowed. The administration and telephone companies concerned will make every effort to carry out the demand, though without guaranteeing that the broadcast transmission can be effected.

In cases where the broadcast transmission requires more extensive organization of circuits and installations, the demand should be given at least 15 days in advance.

The demand for transmission of a wireless program for another continent should as a rule be given not less than 15 days in advance.

When a transmitted program is relayed by the stations of only *one* country, the broadcasting organization to which these stations belong shall confirm in writing to the central bureau of its own country the booking of the circuit made by the broadcasting organization in the country where the receiving microphone is put up. At the same time the broadcasting organization shall undertake to pay the full charge for the use of the circuits booked.

When broadcasting stations in *several* countries are relaying a program, the procedure will be as follows:

a. A list of the broadcasting stations receiving the transmission, with information as to the telephone exchange to which the transmitting microphone is connected, will be sent by the broadcasting organization in the country where the receiving microphone is installed to all broadcasting organizations relaying the program; each of these broadcasting organizations will forward this list to the central bureau of its own country with any alterations and additions which it may consider necessary. This list shall contain information regarding all telephone circuits booked and any reserve circuit booked.

b. The central bureaux together appoint a "directing central bureau" for the transmission in question.

This directing central bureau will, in conjunction with the central bureaux of the other countries prepare a scheme, as shown below, giving the circuits and reserve circuits booked.

This scheme shall also contain information as to the special repeater stations to which the broadcasting organizations can apply if during a transmission, which has otherwise proceeded normally, some unforeseen hitch occurs which has to be seen to at once.

The directing central bureau will send (as soon as possible, and not later than three days after receipt of the above list) two copies of this scheme to each of the central bureaux in the countries concerned. These in their turn will forward copies of it to the broadcasting organizations of their country. *In simple cases the directing central bureau may confine itself to informing by telegraph or telephone, instead of by a written scheme, the central bureaux of the countries concerned of the circuits to be used and the special repeater stations to be applied to in case of sudden faults.*

c. A broadcasting organization, to which one or more relaying stations belong, shall, on receipt of the information as to the circuits for which it has to pay, within 24 hours give the central bureau of its country a written undertaking to pay the whole fee for the use of those circuits. To facilitate the above procedure it is desirable that a broadcasting organization should examine in advance such cases of relaying from several stations as may be expected to recur with any regularity. Further, the International Bureau of the Telegraph Union should prepare a map of the international telephone circuits in Europe which are specially arranged or adapted for broadcast transmissions.

2. Charges.

Except when transmitted on a circuit specially arranged for the transmission of music, the following charges are payable for broadcast transmissions:

a. for that part of the transmission which is carried out during the time for full tariff; the same as for ordinary calls;

b. for that part which is carried out during the time for reduced tariff:

by subscription or when the transmission proceeds for *at least* an hour during the time for reduced-tariff, half ($^1/_2$) the charge for ordinary calls during the time for full tariff;

in other cases three fifths ($^3/_5$) of the fee for ordinary calls during the time for full tariff.

The charge is debited to the broadcasting organization (state or private) receiving the relayed program, and is payable for the whole of the time during which a circuit has been at the disposal of the company in question, including the time taken by the company for testing before the transmission proper.

The central telephone exchanges should have such equipment as to enable the operators who usually determine the chargeable length of telephone calls also in the same sort of way to determine the chargeable length of broadcast transmissions.

If the equipment of the central telephone exchanges concerned does not permit this, the technical officials who set up the connexions shall between them determine:

a) the time when the circuit is put at the subscribers' disposal (the beginning of the period charged for), and

b) the time when the line is restored by the subscribers (the end of the period charged for).

If the transmission is received by intermediate stations for relaying, it will be charged for as so many separate calls, viz. both as call on the circuit between the originating station and the first intermediate broadcasting station, and as a call on each line between two consecutive intermediate broadcasting stations or between the last intermediate broadcasting station and the end station.

The fee for each separate transmission section will not be shared out, but will be paid wholly by one broadcasting organization.

Since a reserve circuit is not normally provided, when a broadcasting organization considers such a circuit necessary for the relaying of a certain program, the charge for it shall be the same as for if it had been used throughout the whole period of transmission. The same fee is payable for a speaking circuit as for a transmission circuit.

If a circuit which is let for broadcast transmissions requires special supervision, or putting in special technical devices, or changing the settings of the regular instruments, the extra costs for this, and for restoring the normal conditions afterwards, shall be paid by the broadcasting organization responsible for the fee for the circuit.

For this purpose the administrations concerned shall inform the administration in the country of the broadcasting organization in question of the amount of these costs, which shall then be credited to the former by the latter.

The monthly accounts should give full details of every broadcasting transmission.

Example: In the case illustrated by the fol-

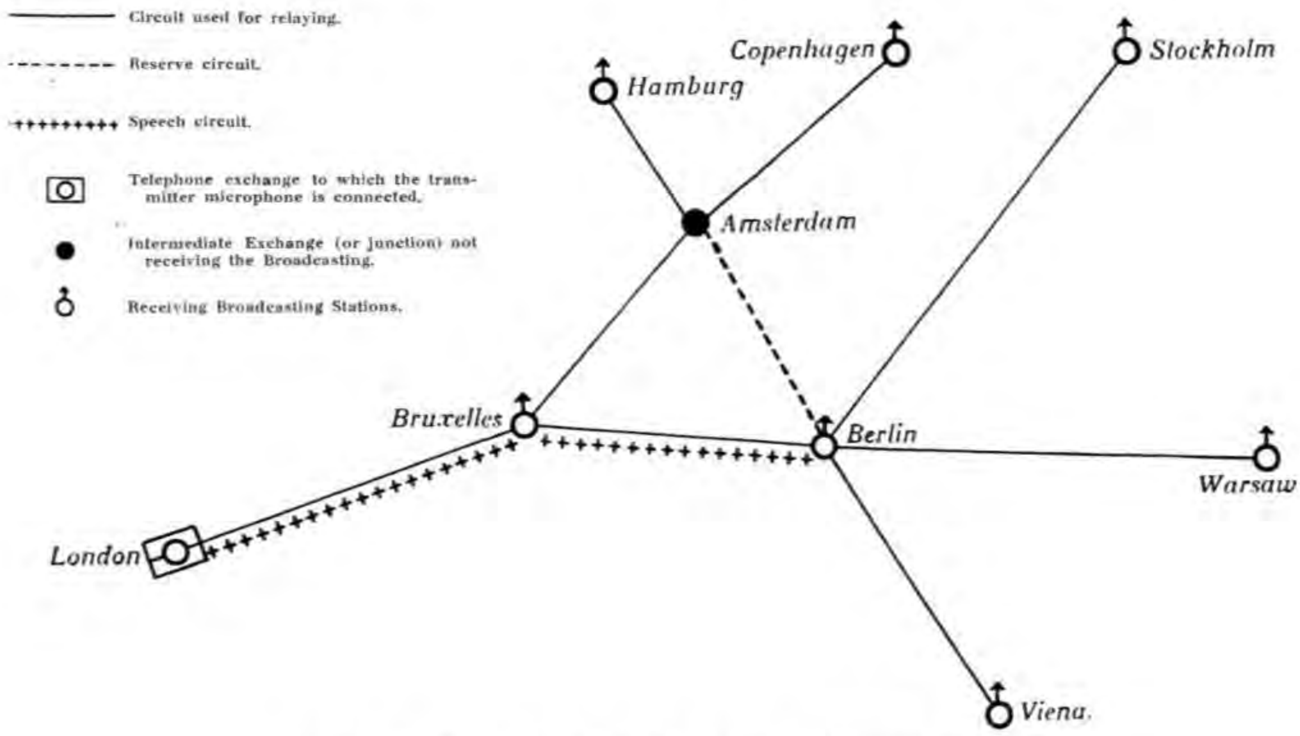


Diagram for relaying a Broadcasting Program from several Stations.

lowing chart, Brussels, which is relaying a London program, has to pay for the circuit from Brussels to London. When this program is also relayed by Berlin, and by Stockholm, Warsaw, and Vienna as well, the Berlin Broadcasting Company has to pay for the section from Berlin to Brussels and the Stockholm, Warsaw, and Vienna Broadcasting Companies the fees for their respective circuits from Berlin to Stockholm, Berlin to Warsaw and Berlin to Vienna.

As Amsterdam is not relaying the program, the broadcasting companies of Hamburg and Copenhagen should in advance agree whether the latter is to pay for the section from Brussels to Copenhagen or only for the section from Amsterdam to Copenhagen.

The broadcasting companies concerned should likewise come to some agreement in advance as to who should pay for such speaking circuits and reserve circuits as may be required.

Chart for relaying a brodcasting program from several stations.

Explanation of symbols:

Circuit	Ordered by (the broadcasting company which is to pay the charge for the circuit)	Special repeater station to be applied to in case of unforeseen faults in the circuit
London–Brussels	Brussels	
Brussels–Amsterdam	The broadcasting companies of Hamburg and Copenhagen should agree which of them is to pay for this circuit.	
Amsterdam–Copenhagen	Copenhagen	
Amsterdam–Hamburg	Hamburg	
Brussels–Berlin	Berlin	
Amsterdam–Berlin (reserve circuit)	The broadcasting companies concerned should agree which of them (Hamburg, Copenhagen, or Berlin) is to pay for this circuit.	
Berlin–Stockholm	Stockholm	
Berlin–Warsaw	Warsaw	
Berlin–Vienna	Vienna	
London–Berlin (speaking line)	Berlin	

Picture Transmission.

This is another use for telephone circuits which is still developing and for which, therefore, only provisional rules can be laid down.

It was resolved that the following should apply until further notice:

I. *Picture transmission direct between owners of the necessary equipment* is permitted without limitation of time

a) During the reduced-tariff period,
b) During the full-tariff period except during the busiest hours (these are determined jointly by the frontier control exchanges concerned) provided that either:

1) Special circuits are available, or
2) The average waiting time for ordinary calls at the time stipulated for the picture transmission does not exceed, or does not, by reason of this transmission, appear likely to exceed,

15 minutes for circuits less than 500 km in length.
30 minutes for circuits between 500 and 1 000 km. in length.
45 minutes for circuits more than 1 000 km. in length.

Until further notice the following rates shall apply:

a) for that part of the time of transmission falling within the heavy-traffic period: the rate as for ordinary calls.
b) for that part of the transmission period falling within the light traffic period:
   1) If the transmission is by subscription, or for a transmission lasting not less than one hour during the light-traffic period, half the rate for ordinary calls during the heavy-traffic period.
   2) In all other cases three fifths ($^3/_5$) of the fee for ordinary calls during the heavy-traffic period.

The technical equipments of the central exchanges should be such as to enable operators to determine the chargeable length of a picture transmission with the same accuracy as that of a telephone call.

If the exchange equipment does not allow of this, the technical staff of these exchanges should between them determine:

1) the time when the connexion is first available (the beginning of the period charged for) and
2) the time when the connexion is free (the end of the period charged for).

Note: Transit administrations are requested to facilitate transmission tests asked for by terminal administrations, provided that the above rates be applied to these tests.

II. *Picture Transmission from an Instrument belonging to and maintained by a user to an Instrument owned by the Telephone Administration of another country.*

In this case the same regulations and rates are used for the international circuits.

The administration assisting the private instrument will receive a surcharge which is not included in the international account.

Refusal or no reply from the calling or called subscriber.

The regulations were changed as follows:

1. That in the case of a refusal from the calling or called subscriber as well as in the case of no reply from the former, a charge shall be made as for one minute of an ordinary call during that tariff period during which the refusal or no reply occurred.
2. That for occasional fixed-time calls the only fee payable on refusal or no reply is as above; that is, there is nothing to pay for booking the fixed time.
3. For calls with préavis or avis d'appel and for "bourse" calls, in case of refusal or no reply on the part of the calling or called subscriber only the surcharge for those communications is payable.

Charges for calls extending into another call-rate period.

The international telephone regulations, Section K, par. 8, prescribe that every call shall be charged for according to the rate in force in the country of origin at the moment when the call begins, even if the call ends at a time when another rate is in force.

If a call begins during the last minutes of the heavy-traffic period, that part of the call which extends into the light-traffic period shall nevertheless be charged for at the higher rate, and vice versa.

This might perhaps be done for short calls, but for calls of any length this method is obviously unfair. In Sweden we have, with the consent of the countries cooperating, long charged for such calls at the rate proper to each portion of them.

At the plenary meeting in Paris the following rules for charging were now adopted:

For calls extending over both heavy and light traffic periods the charges will be as follows:

a) *If the duration of the call does not exceed three minutes,* the rate applicable at the beginning of the call will be applied;
b) *if the duration of the call exceeds three minutes,* the first three minutes are charged for according to the rate in force at the beginning of the call. Each additional minute is charged for according to the rate in force at the beginning of it.

Telephone Statistics.

The international telephone statistics published annually by the International Bureau at Berne have for several reasons been of very little use for comparing the telephone systems and so on in different countries. For one thing, the basis on which the information has been given has varied and the figures have therefore not been comparable, for another, statistics have included some figures which cannot be compared without further information, and again, rapid progress of telephony has added much of interest essential to a study of the several aspects of this progress; finally the statistics have been published so late that the swift advance of telephony has already made them out of date.

Draft regulations for telephone statistics were prepared in London, in conjunction with a representative of the International Bureau of the Telegraph Union at Berne, and were adopted by the plenary session in Paris; they are reproduced below:

1) "Statistique Générale de la Téléphonie" shall be published each year by the International Bureau of the Telegraph Union in the following form.

2) The new form of questionnaire for this proposed by the CCI shall be forwarded by the International Bureau of the Telegraph Union to the administrations and telephone companies not affiliated to the CCI as soon as possible, so that the statistics for 1931, which should be published in 1932, can be made out on this form.

3) Administrations and telephone companies should give their information as soon as possible to the International Bureau of the Telegraph Union so that the statistics for the past year can be published not later than August 1st next year.

Form for "La Statistique Générale de la Téléphonie".

I. *Population.*

II. *Area.*

III. *Number of exchanges* in use (1).
  1) automatic exchanges.
  2) semi-automatic exchanges.
  3) manual exchanges.
  Total number of exchanges.

IV. *Number of subscribers' lines* in use (2).
  1) directly connected to automatic exchanges.
  2) directly connected to semi-automatic exchanges.
  3) directly connected to manual exchanges.
  Total number of subscribers' lines.

V. *Number of instruments* in use.
  1) subscribers' telephones (3) (including extension and service telephones).
  2) public call office telephones (4).
  Total number of telephones.

VI. *Interurban and international circuits* in use.
  1) Total number of internal circuits (physical, phantom and carrier current circuits).
  2) Total number of international circuits (physical, phantom and carrier current circuits).
  3) Total length in km. of open-wire circuits (internal and international).
    a) physical circuits.
    b) phantom circuits.
    c) carrier current circuits.
  4) *Total length in km. of circuits in aerial and underground cables* (internal and international).
    a) 2-wire physical circuits.
    b) 4-wire physical circuits.
    c) phantom circuits (2-wire and 4-wire).
  5) *Total length in km. of circuits in submarine cables* (internal and international) (5).
    a) 2-wire physical circuits.
    b) 4-wire physical circuits.
    c) phantom circuits (2-wire and 4-wire).
    d) carrier current circuits.

VII. *Traffic.*
  1. *Local traffic.*
    a) number of calls (irrespective of length) *from* subscriber telephones.
    b) number of charged calls (irrespective of length) *from* public call offices.
    Total number of local calls.
  2. *Interurban traffic.*
    a) *total number of call minutes charged for*
      1) at ordinary call rates.
      2) at reduced call rates.
      Total.
    b) *number of calls charged for* (irrespective of length)
      ordinary
      urgent
      lightning
      subscription
      with préavis
      with avis d'appel
      fixed-time calls
      broadcast transmissions (6).
  3. *International traffic* (outgoing, incoming, transit).
    a) *Total number of call minutes charged for*
      1) at ordinary call rates.
      2) at reduced call rates.
      Total.
    b) *Number of calls charged for* (irrespective of length)
      ordinary

urgent
lightning
subscription
with préavis
with avis d'appel
fixed-time calls
broadcast transmission (6).

VIII. *Total cost in gold francs of telephone working, internal and international* (including interest and amortisation of the capital invested).

(This information was made optional as a strong minority considered it of slight value in such a general form.)

Total income in gold francs from internal and international telephone working.

Notes.

(1) By an exchange is meant an automatic, semi-automatic, or manual exchange to which *subscribers* are connected and which is operated by the administration or by a telephone company.

(2) In the number of subscribers' lines are included the lines to service telephones and public call offices.

(3) In the number of subscribers' telephones are not included such private telephones as can not be connected to the network of lines.

(4) In the number of public call office telephones are included all telephones which are installed by the administration for public use.

(5) If a submarine cable belongs to two administrations, only the length of the part belonging to the administration is given.

(6) In the internal interurban traffic, every broadcast transmission, whether received and relayed by one station or more, is counted as one transmission only.

In the international traffic each country taking part in a broadcast transmission, whether with a sender station, with one or more receiving stations, or only as a transit country, counts one transmission only.

If in a transit country a broadcast transmission is "tapped" by one or more receiving stations, this is nevertheless to be regarded by that country as only one international broadcast transmission and is not included in the statistics of the internal interurban traffic.

If a program is broadcast at the same time both in the country and abroad, it chould be given by the sending country under the headings of both interurban and international traffic.

If the place of origin of the broadcast is changed during the transmission, each alteration is counted in the statistics as a new transmission.

For the rest, several questions and proposals were discussed which either did not lead to any steps being taken or were of subordinate importance.

Among the more important proposals we may mention:

Proposal to give the members of the board of a national bank the right to make Government calls to other national banks and to the Bank for International Settlements at Basle.

This proposal was not adopted because the majority of administrations were of the opinion that the number of authorities and persons entitled to make Government calls should for many reasons not be increased.

Proposal to change the present regulations about cutting off local calls to make way for interurban calls.

As it is undoubtedly of vital importance in using the expensive international circuits that calls should be established as quickly as possible. and as the majority of the administrations that had expressed an opinion on this point had in principle been in favour of cutting off, the proposal did not lead to any step being taken by the CCI.

Proposal to adopt as the unit charge in international traffic the charge for one minute instead of, as at present, the charge for three minutes at ordinary rates.

This proposal was not accepted for the reasons
that the duration of the majority of calls does not exceed three minutes,
that calls in frontier traffic are always charged for in indivisible 3-minute periods, and
that the latter method of charging in indivisible 3-minute periods is also in use in many countries for internal traffic.

Proposal.

1) to introduce a third rate to apply to certain hours of the day outside the busiest hours.

2) to change the night rate, which is at present $^3/_5$, to $^1/_2$ of the ordinary rate.
3) to change the night rate for subscription calls from $^1/_2$ to $^2/_3$ of the ordinary rate.
4) to change the time for applying the night rate from 19.00 to 18.00 o'clock.

The proposal under 1) was rejected in view of the complication involved by a third rate, both in making out charges and in international accounts.

It was also considered that the reduction of the rates would not be justified under present economic conditions.

For the latter reason the other proposals of this group were also rejected, although there was considerable sympathy for the proposal to change the time for applying the reduced rate from 19.00 to 18.00 o'clock.

The *question* of rates for the lease of telegraph circuits in the international telephone circuits could not, it was considered, at present be definitely settled. For the present a separate agreement as to the charges should be made in each case.

Power Line Disturbances and Electrolysis.

In 1926 there was published a summary of the regulations adopted regarding the protection of telephone lines from disturbances caused by power lines, called "Directives concernant les mesures à prendre pour protéger les lignes téléphoniques contre les influences perturbatrices des installations d'énergie à courant fort ou à haute tension". An editorial committee appointed in Berlin in 1929 had submitted to this year's meeting a new edition of these "directives", and this was now adopted under the title of the 1930 "directives".

Noise Measurements.

No. 1 CR has examined the methods of measuring voltages and currents causing disturbing noise in telephone lines. These voltages may be studied and measured either in the power line, *inducing noise voltage* (tension perturbatrice), or in the telephone line, *induced noise voltage* (tension de bruit). Both these voltages usually contain a large number of different frequencies. As the transmission of these by induction or influence from the power to the telephone line is different for different frequencies, the inducing and induced noise voltages will have different forms of curve. When measuring these voltages from the point of view of the disturbances produced, it is not sufficient to measure the r. m. s. value of the various voltages, but the different frequencies in the voltage must be allowed to appear in the measurement in proportion to the disturbance they create in the call in progress. For *inducing* noise voltages an objective measuring instrument has long existed, designed by Osborne and consisting of a filter, which will pass different frequencies in proportion as they create disturbances in telephone lines, and a thermo-couple which measures the strength of the voltages passed. In the estimation of the disturbing effects of the various frequencies, allowance has been made in designing the filter for the fact that the induction effect from power to telephone lines is different for different frequencies. For measuring the *induced* disturbing voltage, the subjective method has, on the other hand, been employed. The acoustic effect caused in a telephone by the noise voltage has been estimated by comparison with the corresponding effect either from a constant, complex noise voltage (the American method) or from an easily measurable voltage of constant frequency, 800 cycles/sec. (the method hitherto recommended by the CCI). The drawbacks of these methods are obvious. For a long time therefore attempts have been made to produce an objective instrument of the Osborne type to measure the induced noise voltage with. It should thus contain a filter (whose properties should, however, not be the same as for measuring inducing voltage), and a direct-reading voltage instrument. The voltages here passed by the filter being very small, amplifiers are required to bring the value up to such as can be measured by ordinary instruments. The most difficult part of the construction of such an instrument is, however, the design of the filter, i. e. how far the various frequencies should be passed to correspond to the relative noise effects of the same frequencies. This determination will again have to be done by intelligibility tests. The CCI has now approved a curve constructed by the 1st CR for the variation of the noise fre-

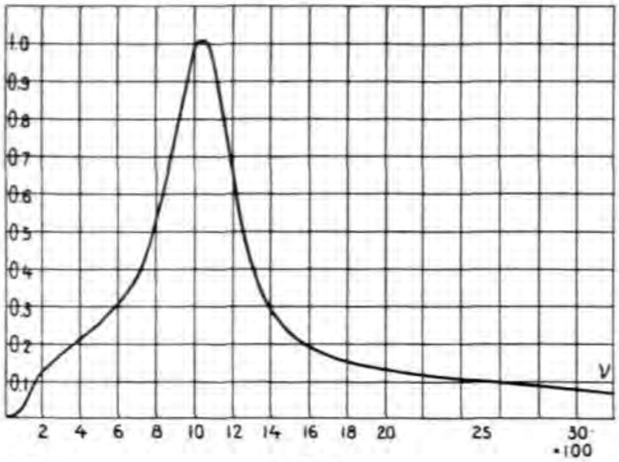


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Fig. 1.

quency with the frequency of the noise voltage (fig. 1). The form of this curve, which refers to conditions obtaining in ordinary telephony, has also been affected by the telephone receivers used in the tests; these were of the usual commercial type and their efficiency varies considerably with the frequency. The curve will thus not apply to the effect of various noise frequencies on a broadcast transmission, where better receiv-

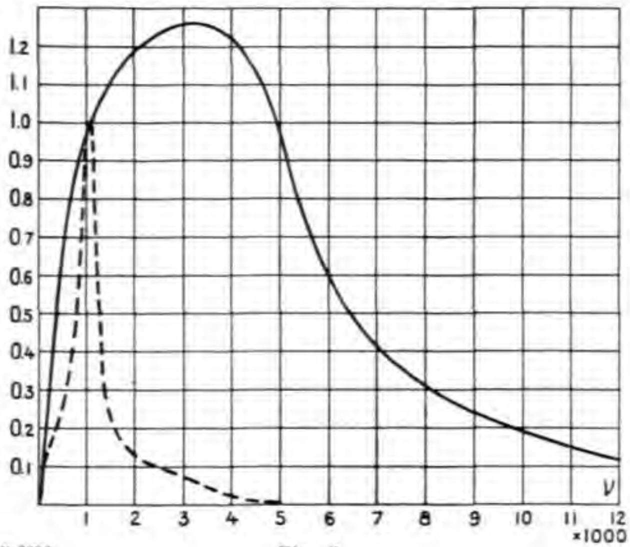

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Fig. 2.

ing devices are now generally used. For this case the curve given in fig. 2 has been obtained by a similar series of experiments. The curve of fig. 1 has been added here too on the same scale for the sake of comparison. Both curves give the ratio of the noise effect to its value at 1.050 p:s, which is given the value 1.

The earlier method meant that the noise effect of the voltage measured was compared with an adjustable noise voltage of 800 cycles/sec. frequency, which was adjusted until it gave the same noise effect, when the value obtained was measured in millivolts. The strength of the disturbance was thus given in mV. To retain continuity in this the objective measuring instrument is also graduated in mV and so calibrated that when a sinusoidal alternating current of 800 cycles/sec. is connected to the input terminals of the filter it will give the correct r. m. s. value of its voltage in mV.

As the instrument is to be in parallel with the receiver of a telephone instrument connected to the line under examination, and as it should not then disturb the voltage distribution in this circuit, it should have a high input impedance, at least 10 000 ohms.

For measuring the inducing noise voltage, which is of a greater order of magnitude and does not require amplification to become measurable, the filter must be supplemented with a frequency-dependent element to correct for the different induction effects of the various frequencies. If it is purely a question of electromagnetic induction, the induced voltage is proportional to the inducing current and to the frequency, but if on the other hand it is a question of electrostatic induction, it is proportional to the inducing voltage and independent of the frequency. In practice the dependence of the induction phenomena on the frequency lies between these two extremes. No details of the properties of the required supplementary filter have yet been determined. The filter in the original Osborne instrument was based on the induced voltage being proportional to the frequency of the inducing voltage. After renewed investigations however, the Osborne curve has been considerably modified.

A question which has long been on the program of the CCI, as to how to characterize and measure the noise effect of a D. C. plant, has been solved automatically by the general definition of inducing noise voltage and by the above method of measuring it.

Disturbances from rectifiers.

As regards this question, which has also been discussed at several CCI meetings and thoroughly dealt with in conjunction with representatives of the power organizations, the CCI has now decided to recommend the use of an inductance coil, with the requisite number of resonance shunts, in the rectifier circuits. In 6-phase-rectifiers, which are the commonest, it is considered desirable that these devices should be so designed that the noise voltage is reduced by their introduction in the circuit to $^1/_{10}$ of its original value.

Twisting of power lines.

The CCI's "directives" propose a twisting of power lines so that each section of 36 km. will be equalized when the wires are put up in triangle, and each section of 18 km. will be equalized when the wires are put up in any other way e. g. all in one horizontal plane. Each of these equalized sections ("barrel") must then in 3-phase systems be divided into 3 equal parts and at the end of each part a twist introduced of $^1/_3$ of a turn. A line with triangular cross section and of total length not more than 36 km. will thus have only 2 twisting points. If the line is longer and therefore divided into more barrels, each such barrel will also have two twisting points. The question has now been, whether or not the line should be twisted at the points where two barrels meet. The American rules have considered twisting at these points to be in general unnecessary. The 1st CR having investigated the question, the CCI has now declared that there is no objection to leaving out the twisting at the point where two adjoining barrels meet. These rules regarding twisting have been applied in Sweden in this latter way.

Symmetrical earthing of telephone circuits in a cable.

In a modern long distance cable the capacity symmetry of the conductors with respect to the lead sheath is so good that the lines remain sufficiently free of disturbances at moderate induced voltages if they are kept completely insulated from earth. But if the conductor is earthed, even symmetrically, there is a risk that the inductive or resistance unbalance present in the circuit will cause disturbances in it. Further, as the dielectric strength between the several conductors of a cable is considerably lower than the dielectric strength between the conductors and the lead sheath, the risk of flash-overs on exposure of the cable to induced voltages will be increased if any conductor is earthed. In that case there is also a risk that the currents occurring will be so large that the magnetic properties of the loading coils will be impaired. The CCI has therefore said on this point that there should be no earthing in a long-distance cable line. Nor should an overhead line be earthed which has metallic connexion with a cable line except in special cases prepared for in advance. It must then be verified that the symmetry of that cable line and the adjoining ones has not been disturbed by the earthing. The dielectric strength between a cable conductor which has metallic connexion with the earthed conductor, and the other conductors must be considerably greater than the highest voltage that can be induced in it by a power line. If the earthed conductor is part of a telegraph circuit, the rules obtaining for telegraphy by telephone cables must also be complied with.

Protective Devices in Telephone Lines.

The 1st CR has taken up the study of the most suitable design and the most suitable properties of protective devices for telephone lines, such as fuses and lightning arrestors, and has for that purpose requested the various administrations and operating companies to supply information as to the designs now used and their properties. In order to obtain internationally uniform methods for testing and judging protective devices, certain instructions on this subject have been prepared. The intention is in this way to enable a perfectly fair comparison to be made between the designs used in the different countries.

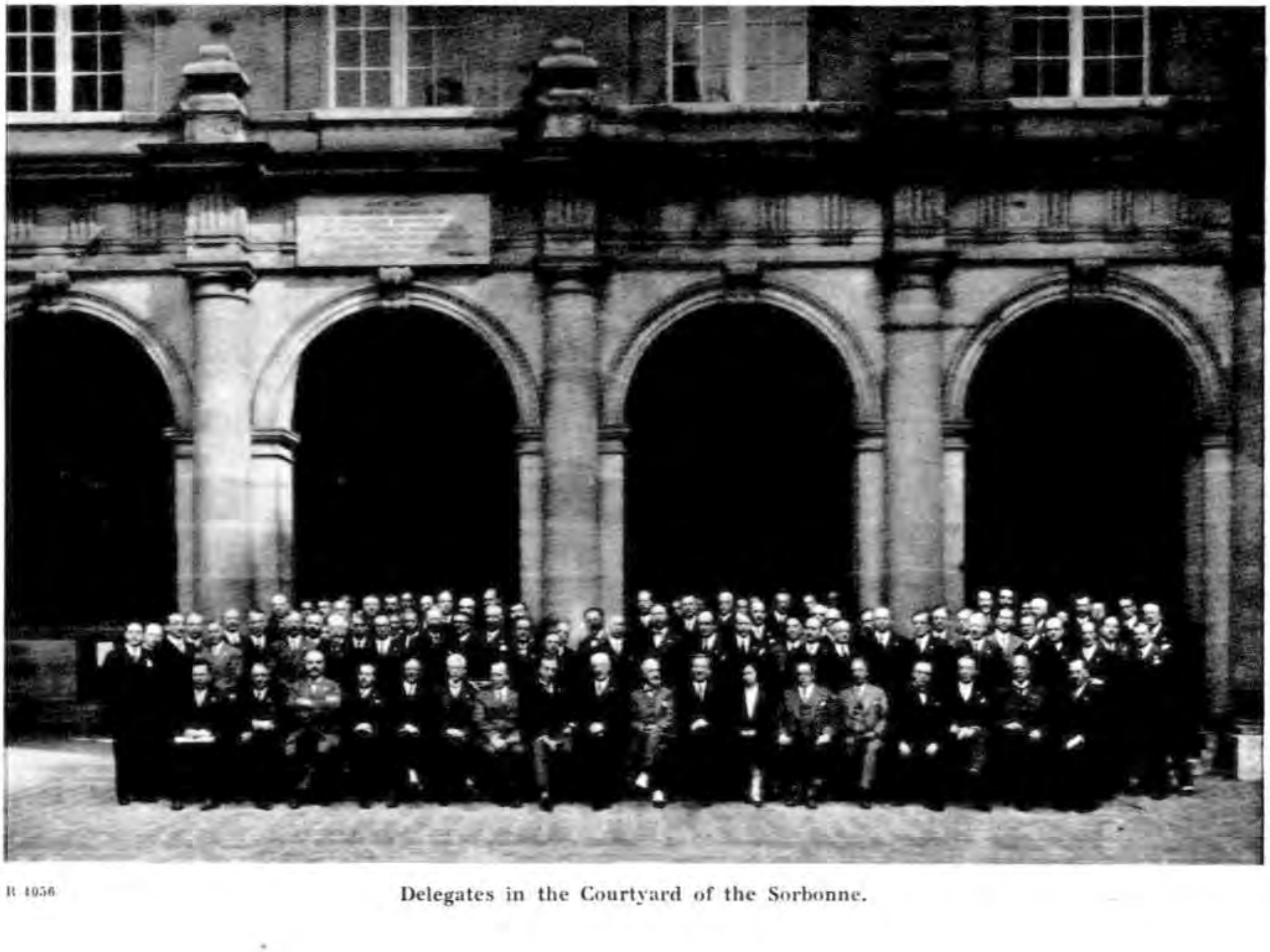
The CCI has given certain general directions regarding protective devices in cables and overhead lines, but these will be supplemented and more precisely specified when the question has been examined further.

Electrolysis and Chemical Effects.

In 1927 preliminary "directives" were issued by the CCI regarding measures for the protection of cables from electrolysis and chemical corrosion. The work in this branch during recent years has chiefly consisted in an examination of proposals made for the alteration of these "directives", and the consequent modifications of detail.

Many of the questions on the agenda of the 1st and 2nd CRs have been referred to a "Commission mixte internationale pour les expériences relatives à la protection des lignes de télécommunication et des canalisations souterrains". This commission (CM) is composed of representaives of various international associations e. g. the CCI, the CCIT ("the CCI for telegraphy"), the UIC (Union Internationale des Chemins de Fer), the UIT (Union Internationale des Tramways etc.) the UIPD (Union Internationale des Producteurs et Distributeurs d'Energie Electrique). Its aim is to organize and jointly to carry out technical investigations on such questions, and to submit results on which to base subsequent regulations. Among questions at present investigated by the CMI we may mention earthing of the neutral point in power lines, symmetry in telephone lines, the laws of mutual induction with earth return, acoustic shocks, and others. The measurements of mutual induction at Skillingaryd in 1930 were part of these investigations.[1]

[1]) See L. M. E. Review.



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Delegates in the Courtyard of the Sorbonne.

The Attenuation at a Double Point in a Band pass Filter.

Communication from the Research and Development Department.

By *H. Pleijel* and *S. Kruse.*

In certain band pass filters containing two or more bands it is possible, by selecting suitable inductances and capacities, to give one common edge to two bands, i. e. to combine them into one single band. The actual meeting point of the two bands we will briefly call a double point.

At the edge of a band, the attenuation increases from a low value within the band to a high value outside it. Formulæ showing how this attenuation increases have been given in an earlier paper. At a double point the previous B will be 0 and A^2 will be 1, so that the expression

$$\sinh 2b = \frac{B}{\sqrt{1-A^2}}$$

will take the form $\frac{0}{0}$. At such a point it will therefore be necessary to take into account terms of higher degree in the loss resistances. Some change must consequently be expected in the attenuation near the points where two bands meet, and an examination of the conditions will therefore be of some interest.

In the paper mentioned, the following expressions were used:

$$\cosh 2\Theta = \frac{I+R}{I-R} = \varphi\,(z'_1 z'_2 z'_3 \ldots\ldots)$$

where I is the open circuit impedance, R the short circuit impedance from one side of the network forming the filter, and z_1', z_2'.... the impedances of the conductors composing the network.

We also introduced:

$$z'_n = z_n + r_n,$$

where r_n is the resistance of the conductor of index n. We expanded φ in a Taylor's series, retained the two first terms, and substituted:

$$A = \varphi\,(z_1 z_2 \ldots\ldots)$$

$$jB = r\nabla \cdot \varphi = r\nabla \cdot A,$$

where $r\nabla$ is the operator:

$$r\nabla = r_1 \frac{\delta}{\delta z_1} + r_2 \frac{\delta}{\delta z_2} + r_3 \frac{\delta}{\delta z_3}$$

For the sake of brevity, we will use p for $r\nabla$. Retaining the expressions for A and B, the function φ is expanded in a Taylor's series, which results in the more general expression.

$$\cosh 2\Theta = A + \frac{pA}{1} + \frac{p^2A}{1\cdot 2} + \frac{p^3A}{1\cdot 2\cdot 3}$$

The odd terms in this expansion are real, and the even terms purely imaginary. If we therefore introduce the expression

$$\cosh 2\Theta = \bar{A} + j\bar{B}$$

we get:

$$\bar{A} = A + \frac{p^2A}{1\cdot 2} + \frac{p^4A}{1\cdot 2\cdot 3\cdot 4} + \ldots\ldots$$

$$j\bar{B} = \frac{pA}{1} + \frac{p^3A}{1\cdot 2\cdot 3} + \ldots\ldots$$

The attenuation will now be determined by one of the two formulæ:

$$\sinh 2b = \frac{\sqrt{2}\,\bar{B}}{[1-k^2+\sqrt{(1-k^2)^2+4\bar{B}^2}]^{1/2}}$$

$$\sinh 2b = \frac{[\sqrt{(k^2-1)^2+4\bar{B}^2}+k^2-1]^{1/2}}{\sqrt{2}}$$

$$k^2 = \bar{A}^2 + \bar{B}^2$$

The first formula is directly applicable when $k^2 < 1$, and the second when $k^2 > 1$.

To retain the same rules as before when determining the position of each band, the cut-off frequencies should be determined by the condition

$$A^2 = 1$$

or the limits obtained when there are no losses.

We now assume that A has the form

$$A = 1 + U$$

with

$$U = U_1 U_2$$

and that the filter is made up so that both U_1 and U_2 are zero at a certain value $\omega = \omega_2$, and that U will be negative for values of ω on either side of ω_2. We will then be concerned only with the case $A = 1$, but the formulæ obtained can without difficulty be applied when $A = -1$ also.

We may now write:

$$jB = pA = U_1 \cdot pU_2 + U_2 \cdot pU_1.$$

This formula shows that B will be zero when $\omega = \omega_2$. According to our assumption, A will be 1 at that point.

In the neighbourhood of the point $\omega = \omega_2$, and at such a distance from it that terms of higher degree in the loss resistances may be neglected, the attenuation formula will be

$$\sinh 2b = \frac{|B|}{\sqrt{1 - A^2}}$$

In the earlier paper we found, by the way, that this expression will be finite when ω approaches ω_2, provided $\frac{U_1}{U_2}$ is finite. Outside a small range about ω_2, the general expression for the attenuation within a band is thus applicable.

As the value of A is at a maximum at the point $\omega = \omega_2$, we find that $\frac{d^2A}{d\omega^2}$ must be negative near to this point.

As $\frac{dA}{dz_2}$, $\frac{dA}{dz_2}$ and $\frac{dA}{dz_3}$ are all zero when $\omega = \omega_2$, $\frac{d^2A}{d\omega_2}$ will be composed, in the same way as p^2A, of the derivates of A with respect to z_1, z_2, and z_3. All that is required is to substitute for r_1, r_2 and r_3 in the last expression the positively imaginary expressions $\frac{dz_1}{d\omega}$, $\frac{dz_2}{d\omega}$ and $\frac{dz_3}{d\omega}$. If r_1, r_2 and r_3 are selected to be proportional to these expressions, $\frac{d^2A}{d\omega^2}$ and p^2A will have opposite signs, as $\frac{dz_1}{d\omega}$, $\frac{dz_2}{d\omega}$ etc. are multiplied in twos and each contain the factor j. It is therefore probable that, at the point $\omega = \omega_2$, p^2A will be positive even with arbitrary values of r. If we were instead at a point $A = -1$, $\frac{d^2A}{d\omega^2}$ would be positive near ω_2. According to the same argument as above, p^2A would then be negative.

At the double point we now have

$$k^2 - 1 = A^2 + B^2 - 1 = \left(A + \frac{p^2A}{2}\right)^2 + \left(pA + \frac{p^3A}{6}\right)^2 - 1$$

$$= \left(1 + \frac{p^2A}{2}\right)^2 + \frac{(p^3A)^2}{36} - 1$$

$$= p^2A + \frac{1}{4}(p^2A)^2 + \frac{1}{36}(p^3A)^2$$

If we neglect the terms of higher order in the resistances r, we get

$$k^2 - 1 = p^2A.$$

As mentioned above, we may expect p^2A to be positive at the point under consideration. For a point $A = -1$, we get $-p^2A$ on the right hand side, and hence in this case also k^2 will be > 1 (p^2A is here negative).

The second of the two attenuation formulæ must therefore be applied, and we get:

$$\sinh 2b = \frac{1}{\sqrt{2}}\left[\sqrt{(p^2A)^2 + \frac{4}{36}(p^3A)^2} + p^2A\right]^{1/2} = \sqrt{p^2A}$$

U_1 and U being zero, we may write:

$$p^2A = 2pU_1 \cdot pU_2$$

The formula for the attenuation at the double point will thus be:

$$\sinh 2b = 2b = \sqrt{2pU_1 \cdot pU_2}.$$

As we are only dealing with conditions at the point $\omega = \omega_2$ we can, in future, for the sake of brevity, write ω for ω_2.

As an example, we use the same filter as in the previous paper, viz. a π-arrangement in which the line impedance z_1 consists of an inductance connected in series with a capacity, and where the connexion to earth at each end consists of an inductance connected in parallel with a condenser. The impedance of the condenser is $2z_2$, and of the inductance $2z_3$.

We may then write:

$$z_1 = j\omega L + \frac{1}{j\omega C}$$

$$z_2 = \frac{1}{j\omega K}$$

$$z_3 = j\omega M$$

To obtain a double point, the condition

$$MK = LC$$

must be fulfilled.

At the double point we also have:

$$1 - \omega^2 LC = 0$$

and $$1 - \omega^2 MK = 0$$

At the double point $A = 1$.

For A we have obtained the expression:

$$A = 1 + \frac{z_1}{2}\left[\frac{1}{z_2} + \frac{1}{z_3}\right]$$

consequently:

$$U_1 = \frac{z_1}{2}$$

$$U_2 = \frac{1}{z_2} + \frac{1}{z_3}$$

$$pU_1 = \frac{r_1}{2}$$

$$pU_2 = -\frac{r_2}{z_2^2} - \frac{r_3}{z_3^2} = r_2 \omega^2 K^2 + \frac{r_3}{\omega^2 M^2} = \frac{r_2 + r_3}{\omega^2 M^2}$$

$$2\,pU_1 \cdot pU_2 = \frac{r_1 (r_2 + r_3)}{\omega^2 M^2}$$

At the double point we therefore get

$$\sinh\ b = \frac{\sqrt{r_1 (r_2 + r_3)}}{\omega M}$$

The attenuation is therefore of the same magnitude as within the two bands.

For comparison, we will examine the attenuation formula obtained by introducing the conditions at the edge of the band into the general equation for the attenuation (see the previous paper).

We get:

$$b = \frac{1}{2}\left[r_1 \sqrt{\frac{C}{M}} + \frac{r_2 + r_3}{\omega^2 M^2} \sqrt{\frac{M}{C}}\right]$$

or

$$b = \frac{1}{2} \cdot \frac{1}{\omega M}\left[r_1 \sqrt{\frac{C}{K}} + (r_2 + r_3) \sqrt{\frac{K}{C}}\right]$$

Since $k^2 > 1$ at the double point, there must be two points, one on either side of it, at which $k^2 = 1$. At this point the attenuation is obtained from the formula

$$\sinh\ 2b = \sqrt{B}$$

We will now consider the position of the points where $k^2 = 1$, and the formula for the attenuation there.

We have

$$k^2 - 1 = A^2 + B^2 - 1 = \left(A + \frac{p^2 A}{2}\right)^2 + \left(pA + \frac{p^3 A}{6}\right)^2 - 1$$

We assume the magnitude of the terms to be determined by the loss resistances, i. e. by p.

If we neglect terms of higher powers than the second we get:

$$k^2 - 1 = A^2 + A \cdot p^2 A + (pA)^2 - 1.$$

If, beginning at the double point, we increase ω by a small amount $\delta\omega$, we may write $k^2 - 1$ at the point $(\omega + \delta\omega)$ as follows (ω being the double point):

$$k^2 - 1 = A^2 + A \cdot p^2 A + (pA)^2 - 1 + \frac{\delta A^2}{\delta\omega}\delta\omega + \frac{1}{2}\frac{\delta^2 (A^2)}{\delta\omega^2}\delta\omega^2 + \frac{\delta}{\delta\omega}[A \cdot p^2 A + (pA)^2]\,\delta\omega$$

But at this point we have:

$$A = 1;\ pA = 0; \frac{\delta A}{\delta\omega} = 0$$

We can therefore write:

$$k^2 - 1 = p^2 A + \frac{\delta^2 A}{\delta\omega^2}\delta\omega^2 + \frac{\delta}{d\omega}(p^2 A)\,\delta\omega$$

The last term is negligibly small compared to the first, and we get:

$$k^2 - 1 = p^2 A + \frac{\delta^2 A}{\delta\omega^2} d\omega^2$$

To determine the points where $k^2 = 1$, we thus have the condition:

$$(\delta\omega)^2 = -\frac{p^2 A}{\frac{\delta^2 A}{\delta\omega^2}}$$

or

$$\delta\omega = \pm\sqrt{-\frac{p^2 A}{\frac{\delta^2 A}{\delta\omega^2}}} = \pm\sqrt{-\frac{pU_1 \cdot pU_2}{\frac{\delta U_1}{\delta\omega} \cdot \frac{\delta U_2}{\delta\omega}}}$$

$\delta\omega$ will therefore be of the same order of magnitude as p

We have further

$$B = pA + \frac{p^3 A}{6}$$

If here also, starting from the double point, we increase ω by $\delta\omega$, and remember that $\delta\omega$ is of the same magnitude as p, and that $pA = 0$, we may write:

$$B = \frac{\delta}{\delta\omega}(pA)\,\delta\omega = \left[\frac{\delta U_1}{\delta\omega} \cdot pU_2 + \frac{\delta U_2}{\delta\omega} \cdot pU_1\right] \cdot \delta\omega$$

B will thus be of the same order of magnitude as p^2, and the attenuation consequently of the same order of magnitude as p, or as the loss factors.

We have

$$\sinh 2b = \sqrt{B} = \sqrt{\left[\frac{\delta U_1}{\delta\omega} \cdot pU_2 + \frac{\delta U_2}{d\omega} \cdot pU_1\right]\delta\omega}$$

and

$$\delta\omega = \sqrt{\frac{pU_1 \cdot pU_2}{\frac{\delta U_1}{\delta\omega} \cdot \frac{\delta U_1}{\delta\omega}}}$$

We apply these formulæ to the same example as before. We have:

$$pU_1 = \frac{r_1}{2}$$

$$pU_2 = \frac{r_2}{z_2^2} = \frac{r_3}{z_3^2} = \frac{r_2 + r_3}{\omega^2 M^2}$$

$$\frac{\delta U_1}{\delta \omega} = \frac{1}{2}\, j \left(L + \frac{1}{\omega^2 C}\right) = \frac{j}{\omega^2 C}$$

$$\frac{\delta U_2}{\delta \omega} = j\left(K + \frac{1}{\omega^2 M}\right) = \frac{2j}{\omega^2 M}$$

consequently

$$\frac{\delta\omega}{\omega} = \frac{1}{2}\sqrt{\frac{C}{M}} \cdot \sqrt{r_1 \cdot (r_2 + r_3)}$$

$$= \frac{1}{2\,\omega M} \cdot \sqrt{\frac{C}{K}} \cdot \sqrt{r_1\,(r_2 + r_3)}$$

The formula for B will be:

$$B = \left[\frac{r_2 + r_3}{\omega^2 M^2}\,\frac{1}{\omega^2 C} + \frac{r_1}{2}\,\frac{2}{\omega^2 M}\right] \delta\omega$$

$$= \frac{1}{\omega^2 M}\left[(r_2 + r_3)\,\frac{K}{C} + r_1\right] \delta\omega$$

Substituting this value for $\delta\omega$, we get at the point where $k^2 = 1$:

$$B = \frac{1}{2}\,\frac{1}{\omega^2 M^2}\left[(r_2 + r_3)\sqrt{\frac{K}{C}} + r_1\sqrt{\frac{C}{K}}\right] \cdot \sqrt{r_1 (r_2 + r_3)}$$

and

$$\sinh 2b = \frac{1}{\sqrt{2}}\,\frac{1}{\omega M}\sqrt{(r_2 + r_3)\sqrt{\frac{K}{C}} + r_1\sqrt{\frac{C}{K}}} \cdot \sqrt[4]{r_1\,(r_2 + r_3)}$$

The formula for the band gave us at the double point:

$$\sinh\, 2b = \frac{1}{2}\,\frac{1}{\omega M}\left[(r_2 + r_3)\sqrt{\frac{K}{C}} + r_1\sqrt{\frac{C}{K}}\right]$$

and at the double point the value of the attenuation was:

$$\sinh\, 2b = \frac{\sqrt{r_1\,(r_2 + r_3)}}{\omega M}$$

The attenuation at the point where $k^2 = 1$ is thus the geometric mean of these two values. This relation between the three attenuations, however, is not confined to this particular example, but is of perfectly general validity, as we shall see below.

As $U_1 = U_2 = 0$ at the double point, formula (7) in the previous paper gives us the following expression for the attenuation at this point.

$$\sinh\, 2b_1 = \frac{1}{\sqrt{2}} \cdot \left[\sqrt{\frac{U_2}{U_1}} \cdot pU_1 + \sqrt{\frac{U_1}{U_2}} \cdot pU_2\right]$$

This will therefore be the value of $\sinh\, 2\, b$ at the double point when we employ the formula valid within the band. b is here designated b_1.

For b_2, the attenuation at the double point, we have above deduced the formula:

$$\sinh\, b_2 = \sqrt{2} \cdot \sqrt{pU_1 \cdot pU_2}$$

If the attenuation at the point where $k^2 = 1$ is b_3, we can write

$$\sinh 2b_3 = \sqrt{\frac{\delta U_1}{\delta\omega} \cdot pU_2 + \frac{\delta U_2}{\delta\omega} \cdot pU_1 \cdot \sqrt{\delta\omega}}$$

$$= \sqrt{\frac{\delta U_1}{\delta\omega} \cdot pU_2 + \frac{\delta U_2}{\delta\omega}\, pU_1} \cdot \sqrt[4]{\frac{pU_1 \cdot pU_2}{\frac{\delta U_1}{\delta\omega} \cdot \frac{\delta U_2}{\delta\omega}}}$$

As U_1 and U_2 are both zero at the double point, we may write:

$$\frac{\frac{\delta U_1}{\delta\omega}}{\frac{\delta U_2}{\delta\omega}} = \frac{U_1}{U_2}$$

The last formula can then be written:

$$\sinh\, 2b_3 = \left[\sqrt{\frac{U_1}{U_2}} \cdot pU_2 + \sqrt{\frac{U_2}{U_1}} \cdot pU_1\right]^{1/2} \cdot \sqrt[4]{pU_1 \cdot pU_2}$$

A comparison of the three formulæ will then show that we have in general:

$$(\sinh\, 2\, b_3)^2 = \sinh\, 2\, b_1 \cdot \sinh\, 2\, b_2$$

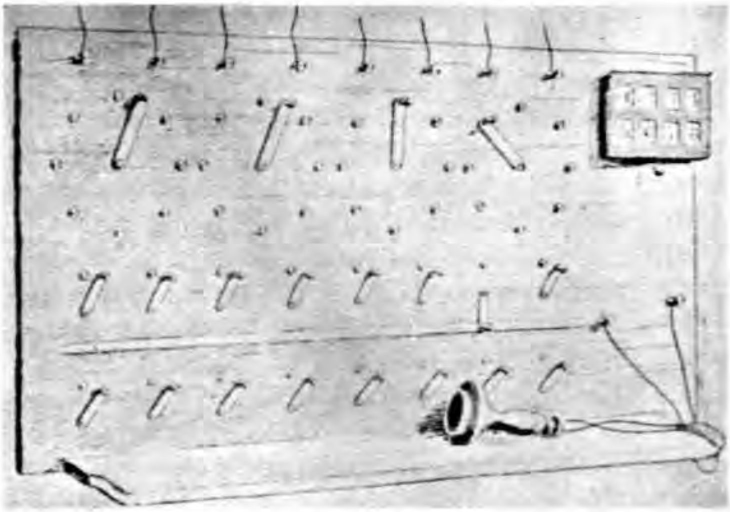
or approximately

$$b_3^2 = b_1 \cdot b_2.$$

50 Years' Progress in Telephony.

By *A. Lignell.*

On March the 7th 1876, Mr. Bell patented his primitive telephone instrument; in January 1878 the first telephone exchange was opened in New Haven with 21 subscribers; on January 1st 1931 more than 35 million telephones are scattered all over the world, and between about 32 millions of these intercommunication is at present possible.



R 3055 The first Swithboard used in New Haven.

This is a brief summary of the progress in just over 50 years of our most rapid, most convenient, and most effective means of communication.

Progress, however, has not been equally pronounced at all times during that period. From the start in 1878 to the end of last century, the increase was comparatively insignificant, as the telephone instruments, exchanges, and lines only gradually reached the perfection necessary for the present effective transmission of speech.

This is clearly indicated by the attached diagram I, showing the number of telephones per 100 inhabitants in the United States, Europe, and Sweden in the years 1878—1930.

At the end of the century, that is 22 years after the start, U. S. A. only had 1.2 telephones per 100 inhabitants—the same figure as Sweden then had—but on January 1st 1931 the corresponding figure was 16.4 in U. S. A. and 8.3 in Sweden, while Europe as a whole at the end of the century had 0.2, and in 1930 no more than 1.9 telephones per 100 inhabitants.

On January 1st 1930, North America as a whole had 13.0, South America 0.7, Asia 0.1, Africa 0.2, Oceania 1.0, and the whole world 1.8 telephones, all per 100 inhabitants.

In U. S. A. the telephone has been employed for private use to a far greater extent than is ordinarily the case in Europe.

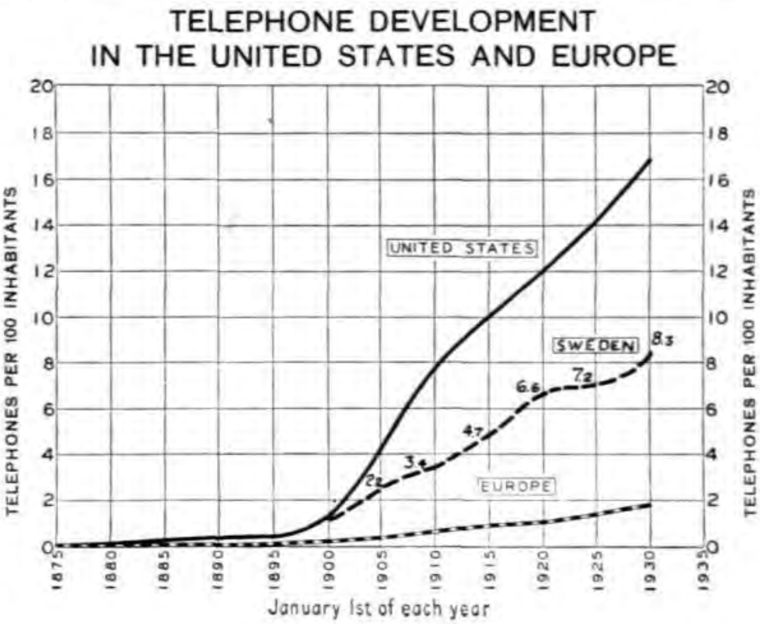


DIAGRAM I.

13 200 000, or 65 per cent. of the 20 060 000 telephones in U. S. A., are residential telephones, while in Europe, with the exception of the Northern countries and Switzerland, residential telephones are still very rare. In Sweden, where the low subscription rates can already be said to have made the telephone everybody's property, more than 57 per cent. of the total number were residential telephones on the 1/1 1928, and this proportion has undoubtedly been increased since, though no exact figures are at present available.

The first State Telephone Exchange in Stockholm was opened on September 1st 1881, and the Swedish State can this year celebrate her 50-year jubilee as a successful telephone entrepreneur.

The Bell invention was utilized in Sweden as early as 1877—the year efter the patent was granted—by the engineer H. T. Cedergren, who then installed telephone communication between two houses in Drottninggatan in Stockholm. The first Stockholm telephone net was, however, built by the Stockholms Belltelefon Aktiebolag—allied to the American Bell Company—which in September 1880 established a telephone net with 121 subscribers. But the subscription rates of this company were high, and when representations to have the rates reduced were refused by the Company, the above named Mr. Cedergren formed Stockholm Allmänna Telefonaktiebolag, constituted on April 13th 1883.

As we have already mentioned, the Board of Telegraphs opened a telephone exchange in Stockholm in 1881, at first only for Government Offices, to which 68 telephones were connected at the end of that year. These were also allowed intercommunication with the 584 subscribers of the Bell Company.

The competition for subscribers started by the competing telephone companies, and not interfered with by the Government, naturally gave a strong impetus to progress in Stockholm.

Charges were reduced, while at the same time technical improvements invented both at home and abroad were utilized at an early stage. The prominent place held by Swedish telephony today is due to these conditions, and to the interested labours of energetic and farseeing leaders.

In 1907 the Bell Company was merged in the "Allmänna Telefonbolaget" which—for the immediate reason that the Company had acquired certain foreign telephone operating rights—on 1/1 1908 was reorganized as A.-B. Stockholmstelefon, to operate the Stockholm telephones. This latter company was bought out by the Government as from the 1/7 1918, and the Government has since operated practically all the telephones in Sweden.

The number of inhabitants and telephones in Stockholm and in certain of the larger cities of Europe in 1885 and on January 1st 1930 are shown in the Table below.

	1885 [1]			1/1 1930 [2]		
	Population	Telephones		Population	Telephones	
		Number	Per 1000 inhabitants		Number	Per 1000 inhabitants
Stockholm	215 000	4832	22.5	414 672	126 916	306
Berlin	1 980 000	4248	3.3	4 330 000	515 175	119
London	4 765 000	4193	0.9	7 740 000	675 783	87
Paris	2 800 000	4054	1.4	2 955 000	370 308	125
Rome	300 000	2054	6.4	950 000	40 393	43
Oslo		1550		250 000	45 353	181
Copenhagen	274 000	1336	4.9	790 000	136 528	173
Amsterdam	336 000	1195	3.6	749 000	47 048	63
Leningrad	850 000	1100	1.3	1 840 000	63 104	34
Vienna	1 200 000	946	0.8	2 000 000	148 432	74
Bruxelles	380 000	803	2.1	938 000	86 635	92
Helsingfors	46 000	575	12.5	234 000	31 180	133
Madrid	477 000	270	0.6	814 000	35 320	43

[1]) The figures are quoted from "Bulletin international de l'éctricité".
[2]) The figures are quoted from "Statistics of the world: American Telephone and Telegraph Company".

The Table shows that the position of Stockholm, foremost already in 1885, is still unchallenged as regards number of telephones in relation to population.

As the rate of increase of both population and number of telephones in Stockholm during the

Year	Population of Stockholm (exclusive of suburbs)	Per cent. increase from previous year	Number of telephones	Per cent. increase from previous year	Number of telephones per 100 inhabitants
1900	300.523		30.349		
1901	301.697	+ 0.4	33.254	+ 9.6	11.0
1902	305.115	+ 1.1	35.824	+ 7.7	11.7
1903	309.647	+ 1.5	38.734	+ 8.1	12.5
1904	317.946	+ 2.7	42.298	+ 9.2	13.3
1905	324.488	+ 2.1	46.441	+ 9.8	14.3
1906	332.738	+ 2.5	50.692	+ 9.2	15.2
1907	337.460	+ 1.4	55.057	+ 8.6	16.3
1908	339.582	+ 0.6	58.434	+ 6.1	17.2
1909	341.816	+ 0.7	63.502	+ 8.7	18.6
1910	343.882	+ 0.6	68.413	+ 7.7	19.9
1911	346.599	+ 0.8	73.217	+ 7.0	21.1
1912	350.955	+ 1.3	79.959	+ 9.2	22.8
1913	354.783	+ 1.1	85.900	+ 7.4	24.2
1914	357.977	+ 0.9	90.831	+ 5.7	25.4
1915	363.891	+ 1.7	97.112	+ 6.9	26.7
1916	370.925	+ 1.9	107.460	+ 10.7	29.0
1917	373.286	+ 0.6	118.917	+ 10.7	31.9
1918	368.299	— 1.3	124.780	+ 4.9	33.9
1919	373.159	+ 1.3	126.904	+ 1.7	34.0
1920	375.935	+ 0.7	117.974	— 7.0	31.3
1921	376.510	+ 0.2	110.327	— 6.5	29.3
1922	376.284	— 0.1	103.833	— 5.9	27.6
1923	375.271	— 0.3	100.390	— 3.3	26.8
1924	380.503	+ 1.4	103.115	+ 2.7	27.1
1925	380.565	+ 0.02	107.445	+ 4.2	28.2
1926	388.730	+ 2.1	111.737	+ 4.0	28.7
1927	397.843	+ 2.3	115.176	+ 3.1	29.0
1928	404.375	+ 1.6	120.795	+ 4.9	29.9
1929	414.672	+ 2.5	176.916	+ 5.1	30.6
1930	427.688	+ 3.1	133.983	+ 5.6	31.3

last 30 years might be of interest, this is shown in the next Table.

Since the beginning of this century, the population of the City of Stockholm (exclusive of suburbs) has risen from 300 523 to 427 688, or by 42.3 per cent., while the number of telephones has increased from 30 349 to 133 983, or by 340.5 per cent. The war years 1916—1917 show the greatest increase, 10.7 per cent. each year, while the years 1920—1923 show a reduction in the number of telephone, to some extent by reason of the economic depression, but above all because of the amalgamation of A.-B. Stockholmstelefon and the State Telephones, and the consequently introduced free intercommunication between the two systems, which led to over twenty thousand double subscriptions being discontinued.

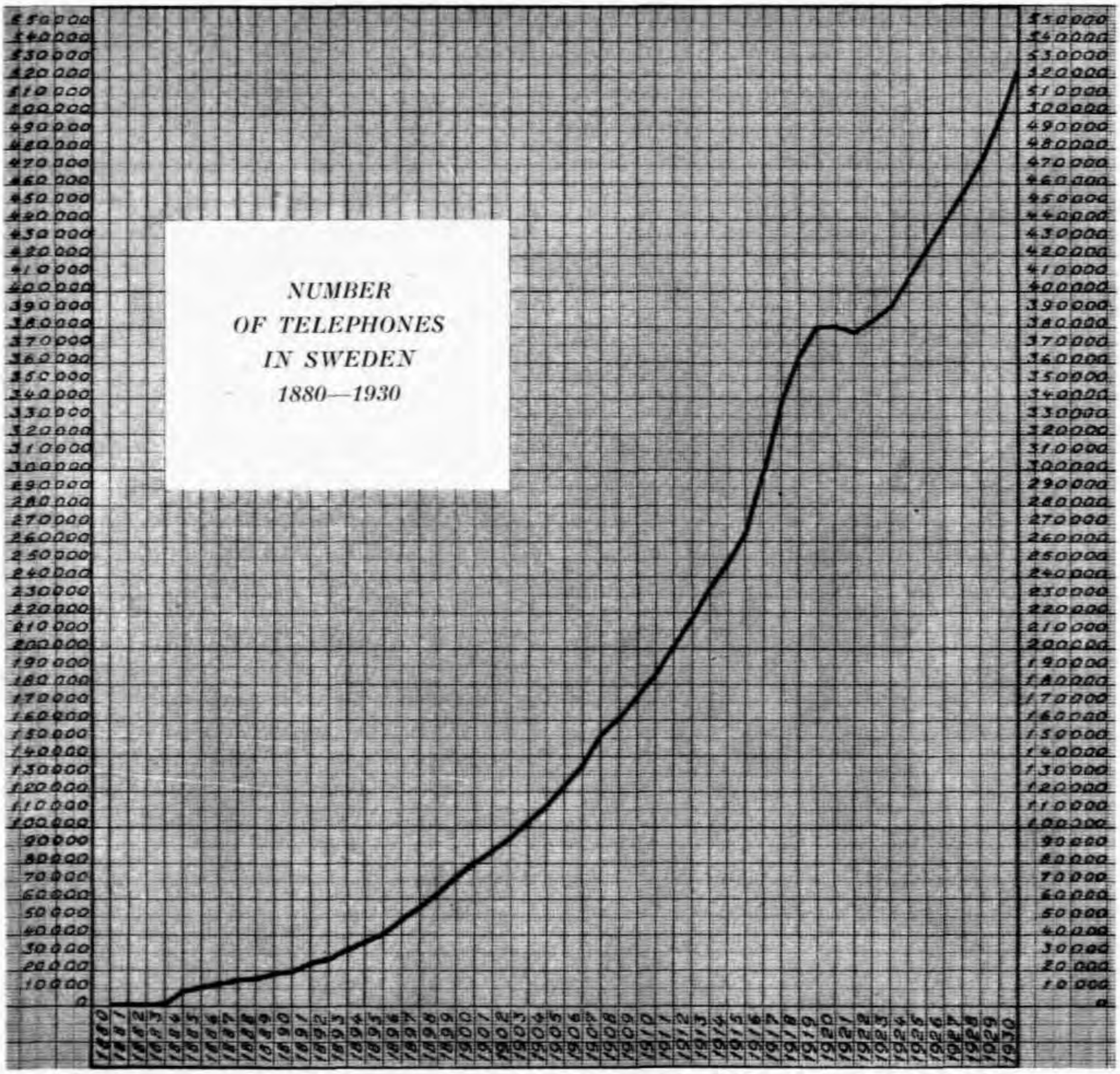
After the introduction of telephones in Stockholm, private telephone associations were formed all over the country, but these were practically all taken over by the State while Mr. Eric Storckenfelt was Director General of the Board of Telegraphs from 1890—1902. The sole credit for the early unification of the Swedish telephone net, which greatly promoted its development, is due to Storckenfelt.

Diagram II shows the increase in Sweden of telephones.

The most powerful advance occurred from 1911—1918, during which 8 years the number of telephones was doubled, with an average increase of 23 300 instruments a year. The war years 1916—1917 show the largest increase by 35 and 40 000 respectively. The years 1920—1921 indicate stagnation, 1921 even some retrogression, which, as we said, was mainly caused by intercommunication being opened in June 1920 between the two separate Stockholm telephone nets. From 1924 the increase is again strong, with the maximum absolute annual increment in 1930, 27 142 telephones or 5.5 per cent.

At the beginning of 1931, the total number of telephones in the Swedish telephone net was

R 1803 1905. A manual exchange with 9 000 subscribers.



R 3054

DIAGRAM II.

522,454, distributed between 4 008 main- and subsidiary exchanges (making 8.7 per 100 inhabitants).

The use of the telephone was in the beginning rather locally limited, which was natural as the instruments, and above all the lines, were unable to effect satisfactory transmission of speech over long distances.

Before the outbreak of war, international telephony was thus confined to adjacent countries, and the lines used were generally aerial.

As transmission improved, the range of the telephone was extended, but the present real long distance telephony is rendered feasible chiefly by the use of loading coils and repeaters, which latter were not perfected until during the war.

The rapid spread of long distance telephony, however, is made possible by the advance in cable design.

In U. S. A. traffic was opened in 1913 on a coil loaded underground cable, 454 miles long, between Boston and Washington. But, as we have just said, telephone repeaters were not perfected until during the war years, and it is only with the use of repeaters and loading coils that long distance cables, in conjunction with wireless, have opened the way for world-wide telephony.

The possibilities and enormous significance of long distance telephony were soon recognized. On the initiative of the French Government, delegates from the Telephone Administrations of the Western Powers met in Paris in 1923 to discuss the question of European long distance telephony. This meeting was followed in May 1924 by another meeting in Paris, to which all the European states were invited. At this meeting the Comité Consultatif International des Communications Téléphoniques à grande distance (C. C. I.) was formed, which Committee has since done excellent work in promoting international telephony in Europe.

	Number of connexions with other countries		
	$^1/_1$ 1925	$^1/_4$ 1931	
		Completed	In preparation
Belgium	5	24	—
Bulgaria	—	4	3
Denmark	3	23	3
Danzig	2	22	2
England	3	24	2
Esthonia	3	22	—
Finland	3	22	2
France	8	24	2
Greece		2	3
Ireland	—	23	3
Italy	7	24	—
Jugoslavia	4	14	4
Latvia	3	22	3
Lithuania	4	22	2
Luxemburg	3	22	—
The Netherlands	4	24	3
Norway	3	23	1
Poland	6	23	2
Portugal	—	17	6
Rumania	4	7	9
Russia	2	7	8
Switzerland	5	25	—
Spain	2	17	6
Sweden	4	24	2
Czechoslovakia	7	25	1
Turkey	—	2	1
Germany	16	25	4
Hungary	5	25	1
The Vatican	—	24	—
Austria	7	25	2
Albania	—	—	—
Total	113	586	75

To give an idea of the rapid progress of international communications, we quote here from "Europäischer Fernsprechdienst" of 1925 and 1931 the number of telephone lines connecting each of the European states to other countries of Europe on January 1st 1925 and April 1st 1931.

These lines, we note, numbered 113 on January 1st 1925, against 586 opened and 75 on the eve of being opened on April 1st 1931.

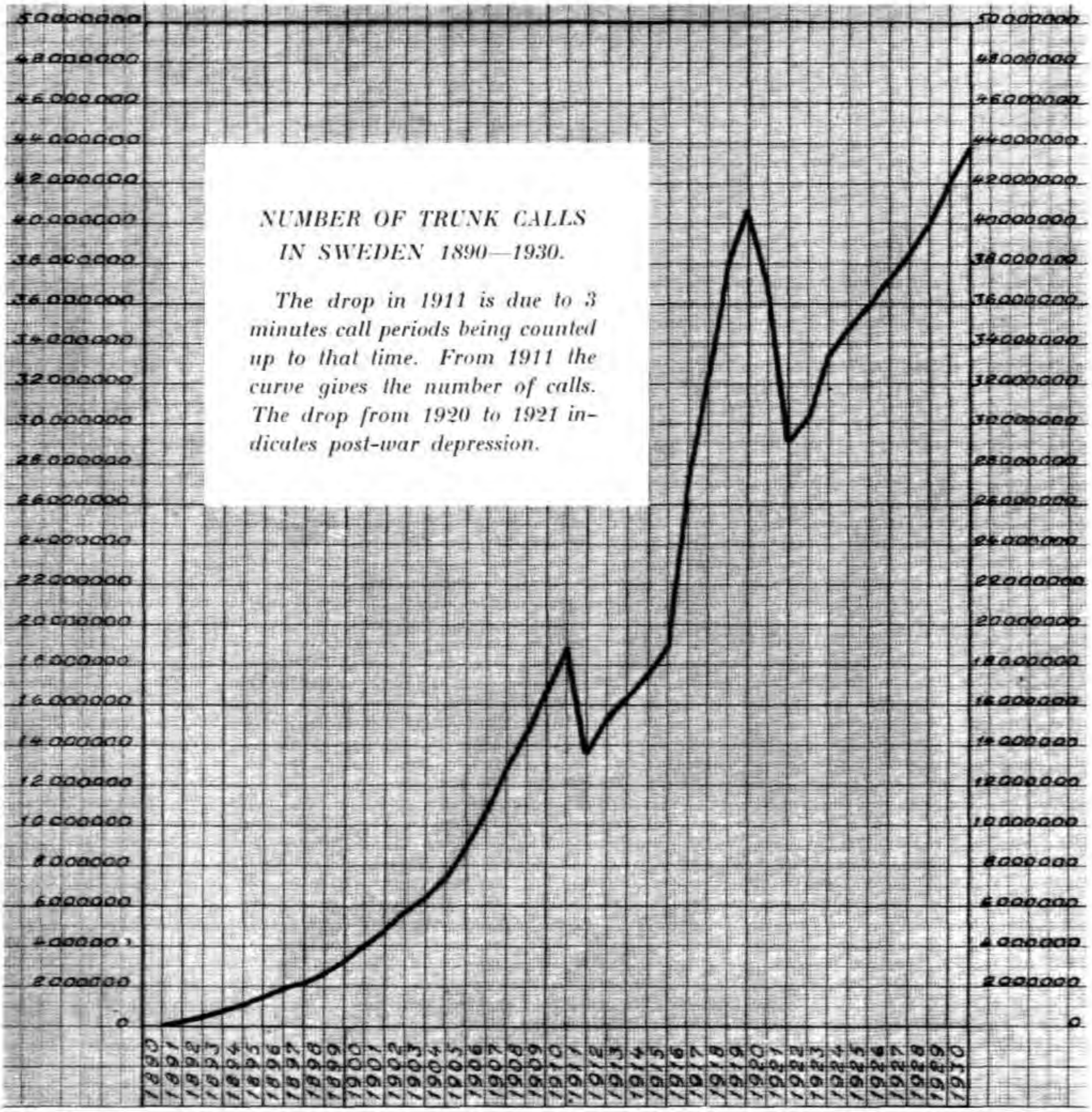
Of the 930 possible connexions between the 31 states of Europe, 586, or 63 per cent., are thus now opened; 75, or 8 per cent., are on the eve of being opened; while 265, or 29 per cent, have so far proved impossible to arrange. 156 of these last 265 connexions are in the South Eastern corner of Europe and in Russia.

With some reason, this may be considered extraordinarily good going in 6 years, particularly if we consider that uniform technical as well as traffic and operating regulations have had to be established to render a telephone net comprising the whole of Europe possible. This creditable and consolidating work of the C. C. I. has rendered international intercommunication possible, but it should not be overlooked that European telephony is greatly indebted to the centrally situated Germany for being farsighted enough to build the extensive and high class cable net which has made this rapid interconnexion of the European telephone nets possible.

Call facilities—all of them wireless—are at present provided between the European telephones and 18 extra-European countries. Of these, communication with America was opened in 1927, and the remainder have followed at short intervals. Without exaggeration it may be asserted that within the next few years all the telephones of the world will be connected.

The first fully modern large long distance cable of Europe—540 km. (325 miles) in length—was laid down in Sweden between Stockholm and Gothenburg in 1921—1923 by the "Western Electric Company", and was taken into use in September 1923.

The progress of interurban traffic in Sweden during 1890—1930 is shown in diagram III. The powerful decrease of the number of calls in



R 3063 DIAGRAM III.

1920—1921 indicates that interurban traffic is far more sensitive to economic crises than the number of telephones has proved to be.

When comparing the Swedish interurban traffic with that of foreign countries, allowance must be made for the large free traffic areas in Sweden, in which nothing beyond the annual subscription is charged for calls. There is consequetly quite a considerable amount of traffic, which abroad would be taxed and counted trunk calls, in these areas. At the present time, 200 000 calls per diem are for instance exchanged between Stockholm and the exchanges within the surrounding free traffic area.

In 1930, a total of 43 624 300 interurban calls were put through in Sweden, aggregating 61 903 700 taxed three minute periods, or an average of 1.4 periods per call.

The growth of foreign traffic during 1924—1930 appears from the Table below, giving the number of calls exchanged between Sweden and foreign countries, and the number transited through Sweden.

Year	Number of calls from and to Sweden	Per cent. increase	Number of transit calls	Per cent. increase
1924	530.573		45.000	
1925	565.878	6.7	49.296	9.5
1926	583.835	3.2	56.077	12.1
1927	614.587	5.3	60.118	7.2
1928	668.339	8.7	81.594	35.7
1929	*852.309	27.5	122.181	49.7
1930	879.163	3.2	130.785	7.0

*The cable Sweden—Finland was opened in 1929.

We note that in 1930 the traffic was affected by the economic depression prevalent in Europe.

When the parts of the world which are behindhand in telephony have had time to complete and modernize their telephone nets, and when the lanes of communication have been made "wide" enough to clear the traffic rapidly, a means of communication will be obtained which effectively eliminates the distances in time between the countries of the world.

The widespread international cable net has also provided new important opportunities for business and news services, as, by using multiplex carrier current, it is possible to send 12 telegraphic messages on a twin wire, while this is at the same time used for telephony. Appliances with ordinary typewriter keyboards, worked like ordinary typewriters, may be used for telegraphing, and render a staff of trained telegraphists superfluous. Full typewriting speed can be used. A business office equipped with this apparatus can thus, after previous negotiations on the telephone, immediately confirm a deal or agreement by wire to another office also equipped with this apparatus, i. e. direct communication without any middlemen. The time taken by the message can be charged for, exactly like the preceding telephone message. For rapid and reliable news service this will obviously be of tremendous importance.

To appreciate the eventual quantitative development of the telephone, all we need do is to compare the figures given at the beginning of this article regarding the density of telephones in U. S. A. with the correspondig figures for Europe and other parts of the world. These figures clearly indicate the magnitude of the work which remains to be done before the prospective world telephone net can be considered completed.

R 1795 1930. A modern automatic telephone exchange of the L. M. Ericsson system with 15 000 subscribers.

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SPECIAL NUMBER — ENGLISH EDITION — 1931

The Ericsson Concern's Electrotechnical Course of Instruction in Falun 13—15 March, 1931.

By *W. B.*

The instructional activities initiated in Sweden by Sievert's Cable Works in 1925 were originally intended to promote knowledge of rational installation systems for power plants alone. After the amalgamation of that enterprise with the Ericsson Concern in 1928, however, the activities were continued in the name of the latter according to an amplified program including all electrotechnical subjects covered by its several branches. From time to time detailed accounts have been published in the Ericsson News of these courses and the lectures given at each; in the majority of cases an abridged summary, but often the full paper, has been printed. Many of the lectures have also been revised and published in the L. M. Ericsson Review in the form of articles. Amongst the literature dealing with this instructional activity we can especially mention the special numbers of the Ericsson News published in connexion with the courses held in Stockholm and Malmö in 1930, and in Helsingfors in 1931. In these publications a historical survey of the origin of the work, its purpose and successive growth, will also be found, with indexes of the lectures delivered since the courses have been held by the Ericsson Concern, i. e. since 1929. Our readers have therefore been well informed on the instructional work of the Concern. It is, moreover, well known through our publications that the Concern's activities, especially during the last few years, have grown rapidly, and have gradually been extended to include more and more branches of electrotechnics until they now embrace practically all of them. — Below, a few words are devoted to the Falun course on the 13—15 March, 1931, with special reference to the importance of this course in the history of our work.

This was the fifth year of electrotechnical instructional activity in Sweden, and the course was held in the same town in which it had its origin almost exactly five years ago, viz. on the 13th November 1925.

The first instructional course was opened by the Governor of the County, S. H. Kvarnzelius. Among the lecturers was Chief Engineer T. Holmgren, one of the initiators and organizers of the enterprise. Five years ago Mr. Holmgren, who took part in the present course also, spoke on the subject: "*Notes on power-distribution and its present tendencies of progress.*" Other lecturers on that occasion included Government Inspector R. Holmer, who spoke on "*Dangers and precautions in electrical constructions*", Mr. C. O. Rahm, with a paper on "*Electrical energy for cooking and other heating purposes*", Mr. E. Sjölander, C. E., who spoke about "*The importance of good illumination and how to arrange it*", and Mr. K. Ödman, who lectured on "*Domestic and industrial electrical heating appliances*". Amongst the engineers of Sievert's Cable Works we note Mr. E. Olson, who during the past five years has unceasingly contributed to the program of the course. In 1925 he lectured in Falun on the subjects: "*Paper-insulated Power Cables*", and "*Lead-sheathed rubber cables from a safety point of view*".

Those of the audience attending the first Falun course who now, after the lapse of five years, honoured the meeting with their presence almost to a man, were able to convince themselves of the progress made and the extent to which the work has grown in comparison with the first modest effort. They could also observe the progress in the branches of electrotechnics included in the activities of the Ericsson Concern. For this year's course in Falun the Concern had succeeded in obtaining the cooperation of the following persons, non-members of the concern, each a well-known authority in his branch:

Mr. *Torsten Holmgren*, Chief Engineer of the Electric Testing Institute, Stockholm, who dealt with the subject: "Practical experiences from the Fire Insurance Offices' Electrical Committee".

K. G. Sjöberg, director of the Power Department, Stora Kopparbergs Bergslags A.-B., Falun, who spoke on "Thunder, excess voltages, and the effect of electricity on the human body".

Captain R. Götherström, Fire Prevention Committe of the Federation of Swedish Industries, who gave a lecture on "Electricity and the risk of fire."

Mr. *Ove Mogensen*, proprietor of Dalarna's Electrical Consulting Bureau, discussed "Efforts at Rationalization in Minor Power Concerns in Dalarna".

The staff of the Concern contributed nine lectures on the following subjects: "Telephones and Signals in offices and factories", "Automatic Fire Alarms", "Lead-sheathed cable installations", "High tension condensers for improving the power factor in A. C. lines", "Electricity meters", "Modern high tension cables", "Modern industrial and agricultural installations", "Bakelite and its uses", "D. C. and A. C. lines" and "Wireless mains-connected receiving Sets".

The importance which should thus be attached to this years' course in Falun has caused us to *devote to it this special number*, in which are published in full some of the lectures held — first and foremost three given by non-members of the Consern: Chief Engineer T. Holmgren, Director K. G. Sjöberg and Mr. O. Mogensen. Captain R. Götherström's lecture on "Electricity and the risk of fire" has already been published, and may be obtained in pamphlet form from the Fire Prevention Committee, Stockholm, from Sievert's Cable Works, Sundbyberg, or from the Editor. With the assent of the lecturer this has therefore here been replaced by a quinquennial review of the subject.

Of the lectures given by the staff of the Concern, only the following are reprinted:

"Modern High Tension Cables", by B. Ell, Chief Engineer.

"Swedish Electricity Meters", by O. Jöhnk.

"Modern Industrial and Agricultural Installations", by Mr. E. Jensen, C. E.

The lectures by Messrs. B. Ell and E. Jensen have not previously been dealt with as fully as in this number. Mr. Jöhnk's lecture has been printed in the L. M. Ericsson Review as well as in pamphlet form, but the author has here thoroughly revised and supplemented it. The remaining lectures at Falun this year have been previously published: some as pamphlets, and some in the L. M. Ericsson Review or in the Ericsson News.

Finally, we have the painful duty of informing our readers of the sad loss suffered by the death of Director K. G. Sjöberg, shortly after the conclusion of the Falun course. The obituary reprinted here from the April issue of the ERA journal, tells of the importance of the deceased to Swedish electrical industry, and expresses the esteem and regard in which his memory is held by all who knew him.

R 8019 The City Square, Falun.

K. G. Sjöberg

In Memoriam.

R 1992

Director K. G. Sjöberg died on Good Friday morning in his home in Falun.

He was born in Neder-Luleå on the 8th October, 1876, and passed the final examination at the Technical High School in 1898. During the years 1898—99 and 1900—01 he worked for Asea; at one time he was employed by Mr. Ernst Danielsson, C. E. In 1902 he came to Messrs. Bergman & Co., Consulting Engineers, Stockholm, where he remained until 1907. He afterwards joined the United Electrical A.-B. in Ludvika, where be bacame Chief Engineer a year later. He returned to Asea in 1916 as Chief Engineer. From 1918 he practised as a consultant until 1926, when, on January 1st, he became head of the power department of Stora Kopparbergs Bergslags A.-B. in Falun — an appointment which he held until his death.

Director Sjöberg's speciality was electroengineering and related subjects, but as a consulting engineer he also had to deal with installations and purely technical work. This many-sided training made him particularly suitable for his last appointment as manager of the Bergslag's power stations. During the short time he held this post he achieved much. Under his leadership a multiplicity of reconstructions and new buildings were carried out and proposed; many of them unique and interesting.

As a technical expert, Mr. Sjöberg enjoyed an unusually good reputation and was known for his fertile mind. He was a keen Freemason, as well as a popular member of numerous clubs and associations, both technical and cultural. His geniality was much appreciated in these bodies as well as in the private circle of his friends and family. Many will remember and miss his skill on the piano. As a singer to the lute the deceased was also much valued, and was often heard, especially up to a few years ago. He was an unassuming and charitable man and a pleasant companion, and moreover a sparkling wit and a brilliant raconteur, which made him an exceedingly popular and always welcome guest.

Many will mourn his sudden passing, and his memory will be cherished with gratitude as that of a good fellow-worker and man.

M. H.

Notes on Thunder, Excess Voltages, and the Effect of Electricity on the Human Body.

By *K. G. Sjöberg.*

Thunder is one of those natural phenomena which only with difficulty permit direct experiments by man, and it is only in very recent years that ingenious appliances have been designed, by which at least some of the phenomena associated with thunderstorms can be photographed. That thunder is an electric discharge was proved already by Franklin. Certain photographs of lightning, however, long made it seem likely that thunder is an oscillatory discharge, i. e. comparable to an alternating current of very high frequency. Recent researches have established that such is not the case, but that thunder generally is a uni-directional though variable discharge of short duration, sometimes between adjacent clouds, sometimes from clouds to earth.

A thunderstorm is at present believed to arise from certain abnormal vertical air currents causing an electrical field which may attain fairly considerable strength. I will quote from a paper by Mr. Norinder (January 15th, 1921).

> "To explain the genesis of a hot-weather thunderstorm, we will assume the following conditions:
>
> A sultry summer day, with level and uniform atmospheric pressure, consequently excluding any strong vertical or horizontal air currents. The sun raises the temperature in the air nearest to the ground so much that labile conditions of equilibrium arise in this. Local differences in heating, topographic details of the ground, detached clouds etc., may at certain points lead to the superheated air violently breaking through the colder strata of air above. This causes a violent up-current of warm air. The rapidly rising air masses expand strongly, and are consequently cooled.
>
> Under certain circumstances, the vaporized water carried by the air will rapidly condense, and the drops formed may quickly increase in size. If the vertical current is sufficiently fast, the drops will not fall down, but are shattered and carried to great altitudes. The size of the drops must then keep within certain bounds determined by the velocity of the current and the density of the air in the locality.
>
> The vertical current may sometimes reach such altitude that the water is chilled and frozen to ice, falling to the ground as hail. No very great altitude is required for this. According to a table in the same article (see Technical Notes from The Royal Board of Waterfalls, 1921, series E, No. 1), the temperature drops very rapidly in the higher strata of the air. In the month of July for instance, when the temperature at the ground was about +18° C, 0° has been observed at an altitude of 3 km., —26° at 7 km., and —51° 11 km. up.

Many of us have felt the strange lassitude induced by this electrostatic field in men and some animals. We have often experienced a sudden sleepiness. It is particularly interesting to note this in little children, who may suddenly fall asleep while playing. (Tensions of over 100 000 volts per met. of altitude, and even values between 3—400 000 volts have been observed.) These electrostatic fields gradually cause an incandescent discharge or ionization of the air, involving a charging of the atoms, and arrange these in a sort of ranks or chains which eventually form one, or usually more, paths or bridges for the final electric discharge. The attached view (fig. 1) of a thunderstorm at Copenhagen (1918) shows the typical broom-like formations thus produced by the actual discharge.

Hardly anybody nowadays doubts that lightning as a rule follows the "law of least resistance", but as the incidence of thunder and strokes of lightning may often seem rather surprising and erratic, some commentaries may be of interest.

Many experiments have been made to determine the conditions which in such cases might be decisive for the path of the lightning, but much apparently remains to be investigated. One

It has further been noticed that lightning will generally strike those parts of a building where the field is most concentrated. This is also indicated by statistical investigations exemplified in Table 1, which gives the distribution of the lightning in 9 500 buildings struck. The buildings included in this comprehensive list all lacked lightning conductors.

R 3011

Fig. 1.

might think that high mountain tops, church towers, high chimneys, very high trees etc., would be particularly exposed to lightning. As late as in 1930, suggestions published by a special committee of the Association of Swedish Electrical Engineers, entitled "Rules and Advice regarding the Application and Design of Devices for Protection against Lightning", states that high spires, chimneys etc., being especially exposed to lightning, should primarily be protected by lightning conductors.

Experience has shown that lightning prefers to follow objects connected to earth which project considerably above the ground such as mountains, ridges, trees, buildings, poles etc. This is explained by the increase of the field strength occurring in the immediate vicinity of an object projecting from the surface of the ground, in comparison with the field strength above for instance level ground.

Table 1. The percentage of strokes of lightning hitting various parts of 9500 buildings, not fitted with lightning conductors (Bavarian Statistics).

Point of towers or gables	55	per cent.
Chimneys	25	„ „
Roof ridges	14	„ „
Surface of roofs	6	„ „

These statistics show that the height above ground level does not decide the path taken by lightning.

In southern France, however, the Director of the Observatory at Pie Du Midi in the French Pyrenées, Mr. Dauzere, has made fairly comprehensive statistical investigations regarding the incidence of thunder. In a brief summary of these, the statement is found that this presumed tendency of lightning to strike steeples, chimneys, etc. is *not* generally applicable, but that the path of the lightning will depend more on the properties of the ground and the soil. Fig. 2, a photograph of a thunderstorm above the Eiffel Tower, shows that a simultaneous discharge has struck a small building close to the foot of the tower.

In 1925 the author had an opportunity of observing the obvious contempt of lightning for the points of lightning conductors fixed to high chimneys. As this instance is rather instructive, a short account of it will be given.

Fig. 2.

During the Whitsun holidays — on Whit-Monday, May 3rd, 1925 — work was proceeding on a power-distribution station in the rolling mill of A.-B. Svenska Metallverken, Västerås. The current was switched off. Close to this building 4 chimneys (one is now pulled down) were placed approximately as shown in fig. 3, each of them about 3 times higher above the ground than the ridge of the roof. All the earth plates of the lightning conductors, examined the following day, had resistances of 3—5 ohms, i. e. values commonly regarded very low and generally satisfactory. During this thunderstorm, however, the ridge pole was struck by lightning some distance from one of the gables. The lightning then followed the corrugated sheets of the roof, went down along the inner side of the gable wall, subsequently finding its way to the 4 very heavy underground cables (3×240 mm^2) of a large power distribution station there. The cable boxes were connected by copper wires in the usual manner to the mantles of the underground cables. These wires fused, and the cable end from the box down to the ground was burnt and destroyed. I have included an illustration to show the approximate distances, and that the rolling mill was not protected in spite of the four lightning conductors. This instance also appears to confirm that the height above the ground is not decisive, but the path which offers the least resistance to "earth".

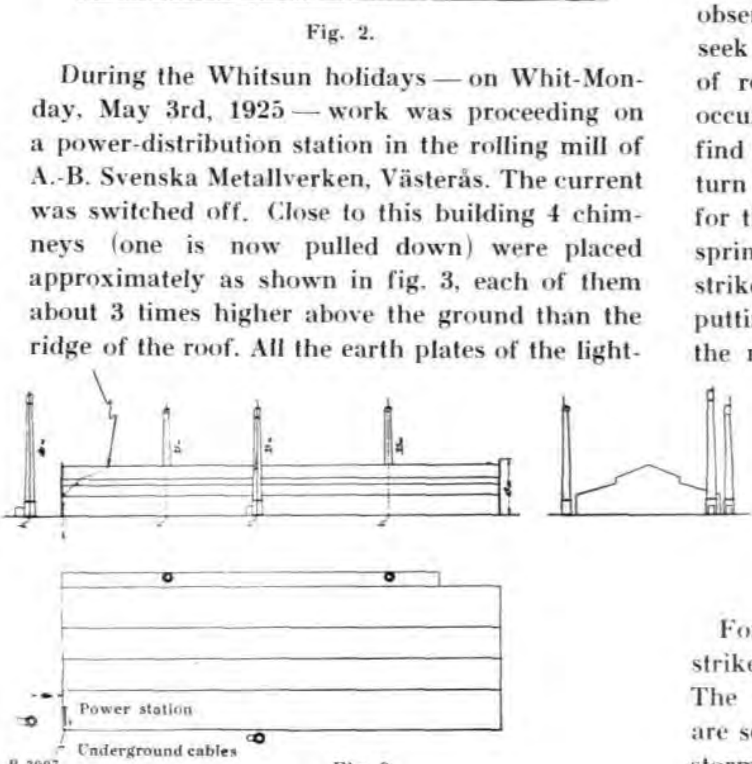


Fig. 3.

The Frenchman Dauzere has charted the occurrence of strokes of lightning. He has also come to the conclusion that certain kinds of soil or rock seem to have a tendency to "attract" lightning, so to speak, and shows that, above all else, underground springs play a very decisive part. This may have some connexion with another observation of his, viz., that lightning seems to seek the border line between two different kinds of rock. In such border regions, cracks often occur in the crust of the earth, and the springs find their natural way through these, and in their turn provide a good conducting path in the earth for the lightning. It is also a fact that wherever springs occur, they seem to invite the lightning to strike. Anyone who has had anything to do with putting down earth-plates knows that not only the moisture, but still more the quality of the soil, is decisive in this respect. In sandy ground, for instance, it may be very difficult to get good earthing, even if one goes down to the subsoil water, while in ordinary soil or mould an excellent earth connexion is easily obtained.

Fortunately, lightning comparatively seldom strikes either buildings or electrical lines directly. The ordinarily occurring lightning phenomena are secondary phenomena induced by a thunderstorm in the vicinity. The field strengths occurring on these occasions are also of considerably smaller magnitude. As an instance of their variation, I will refer to Mr. Norinder's investigations in Uppsala in the summer of 1919, when he, during several thunderstorms, observed field strengths of various magnitudes in his laboratory. On September 7th, for instance, he observed field strengths of 100—140 kV per met. of altitude, while on July 28th and August 7th they did not rise to more than 30 kV, on August 14th to c. 40 kV, and on August 23rd to c. 70 kV, all values per met. of altitude.

These electrostatic fields, which appear all round the actual centre of the thunderstorm, become weaker the further they are from this centre. But these fields induce an electric charge in conductors which — as we know — consist of a metal wire (usually copper) suspended about 5—6 m. above the ground and insulated from this. As long as equilibrium obtains, nothing happens, but the moment there is a discharge of lightning anywhere, the electrostatic field changes, and the electric charge in the metal wire is liberated and flows along the conductor as a momentary current impulse or, as it is usually called, an "impulse wave". It will depend partly on the amplitude of the wave, partly on the appearances of the so-called wave front, how dangerous this wave will be for the insulators of the conductor. The steeper the wave front, the higher the corresponding voltage, and the more readily will flash-overs occur at the weak points passed by the wave front. In certain cases, e. g. in a telephone line, the insulation is weak. The telephone wire may have comparatively small insulators, perhaps even several of these may be defective, without telephony being prevented. In such conductors, the quantity of electricity leaking over the insulators from the wire to the pole may be fairly considerable, and its discharge may consequently be complete, and the impulse wave thus rendered harmless. In a high tension conductor, on the other hand, which as a rule is considerably better insulated to earth, and has more effective porcelain insulators, the leakage will be considerably less, and the "impulse wave" and the consequent dangerous voltage may reach considerably further, and cause flash-overs where the line enters buildings, in wall boxes, in safety appliances, and in other places where the insulation to earth is weaker.

I will illustrate this by an instance from my own experience. During a thunderstorm at night at Ludvika in 1908, I was watching a table telephone set in my house (I had recently heard of a fire caused by a thunderstorm at night, when the discharge had passed through the telephone apparatus on the writing desk, and so caused a fire). Intensive light phenomena, accompanied by a crackling sound, occurred in all the light installation connecting-boxes in the house during the innumerable lightning discharges, but no similar phenomenon could be observed either where the telephone wires passed through the walls, or elsewhere on them. The explanation is probably that the violent rain falling at the same time would cause so great leakage on the telephone insulators that no voltage wave reached the building along the telephone line, while the light supply insulators had nothing like the same leakage, and the excess voltage therefore reached the house and was discharged in the wall connecting-boxes.

In connexion with the above, I wish to point out the great advantage of using wooden poles for electric lines. In cases of excess atmospheric tensions of this kind, a fairly appreciable quantity of electricity may, on account of the great resistance of the pole itself, "overflow" along the insulator and the pole to earth without causing an electric light-arc, which may burst the insulator and set fire to the pole. The wooden pole is a series resistance between the insulator and earth, limiting the discharge, and absorbing a large portion of the discharge voltage. The use of iron poles, often necessary for certain high tension lines, makes conditions more unfavourable. When a leakage occurs over an insulator fixed directly on the earthed iron pole, a powerfull luminous arc will more easily form, which will burn through the insulator and cause a short circuit in the line, with consequent release and interruption of current supply.

A phenomenon which I wish to call to mind in this connexion, is that if a so-called impulse wave, with its attendant excess voltage, in following an electric conductor reaches a transformer- or power-station, and there meets with an induction, e. g. a transformer winding, a current transformer, or a generator pole, this self-induction will act as such a powerful brake on the flow of electricity that this will be checked. The consequence will be that the voltage may be violently raised by this aggregation of electricity, frequently reaching double the value of what it had immediately before encountering the induction in question. To connect the air line direct to high voltage generator windings is thus fairly risky, a fact which is amply confirmed by experience. By introducing for instance a transformer, the windings of which are immersed in oil, the presence of the oil considerably increases the disruptive strength of the insulation, and considerable excess voltages may be endured at the transformer taps without risk, compared with what an air-insulated generator coil will stand. As an illustration of this I will mention that the Stora Kopparbergs Bergslags Aktiebolag power station at Forshuvudforsen is provided with 3 generators, the windings of which are designed for 10 000 volt, and directly connected to collecting bars and lines. Some years ago several flash-overs also occurred, causing considerable damage with interruption of work and costly repairs etc. To prevent a repetition of this, Bergslaget then installed transformers between the 10 000 volt system and the supply lines to the surrounding district. A transformer was already insulating a 20 kV line to Säter from the 10 kV system, but the other outgoing distribution lines in the Domnarfvet district were provided with a 3-phase transformer of a 1:1 ratio, from 10 000 volt to 10 000 volt. This so-called protective transformer thus serves no other object than to separate electrically the outgoing district distribution lines from the industrial system proper and its extensive line net in the Domnarfvet iron works, i. e. to absorb and endure any excess voltages caused by atmospheric discharges. A similar protective transformer has also been installed in the Forshuvudforsen power station, from which fairly extensive lines originate. When the Builerforsen power station was modernized some time ago, in connexion with the change from 60- to 50-cycle current, transformers had to be procured to compensate the consequent change of voltage. One of the generators had earlier been run by introducing a so-called auto-transformer when the generator was switched over to the 50-cycle system. Such a transformer is considerably cheaper, as it has only one common winding, with several taps for the various voltages required. When this proposal was discussed, the author strongly objected to this cheaper solution, for one reason because of the risk of getting excess voltages on the generator windings. Ordinary transformers were instead procured, with wholly separate windings, and all excess voltages coming from the outside are thus stopped at the transformer, which forms a protective wall for the generator. The increased working reliability is obvious.

We may ask: Is there no protection against lightning and consequent excess voltages? Well, if a certain building has to be protected from being struck by lightning direct, the house must be surrounded by a net work, or "cage", of well earthed conductors of ample size. Information on this subject can be obtained in a booklet containing what is as yet only a proposal, but which will probably soon be approved and available from the Swedish Association of Electrical Engineers i. e. from Svenska Teknologföreningen. If we remember that in a *direct* stroke of lightning the current — though momentarily — may rise to several 10 000 amp., we will understand that very ample earthing must be provided.

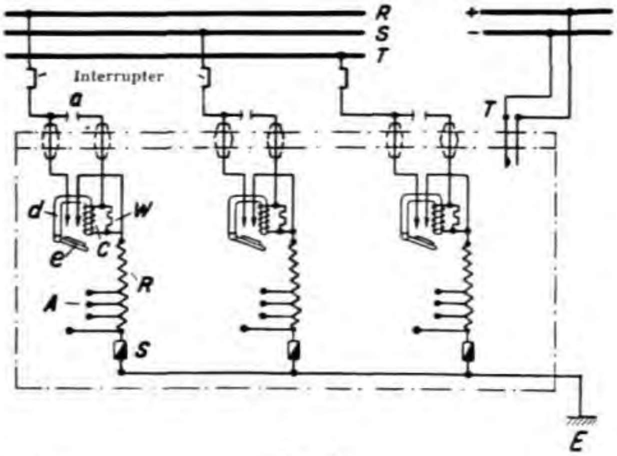
Unfortunately, it must be acknowledged that so far no successful protection against a *direct* stroke of lightning in an electric conductor has been designed, capable of diverting currents of this magnitude to earth while work is in progress. The dictum of the foremost of American electricians, the late Professor Steinmetz, is still valid for such cases, viz. "Most devices now in use will furnish protection against ordinary small over-voltages, but if an actual *direct* stroke of lightning should hit the power lines, the only thing to be done is to sit down calmly and wait until the thunderstorm has passed, and then to repair what might be left."

At an early stage, attempts were made to divert these over-voltages by fitting so-called horn gaps, which provide a weak point and offer the lightning a permissible path to earth without damaging other parts. A description of the multitude of devices resorted to to limit the amount of the discharge would take us too far, but the same principle is still applied in various forms.

A few illustrations might, however, be of interest. The apparatus shown in fig. 4 is mounted in the Bergslaget power station at Forshuvudforsen, on the 10 000-volt line to the Domnarfvet distributing station, a line about 5 km. long. As the introduction of protective transformers between the generators at Forshuvud and the line would have been far too expensive, Bergslaget has fitted an excess voltage protection apparatus there, consisting of an ordinary horn gap which, for the purpose of getting a more constant flash-over voltage, is provided with so-called sphere-gaps, one for each phase. The apparatus looks like an ordinary oil switch, but has in the oil tank an automatic contact for each phase, which is automatically closed by the current impulse when a flash-over occurs in the horn gap, thus short circuiting the gap (fig. 5). The arc of light in this is then immediately quenched, the automatic contact drops, and the device is again ready to function. This provides a repeated number of discharges which are able to limit a gradually rising tension, even though large quantities of electricity cannot be dealt with.

Sometimes, though fortunately not very often, a person will be hit by a discharge of this kind, caused by a thunderstorm. It is still more rare to hear of somebody being killed by a direct stroke of lightning, as particularly unfavourable conditions are necessary for this to happen. In this connexion it may be of interest to call to mind the effect of the electrical current on the human body. The current which on such an occasion passes through the body will depend — apart from the voltage — on the resistance the current has to overcome, partly in the body itself, partly, and principally, in the points of contact where the current enters or leaves the body. The path of the current through the body is also of decisive importance.

The strength of the current the body is able to stand is of course rather variable, and differs for different persons. As a general rule, no more



R 3010 Fig. 4.

R 3009 Fig. 5.

than 0.1 amp. can be endured without serious damage, and this may be fairly easily reached with good contact surfaces, e. g. by touching with wet hands a live metal part, or by standing in wet boots on a well earthed floor, or by grasping a water pipe with the other hand. Under such unfavourable circumstances, an A. C. voltage of 110 volt may prove fatal, particularly if it passes through the heart.

There are two rules for electrical fitters and other persons who may handle electrical devices and do installation work, viz:

1) always keep your left hand in your trouser pocket, and

2) if possible, always put on whole goloshes or rubber boots when doing work of this kind.

The first of these rules aims at preventing the current going from one hand to the other via the heart, and the second to prevent the current passing from the hand through the heart to the feet, as the action of the heart is primarily affected by electric currents. I also wish to point out that ordinary A. C. is considered more dangerous than D. C. of the same maximum voltage. The reason for this is that alternating current will cause continuous cramp in the muscles, consequently also in the muscle which is called the heart. If an alternating current passes through the heart, this will be subject to cramp, and will have difficulty in recovering its normal action even when the current is broken. A direct current, on the other hand, although also causing a momentary spasmodic contraction when closed, will not give rise to the convulsive muscle action sometimes produced by alternating current. Experiments have proved that human muscles, when affected by cramp originated by other causes, e. g. by overstrain, have a natural periodicity of c. 30—40 cycles per sec. It is therefore easy to understand that an alternating current of 25 or 50 cycles may easily cause naturally persistent cramp, and is therefore exceedingly dangerous to the action of the heart. At very high periodicities the risk is also less. As a curiosity I will mention that Professor Jellineck of Vienna, who has devoted a lifetime of study to these matters, has proved by experiment that an animal rendered unconscious by an alternating current may be restored by a direct current of short duration. The explanation given is that the direct current stops the natural convulsive cramp of the heart muscle, which is held still and spasmodically contracted by the direct current. This phenomenon is of course of no practical importance, as suitable direct current unfortunately is never available for restoring people who have been stunned by alternating current. As a result of his exhaustive investigations, Professor Jellineck strongly emphasizes that an electric current through the body very seldom is directly fatal, but may indirectly cause death by the action of the heart not being resumed sufficiently rapidly. In case of an accident of this kind, it is therefore necessary to begin restoring efforts *as quickly as possible*, as every second is of importance. Such attempts should primarily include respiratory movements, which also contribute to set the blood circulating, thus on the one hand facilitating the recovery of the heart action, and on the other supplying new blood to the brain, and gradually restoring consciousness. As everybody should know how to give artificial respiration, it is my intention to finish by a small demonstration of this.

Of the 3 different methods usually practised, the so-called Schaefer method, ("face-down method") is probably the most convenient, especially if no assistance is available, but I find it hard to believe this method to be quite effective, although it is accepted as standard and recommended by the Swedish Association of Electrical Engineers, the Swedish Electrical Association, and the Swedish Association of Electrical Industries (see fig. 6). Although the lungs are effectively emptied, no appreciable amount of fresh air will be pumped in, as in a state of unconsciousness all the muscles are relaxed, and the unconscious person is placed face down in this method. By pressing the back at about the usual rate of breathing, the chest is supposed to expand when the pressure ceases, but this is sometimes doubtful.

The so-called rolling method (Hall's method), used in cases of drowning, is better but rather troublesome, and most doctors therefore recommend the immediate use of the so-called Sylvester method. Most of us are aware of this procedure, which consists in the unconscious person being placed on his back, preferably with his coat off (see fig. 7). Underneath his back, somewhere below the shoulderblades, some suitable object serving as a pillow, e. g. a wrapped-up coat, is placed so that the chest is arched upwards. If it also is possible to put something underneath his head which, particularly if no help is available, should be laid to one side, this is still better. Kneeling above the head of the unconscious person, and grasping his arms or wrists, these are alternately carried upwards, stretching the arms out, and alternately downwards towards the chest, which is thereby somewhat compressed. To prevent the tongue falling back in the throat and covering the epiglottis, the head, as we said, should be turned to one side. If there are two helpers, these may take turns at such breathing movements, which are rather exhausting, and the one who is resting can assist by trying to keep the mouth of the unconscious person open and his tongue forward. A piece of fabric, for instance a handkerchief, must be used for grasping the tongue, which is otherwise difficult to hold.

Usually signs of returning life will show fairly soon, generally during the first half hour, but if this does not happen artificial respiration movements should if possible be continued for three hours or even more, as there are cases on record where the doctor has abandoned hope after three hours, but a private person has continued after he had left, and finally succeeded in restoring

R 3005 Fig. 6 a.

R 3004 Fig. 7 a.

life to the unconscious person. The chief thing is to know what to do *at once* and, remembering that every second counts, start artificial respiration without any delay.

Before commencing the demonstration, I should like to relate a couple of instances showing the importance of wearing whole goloshes or rubber boots. When testing a power station at Vansbro of c. 5000 volt on the generators and collecting bars, I had to disconnect a short circuit in a current transformer just before the actual measurements began. In some respects, however, the design of this current transformer was unsuitable, the short circuit terminal being placed on top, near the high tension lines. As it also stuck rather hard, I had to use more and more force to turn it, and entirely forgot the dangerous proximity of the 500-volt lines. As usual, I worked with my right hand, keeping my left in my trouser pocket, and fortunately I had whole goloshes on. My right wrist touched the high tension line, which had about 3000 volt to earth. The shock made me jump, and my right hand was laid still more directly on the high voltage line, and simultaneously my thumb and forefinger drew an arc of light from the earthed terminal I had just been holding to the high tension lines. A strong flash appeared, accompanied by a loud noise, which made the staff present run out of the station. Both my thumb and forefinger were rather badly pitted where the arc had touched, but otherwise I was perfectly unhurt. Such burns, however, are comparatively harmless, as the wounds are sterilized by the arc of light and also encapsuled by the cauterization. If I had not on this occasion had on whole goloshes, a considerable part of the current might have gone through my right arm, past my heart into my feet, and the result might then have been quite different.

In the second instance, two fitters were engaged in setting up a pole, to which a 10 000 volt line passing close by was to be moved. To lift the pole, a special contrivance was used, consisting of a spar which had a pulley with wire over the top for lifting the new pole to a vertical position and placing it in its hole. The older of the fitters, who was in charge of the work, wore whole

R 3006 Fig. 6 b.

R 3003 Fig. 7 b.

rubber boots, while his assistant, about 20 years old, wore ordinary shoes. Both were busy putting up the pole-raising device, the older man grasping the spar and the steel wire further up, nearer the pulley, than the younger man, who had hold of both pole and wire with his hands a little lower down. Inadvertently, the top pulley happened to touch the live 10 kV wire, when the older of the fitters felt a slight shock in his arms, but otherwise no inconvenience, while the young assistant dropped dead, and could not be restored to life in spite of strenuous efforts.

A direct stroke of lightning, causing the death of two people, occurred about noon of July 29th last summer on an estate between Copenhagen and Køge in Denmark. The case is described in the Danish journal "Electroteknikeren" No. 23, December 7th, 1930. Four buildings, the farmhouse and 3 outhouses, were grouped fairly close together (see fig. 8). The lightning was found to have struck one of the living house chimneys, as well as the east gable of the more northerly byre (probably not the roof). The discharge, which had obviously not been very heavy, had in the first named place succeeded in finding a path to earth without much damage to the building, and without hurting the owner and his wife who were inside it. In the byre, on the other hand, the discharge had apparently been much stronger, and had caused quite a lot of damage. Next to the gable hit by the lightning was a pen holding two pigs and another holding two calves. While the two pigs were struck by lightning, one in the back and the other in the head, and instantly killed, the calves were quite untouched. The earthen floor of the pigsty was probably dirtier and more sodden, and therefore a better conductor. A considerable part of the discharge had therefore taken this road, which offered comparatively low resistance. As work had recently been commenced for the installation of electric light in the building, a byre-cable, indicated in the illustration, had been put in which ended at "N" by a free end hanging vertically down to about 0.5 m. of the ground. The other end of this cable was touching the gable struck by the lightning, and a switch was connected in the corner of the byre next to the door. In this doorway three telephone fitters were sheltering from the storm. Two of these, *A* and *B*, were standing close together by the door, *B* leaning against the corner where the switch connected to the cable was put up. The third man was standing further along in the passage, in the place marked *C*. All three were knocked down by the lightning. *C* immediately recovered his presence of mind, and then observed that the barn had caught fire close to the gable where the lightning had struck. The two others, *A* and *B*, remained unconscious and artificial respiration was applied. As this had no result, a trap was procured and they were driven to a doctor as fast as possible, but their lives could not be saved.

The doctor should of course have been sent for instead, and artificial respiration continued, though it is difficult to say that the result would then have been different. It might have been impossible to save their lives anyway, as the bodies of both proved to have typical marks of the ravages of the electric current. Both *A* and *B* were wet through from the rain, their boots were also sure to be wet, and they were standing on the conducting earthen floor. Personally, I am perfectly convinced that if these fitters had worn whole goloshes their lives would have been saved.

I will now proceed to demonstrate the two

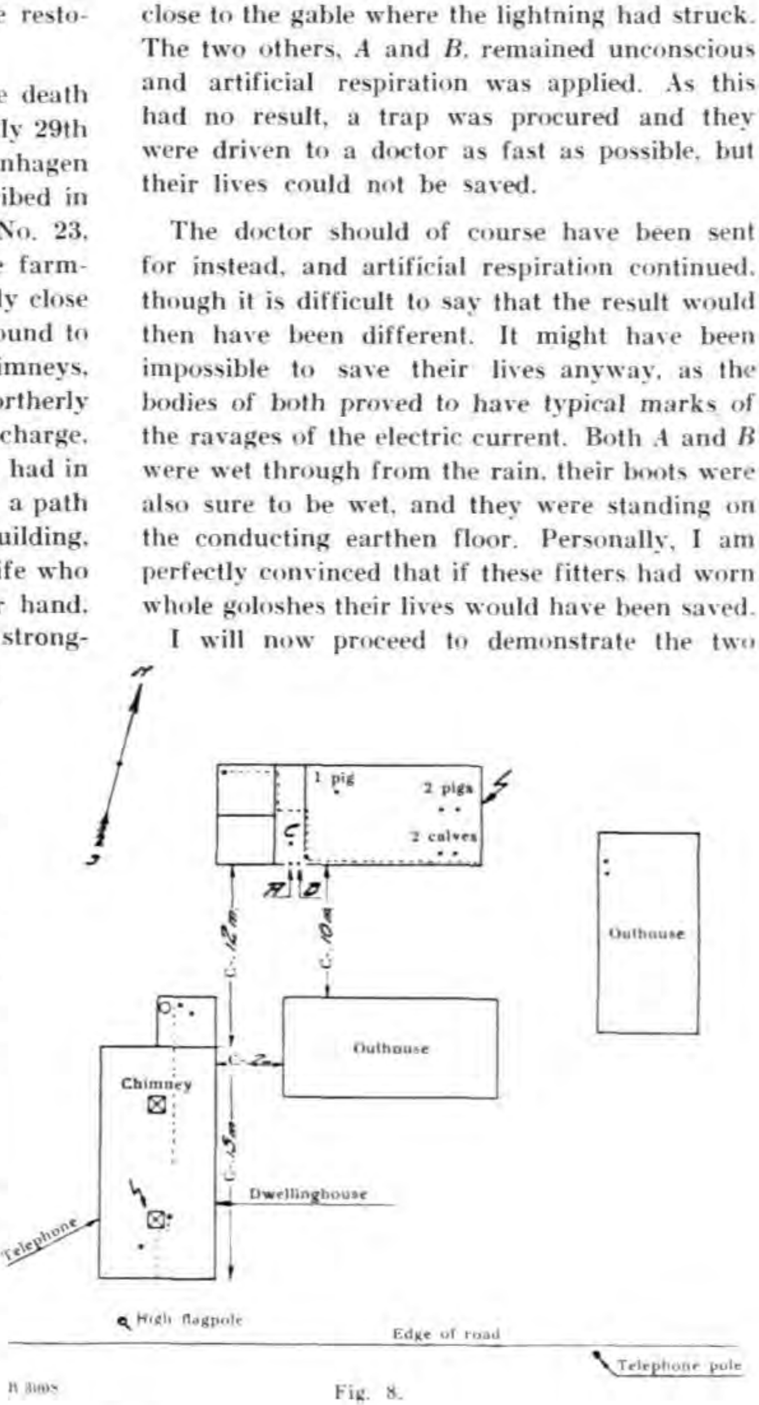


Fig. 8.

restoration methods, and only mention incidentally that a special mechanical contrivance has been designed to facilitate the application of the movements, but as this will rarely be available when an accident occurs, we may totally disregard it. In large power and transformer stations, however, these machines are generally provided, but require special training in their use. Several valuable seconds are also lost in applying the apparatus.

In summing up, I should like to emphasize that the Sylvester method (placing the sufferer on his back) is probably the most effective, but so strenuous that at least two people are required to take turns, preferably more. If one is alone with a person unconscious from shock, it is therefore probably wiser to use the Schaefer method (face downwards) even though it is not quite as effective. The main thing is that *something is done at once,* as every second counts.

That the actual method used is of less consequence than that the body is immediately moved about, is illustrated by the following episode.

Two small boys were surprised by a violent thunderstorm while they were up in a church tower to toll the bells in place of the ordinary ringer. The older boy, who was about 13 years of age, was knocked out, while the younger, a lad of 11, was fully conscious. In desperation, and scared at seeing his elder brother apparently lifeless, he managed to drag him down the steps of the tower, which action restored natural respiration. The illtreatment and the movements to which the unconscious boy was subjected when he was brought down the steps were thus sufficient to restore him to life.

If several persons are present when an accident of this kind occurs, doctors recommend that somebody should take off the victim's boots and socks while the respiratory movements are continued, and tickle the soles of his feet with a brush or anything else. The reflex movements thus caused may assist in restoring the circulation, so that blood is sent to the brain and consciousness returns. Another measure with the same object is to tickle the victim's nose with a straw or a feather to make him sneeze.

B 8017

The Falun Copper Mine.

Practical Experiences of the Fire Offices' Electrical Committee.

By *Torsten Holmgren*, Chief Engineer.

The development of organized inspection in the sphere of electrotechnics.

The first regulations for electrical plants issued in Sweden were prepared by Svenska Teknologföreningen (The Swedish Association of Engineers and Architects) in 1892 on the initiative of the Swedish Fire Offices' Committee. These alone were applicable to electrical installations until 1904, when the regulations of the Swedish Board of Trade (Kommerskollegium) were approved as a supplement to the Electricity Act of 1902, and the Fire Offices' Committee at the same time introduced periodical inspection of electrical installations in industrial plants and large warehouses. As a rule, the inspection was made every third year, but in certain industries where the risk of fire was greater the interval was generally at the most 15 months. The inspection had to be made by an "impartial expert".

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Chief Engineer Torsten Holmgren

The rural electrification having received a powerful impetus in 1917, when no regulations adapted for farmsteads existed, and the so-called war time regulations, allowing the use of installation materials which in normal circumstances would not have been considered acceptable, the Board of Trade in 1919 issued some farmstead regulations which in 1921 were extended, as far as applicable, to other installations also.

Regulations regarding the authorization of fitters were issued in 1919, and the Fire Offices' Committee accordingly resolved that the impartial expert making the inspection had to be a fitter duly authorized by the Board of Trade. Otherwise the rules were largely unchanged. The makeshift material used during the war, however, caused so many fires that the insurance companies started a special razzia about 1920 to get rid of them in industrial and agricultural installations. The effect of this was speedily apparent in the fire statistics, and in 1924 an enquiry was instituted into the actual performance of the prescriped inspections. As a result it was established that they were frequently neglected, and that very few were made in a manner which was satisfactory from the point of view of safeguarding against fire. The Fire Insurance Offices' Electrical Committee was therefore created in 1925, with the primary object of supervising the due performance of the prescribed inspections.

Subsequently to 1921 the regulations have been amplified only by the "Notes", issued by the "Electrical Inspection", partly in intimate cooperation with this Fire Office organization, and containing directions for their interpretation and application in special instances.

The Electrical Committee.

The Fire Offices' Electrical Committee, which in the following I will call the Electrical Committee or just the Committee, is appointed by about 50 Fire Insurance Companies in Sweden. Its activity is based on a mutual agreement stipulating inter alia that for the prescribed electrical inspections an insured party is only allowed to employ inspectors approved by the Electrical Committee. The range of compulsory inspections has been somewhat extended, and now includes any industrial plant of such size that according to the Trade Risks Act it is to be considered an industry, further any large warehouses (of more than 100 000 kronor insurance value), churches, cinemas, theatres, timber yards, certain electrical stations, and finally all buildings in a farmstead of such size that electrical or other power is used for threshing.

This rule about the use of power in a farmstead necessitating compulsory inspection has been made simply to set a limit to the size of farm for which in practice inspection is economically justified.

The supervision by the Electrical Committee of the performance of prescribed inspections has in practice naturally led to the Committee acting in other ways also for the prevention of fires caused by the use of electricity. The object of the inspections, and of the changes resulting from them, is to keep the plant up to the standard prescribed by the regulations of the Public Authorities, and in the practical application of these the Committee attempts to attain an economic optimum. Other than purely economic risks from fires also make it preferable to be on the safe side.

Other preventive measures in the realm of electricity primarily involve instructional work, installation materials, and installation methods, training of fitters, and inspections, of which the last, as has been already said, is of most importance to the Committee.

The organization of inspections in rural mutual fire offices.

The mutual rural fire insurance companies are as a rule not concerned in the activities of the Electrical Committee. A uniform national organization for electrical inspection is of course desirable, and for this purpose rural inspection methods have been investigated. At the time of this investigation, 15 out of the 24 counties were found to have organized a sort of general inspection, when the inspector visits one after another of the electrical installations in farmsteads, irrespective of size, and small rural industries in a parish or belonging to a distribution association. In three of these 15 counties, the inspection is wholly paid by the insured parties, in 12 it is wholly or partly paid by the insurance companies. In 2 counties every plant is inspected every fifth year, in 1 every tenth, and in the remainder every third year. In 4 counties the insured have to arrange for the inspection at their own expense, 3 counties have not arranged for any inspection at all, and in 1 county inspections are made at odd times when required.

The inspectors and their work.

The inspectors of the Electrical Committee must be duly qualified both theoretically and practically. At present about 240 inspectors are enrolled.

The Committee has tried to find suitable men in as many places in the country as possible, so as to have somebody easily accessible to the insured in every locality. Before being engaged, the qualifications of candidates for the inspectorships are examined by a joint body, under the chairmanship of one of the Government Electrical Inspectors, composed of representatives of both the industries and the insurance companies. The Electrical Committee thus does *not* engage the inspectors, but the Committee accepts those engaged by this body.

At the request of an insured party, an inspector must duly ascertain whether an electrical installation which has to be regularly inspected is in the condition required by the insurance policy. The import of this is that the plant must agree with the instructions issued by the Public Authorities. As new instructions from the Swedish Board of Trade always apply only to plants built after their date of issue, older plants need not as a rule be altered, but should be kept in good repair. This principle, however, should be applied with discrimination, and the Committee has published directives in this respect.

Special instructions for inspectors are issued. They are bound by a scale of maximum fees authorized by the Committee, and are only entitled to debit their travelling expenses in certain exceptional cases. Any faults found at an inspection have to be remedied within two months by the insured, who must furnish proof that this has been done by an authorized fitter.

As stated above, the requirements of the fire insurance offices regarding the technical details of a plant agree with the official ones. In certain cases, however, technical progress compels the fire offices to supplement the instructions by directions as to their application, e. g. stipulations regarding paint sprays. On this point a difference has arisen between the requirements of the fire offices and later instructions issued by the Social Board. This difficulty has recently been removed by the requirements of the fire offices being adjusted to those of the authorities. Any demands by the fire offices in conflict with the instructions of the authorities have always been scrupulously avoided.

But there is one stipulation beyond the official ones, viz. the demand for main switches in such workshops or factory buildings as are not used both day and night. This regulation is worded as follows:

"Electrical plants completed after January 1st 1920 or, in the case of farmsteads, after January 1st 1926, should be so arranged that such parts of the supply system as are not constantly required for transmitting energy to some current-consuming apparatus, may be disconnected by easily accessible switches, and they must be disconnected whenever work is not in progress".

As this paragraph has sometimes been criticized, its precise object had perhaps better be explained. On the one hand, the risk of electrical faults will possibly be reduced in something like proportion to the time when the conductors are live, and on the other hand, and this is the most important, security will be obtained against any fault liable to cause a fire occurring while nobody is about, and the prospects of incipient fires being immediately put out will consequently be considerably improved. The regulation is certainly of great importance as a safeguard against fire, and will, if reasonably applied, cause slight cost or other inconvenience. It is of course not intended to prevent the heating of for instance ovens or accumulating apparatuses during the time when work is not in progress.

Control of inspections.

The fact that inspections are actually made is controlled in the following way:

As soon as a fire insurance company has signed a policy on a building or on property in premises subject to compulsory periodical inspection, the company sends a card to the Electrical Committee, giving the address and name of the insured party etc. The Committee files these cards geographically, according to counties and towns, or parish and address. When an inspection has been made, the inspection sends a similar report card to the Committee, which card is attached to the fire office card and moved to another similar file of inspected plants. In this way the plants subject to inspection entered by the insurance companies, but not yet inspected, will be the only ones remaining in the original file. After a certain time the Committee will remind the insured party of his neglected duty according to the policy. When two reminders have been sent, the Electrical Committee will, according to recent practice, cause direct investigations to be made of the reason why no inspection has yet been made. It has then been found that several plants not subject to inspection have been included in the register, and that nowadays it is very rare to find an insured party who deliberately neglects his obligation.

Experiences.

I now arrive at my subject proper, which was to deal with the practical experiences of the Electrical Committee. These may be conveniently grouped into experiences of technical, economical, and administrative nature.

Technical experiences.

The technical experiences have been gained chiefly from causal fire statistics, from the reports of the inspectors, and from correspondence between inspectors and the Electrical Committee on for instance questions of exemption, and of course also from direct observation. The causal fire statistics compiled by a joint statistical office of the fire insurance companies, is not quite reliable regarding the so-called electrical fires, as the information necessarily is frequently based on the investigations of the police. A short circuit is frequently given as the probable cause of fire when no other reason has been established. To avoid this difficulty, the present arrangement is that the fire inspectors send their reports direct to the Electrical Committee when, in settling a claim, they find that the cause of fire has been electrical, giving then as full particulars as possible.

The material thus collected in the course of years shows that electrical fires are frequently caused by devices contrary to current instructions. Cases occasionally occur of electric ignition without any direct infringement of the regulations. Faults will, for instance, necessarily arise now and again from aging or wear of some part, or through some accidental damage, e. g. from a nail driven into a wall. The experience gained, particularly of so to speak excusable faults, may lead to changes and improvements of current regulations, or to improved methods of applying and interpreting them. The Committee therefore encourage the inspectors to report all their observations regarding the origin of an electrical fire, and this has resulted in much valuable information being obtained.

As Captain Götherström tomorrow will speak on Electricity and the Risk of Fire, I need now only relate a few typical instances, more particularly such where experience points to the need of further improvement of present regulations.

I will begin by a brief mention of transformer stations. Transformer stations in this country, and perhaps especially in Bergslagen, originally used to be put up in very light wooden sheds That method is now generally abandoned for new stations, but many examples still remain. This does not matter much when the transformer is placed in the open and does not represent any large capital. The 1919 farmstead regulations contained certain rules regarding methods and constructions permissible in rural districts. Transformer stations in towns often fail to conform to these rules, and sufficient instructions or directions regarding them have not been issued. The Committee has therefore made a request to the Electrical Inspection that instructions regarding the requirements for transformer stations in towns and communities be prepared, declaring its willingness to supply the Inspection with any information available to the Committee. So far, no additional regulations have appeared, but the present procedure is that when a transformer station in a town has been condemned by an inspector according to the farmstead regulations, the Electrical Inspector of the district is requested to look into the matter and give his instructions. The question of the inflammable premises of the wood industry is of special interest in timber districts. The farmstead regulations, which apply in this case also, require all woodworking premises to be lighted by electrical lamps in protective glass covers. The rule prescribing that protective glass covers shall be used in sawmills also, has met with considerable opposition, as many persons consider them unnecessary, and inspectors frequently meet with cases of the protective glasses having been taken down when lamps have been exchanged, and not replaced afterwards. A protective glass, conforming to regulations, for so-called concentrating reflectors in saw mills is at present practically impossible to obtain. The Electrical Committee has considered this point in conjunction with the Electrical Inspection, and has come to the conclusion that the use of such open fittings as occur in certain reflectors of American design may for the present be allowed, and a memorandum to this effect has been sent out by the Committee.

One of these reflectors has been put up for observation in a joiner's shop in Stockholm, where I have had occasional opportunities of inspecting it. My experience is that just as much of the fine wood dust is deposited on the lamp as on lamps without any protective cover. Whether this circumstance makes any difference to the risk of fire I am not yet prepared to say, however. The whole question will be jointly investigated by the Electrical Committee and the Wood Exporters' Association. The Association for Improved Lighting has also shown interest in solving this difficulty in a way which if possible will satisfy both the demand for security against fire and the purely technical requirements of industry.

Regulations developed in this country also include the demands that in premises where inflammable dust may cause a risk of fire, motors must have encased slip-rings or be totally enclosed. Objections are occasionally raised even to this regulation. An investigation of the economic import of using totally enclosed motors in spinning mills and similar works is therefore being made. The totally enclosed motors are more expensive than open motors, and their power consumption is generally a trifle higher, but the cost of cleaning them will be considerably less and they might possibly last longer, though that is still too early to say. The use of totally enclosed motors in many cases certainly gives considerably increased security against fire. Many instances are recorded when a spark from a D. C. commutator brush has dropped in wooden shavings or dust and caused a fire.

The farmstead regulations, I will almost say unfortunately, require conductors in premises where there is risk of fire to be enclosed in pipes. The idea of this regulation was that conductors in barns and similar buildings should be mechanically protected, but has caused a widespread misuse of vulcanized twin-conductors in pipes. I believe that the majority of electrical fires, caused by a fault in installations tolerably conforming to regulations, are caused just by conductors in pipes being employed, especially in plants where moisture may condense in the pipes, or where the pipes are exposed to accidental damage from nails etc.

Some instances of this are given below.

In a row of, if I remember rightly, 8 villas in one of the Bromma suburbs of Stockholm, several similar outbreaks of fire occurred a few years ago on different occasions during the autumn and winter. They were caused by warm air from the living rooms passing through open so-called Bergmann pipes to the cool attics. Bergmann pipes are made of cardboard, usually cased in leaded iron. In the attic the water in the pipes was condensed by the cool air. The conductors in the pipes became wet, and the insulation was gradually ruined, until finally a flash-over occurred, forming an arc between the conductor enclosed in the pipe and the casing. An apparently insignificant and overlooked circumstance like air currents in a pipe hardly thicker than a penholder was in all these cases sufficient to cause a fire.

In another instance the conductor in a Bergmann pipe was covered by the plaster of the wall. In hanging a picture, the pipe and the conductor were pierced without this being noticed. The sheath of the pipe consequently became live, which did not matter until the floor of the room above was washed. The pipe was continued in this floor, which was filled with sawdust, near to a water pipe. When the filling became wet, current leaked from the Bergmann pipe to the water pipe, and caused ignition of the filling.

In this case, accidental damage to the electrical installation thus caused ignition much later.

I wish emphatically to warn against the use of pipes in premises which are not permanently heated, and above all against the use of pipes leading from a heated to a cold room, unless air currents from the one to the other are absolutely excluded. I would prefer to avoid metal covered pipes entirely, except where there is absolutely no risk of fire.

Speaking of piping, I will add a few words about leading-in pipes through roofs. Instances of such pipes having caused fires have during recent years been numerous enough to compel the fire insurance companies to take steps to abolish them if possible, or to cure the defects of this method, particularly in southern Sweden. In a gale, a pipe standard with a conductor hanging loose inside it will be subject to a movement which will gradually wear away the insulation at some point of the conductors inside the pipe, and sooner or later a short circuit between the pipe standard and a conductor will be established. Should the pipe standard not be earthed, or if it is earthed in such a manner that the earth current is not sufficient immediately to blow the last safety fuse, which is often the case in the country, the pipe standard will be live, and an arc may play continuously between the conductor and the standard. Some combustible material below or close to the standard may then easily be ignited. In recent years numerous instances have occurred when something like what has been just described has happened. The Electrical Committee has therefore been compelled, after consulting the electrical inspectors, to issue a communication authorizing the inspectors to condemn a pipe standard if necessary. In certain parts of the country, however, the experience of pipe standards has been so good that it has not been considered necessary to remove them there. Probably the earth connexion has been good enough to cause an immediate short circuit and melting of the fuse when a fault has occurred. It is of course in a way inconvenient to have a regulation allowing different practice in different parts of the country, but in this instance another procedure was hardly possible, and the main thing is that the regulations allow a device involving a risk of fire to be condemned. Where pipe standards are condemned, they are usually replaced by underground cable or rubber-lead-cable. Where their defects are to be remedied the vulcanized conductors are generally exchanged for lead sheated cable with reliable outside terminal boxes.

Speaking of the importance of the earth connexion, I will touch upon the troublesome question of earthing. It is often claimed that the middle wire of a system provided with earthing terminal should be used for earthing such parts surrounding the supply lines as ought to be earthed, but this method may under certain circumstances have serious consequences. As an example I will relate an occurrence in a village a good many years ago. A short circuit had occurred in the outlying part of a supply net between an outer pole and the middle wire in the box of an underground cable. The resistance of the line between the electricity works and the point in question, however, was so large that the short circuit current did not exceed the melting current of the fuse. The consequence was that for many hours the short circuited point was under a voltage to earth determined by the resistances of the middle wire and of the outer pole, which latter had double the area of the middle wire. The line voltage being 2×220 volt, the middle wire potential to earth became nearly 150 volt at the short circuited point, diminishing towards the electricity works, but equally high everywhere beyond this point. Fires occurred in two places at once in the vicinity of the short circuit point. In the one case an electric stove was burnt without doing much damage, but in the other the whole attic floor of a large school building, containing a lot of military reserve stores, was gutted.

The regulations stipulate that conductors of different circuits must not be placed in the same iron pipe. Since these regulations were made, the use of so-called rubber-lead-conductors has been considerably developed with excellent results. Recently, however, this has been used in a way which apparently is not to be recommended, viz. the use for several groups of 4-wire or multi-wire conductors in the same lead sheath. Should a flash-over occur between two strands of such a conductor, belonging for instance to different phases of a 3-phase system, two fuses may easily blow, while the arc will nevertheless remain, in series with the loads of the two groups. Such practice is obviously not to be recommended. For similar reasons, the system now frequently used in many places, e. g. in Stockholm, with 220 volt on the lamps and 127 volt to earth, should perhaps be regarded with some apprehension. If an earth fault occur in a conductor, its fuse will melt, but the current to earth may remain with the load of the group as a limiting resistance. The remaining fuse is then prevented from functioning and, worse still, the current cannot even be broken by the load switch if the fault happens to be in the conductor between these two.

I will finally mention that several fires have occurred, caused by contact between a gas-filled lamp and a silk shade. Care is therefore necessary in using gas-filled lamps in fittings liable to catch fire.

By these examples, which do not include any instances of carelessness or neglect, I have wished to show how technical progress constantly gives rise to conditions which have to be regulated by new instructions or by improved interpretation and application of those already in force. The Electrical Committee is naturally striving for due allowance being made for these aspects in the new instructions at present prepared by the Swedish Board of Trade. Time does not allow any mention of causes of fire connected with wireless sets and atmospherical electricity, for the prevention of which the Swedish Association of Electrical Engineers have recently done valuable work.

Economic experiences.

The objection has frequently been raised that the inspections controlled by the Electrical Committee are rather heavy on the insured. In the case of an occasional inspection of small installations, this is sometimes undeniable. The maximum scale of inspectors' fees approved by the Committee must always be sufficient to give the inspector reasonable compensation for thoroughly well done work. The inspector, however, is at liberty to give any discount he likes on these fees, and if the insured parties cooperate, he will generally be able to organize his tours of inspection through small towns and communities so as to make the cost for each installation quite moderate. Attention in the Committee has for several years been directed to promoting the organization of such general tours of inspection both in rural districts and in the towns. The prospects of a uniform organization of the inspections in the whole country has also, as we mentioned, been examined, and the rough estimate made indicates that the net cost of inspection, if arranged in this way, would probably be limited to something approaching 3.5 öre pro mille of the insured sum in rural districts, and a maximum of approximately 2 öre pro mille in towns and villages. Experience during the 5 years of activity of the Electrical Committee provides a basis for estimating the economic prospects of improving the organization, sound enough to justify a further step in this direction.

Administrative experiences.

The economic interests of the insured have, as we mentioned above, made the fire insurers anxious to provide inspectors in as many places in the country as possible. The larger the number of inspectors wanted, the greater concessions must be made regarding their qualifications, and the greater the concessions, the greater will be the risk that the work of the inspectors will not invariably reach any very high standard. Incoming reports and memoranda of inspections certainly indicate considerable variations in the manner of applying current regulations. Some inspectors are inclined to condemn much which perhaps does not correspond to the latest regulations, but which might be defensible from the point of view of security against fire. I have for instance sometimes noted that oldfashioned, probably comparatively good installations in inflammable premises have been ordered to be replaced by conductors in pipes, while other inspectors have shown an obvious disinclination to find faults even with comparatively bad installations. This has been proved when one inspector has been succeeded by another, who has sent in a memorandum containing rather serious objections. Another drawback of the present organization is that it provides for no control of the alterations made by an authorized fitter after some fault has been reported, until the next inspection is made. A fault noted at an inspection has occasionally in a subsequent report been said to be corrected by an authorized fitter, and has nevertheless reappeared in its original form at the next inspection 3 years later. Investigations have recently been made in some towns regarding the quantitative efficacy of the organization, and the result proves that for various reasons very few plants subject to periodical inspection escape these. Quantitatively, the present system is fairly satisfactory. An efficacy of 100 per cent. is not usual in technical branches. The objection might be made that the frequency of the inspections, which according to current regulations are now made every third year in certain plants, every year in others, and never in the large majority, is not sufficiently adaptable to individual requirements. Another objection is that competition between inspectors, especially for the general inspections in the country districts, has here and there depressed the fees to such an extent that it seems economically impossible for an inspector even with very moderate demands on life to do his job satisfactorily. This of course applies to certain very clearly defined parts of the country.

Most people will agree that the ideal arrangement for inspections would be a uniform organization of districts, where each inspector has his area to look after and where he works under the guidance and directions of some superior authority, and where all electrical installations are inspected as and when required. The fire insurance offices would welcome the establishment of such an organization by the Government.

The chief subject of this paper, the inspection organization, is however only one side of the fire prevention measures in the sphere of electricity. The fire offices have assisted in the progress of other branches also. They have thus contributed half the cost of the Institute for Control of Electrical Materials, the activity of which is now beginning to bear fruit. We have already pointed out that the Electrical Committee contributes to the improvement of the regulations to the best of their ability.

The final goal of the activities of the Electrical Committee is to make electrical installations at least as fire-proof as gas pipes are, and thus to render itself and all inspection superfluous.

Efforts at Rationalization in Minor Power Concerns in Dalarna.

By *Ove Mogensen.*

In its report of 1924 on the Systematic Electrification of the rural districts of the County of Kopparberg, the Royal Committee on Electrification states that the total number of power stations in the County is 181, 116 of which are for alternating current, and 65 for direct current. According to the same report, the total number of electricity-distributing plants in the county is no less than 319.

If we consider the building costs, reckoned at the 1914 price level, these amount to no less than c. 46 mill. kronor, of which sum about 13 mill. kronor come on the general distribution, and about 33 mill. kronor on the large industries.

These official figures are very illuminating, and between the lines we may read the history of a progress which is also quite definite. The electrification was done during and immediately after the war, and the actual cash amount spent on the general distribution in this district therefore was c. 30 mill. kronor. The electrification was done by every village or district seeking any available source of power of its own, suitable for development. Sometimes D. C. was chosen, sometimes A. C.; sometimes water power was at hand, sometimes steam power had to be resorted to. The various power companies in adjacent districts frequently progressed by invading the territory of some neighbouring or previously existing undertaking, with consequent competition.

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Ove Mogensen.

Enterprises originally based exclusively on steam power were, however, fairly soon compelled to close down. It is significant that the charge in these plants was usually 15 kronor per lamp and year plus 6 cub. feet of firewood per lamp.

Where two hydroelectric power stations competed, however, the struggle became more protracted, and in some cases still continues. I trust, however, that this will not end by the absolute victory of either party, but by a just and equitable division of the subscribers, or by an amalgamation of the two businesses.

At first, the power tariffs were usually pure kWh-tariffs, charging for instance 50 öre per kWh for lighting purposes and 25 öre per kWh for power. Obviously these rates are not rational, and the question therefore merits some discussion.

To explain what I mean, we will consider the annual expenditure of a distributing organization.

Annual expenditure of a power station X.

Expenses.

(The power station has cost 75 000 kronor to build, and the distribution lines 125 000 kronor, i. e. a total of 200 000 kronor).

Interest on 200 000 kronor at 5 %	Kr.	10 000: —
Amortization	»	7 000: —
Repairs and maintenance	»	4 500: —
Wages (engineer and fitter)	»	5 000: —
Administration	»	1 500: —
Insurance, rates and taxes, and sundries	»	2 000: —
Total expenses	Kr.	30 000: —

These expenses are the same whether 1 000 or 1 000 000 kWh per annum are consumed. A consumer, for instance, who has 25 lamps installed, and lights them all once a year (on Christmas Eve) but for reasons of economy only lights one lamp during the remainder of the year, costs the power company as much as one who normally uses all his lamps, but from the former the company only receives an income of a few kronor a year, while the latter has to pay not only for himself but also for the former. It is consequently not fair to distribute the overhead expenditure of 30 000 kronor on the kWh consumed alone, but this should be split up into a fixed annual charge and a lower fee per kWh consumed, to prevent waste of the electric power. If electrical energy is produced by steam power, the cost of fuel at normal coal prices is less than 1 öre per kWh.

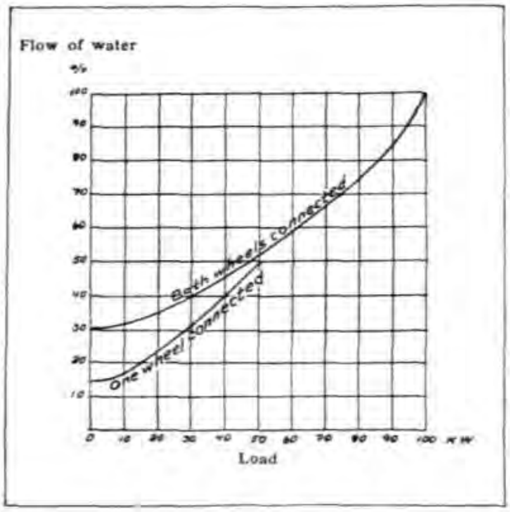
The objection might be made that there is not sufficient water to keep the power stations more heavily loaded than at present. This is only partially true, however. In summer, practically any amount of kWh can be supplied, and no harm done. It is only in the autumn, and above all in the winter, that difficulties would begin. If we therefore could find some method of saving the kWh from the summer for the winter, a considerable step forward would have been taken. Before entering upon the question of this storage, I must first say a few words about the water consumption of a turbine (fig. 1).

The diagram shows that the turbine when running light, i. e. disconnected from the lines, will use about $^1/_3$ of the full load consumption, and at $^1/_{10}$ of full load about half the full load consumption. However sparingly the power is used, it is thus impossible to save more than at the outside half the quantity of water, provided of course that only a single turbine is installed. If the turbine has double suction pipes, so that one of the turbine wheels can be shut off at low loads, the matter will be different, but it is always necessary to keep a certain reserve to meet unforeseen load peaks, and hence I cannot disconnect one wheel as soon as the load has dropped to half, but at best only when it has dropped to say 40 per cent. of the maximum load. It is, however, rather troublesome to connect or disconnect one of the turbine wheels, and this chance of saving is therefore probably not always fully utilized.

Returning to the question whether it is actually possible to save kWh from the summer for the winter, I wish at once to say that this can be done when the water is stored in a reservoir lake. If these lakes are of sufficient size, they can be used for saving kWh in plants lacking dammed up lakes also, provided electrical cooperation between the power stations is established.

I will illustrate this by an account of how this problem is solved in the southern part of the Lake Siljan valley.

Before accounting for the purely electrical part of the problem, I will say a few words of the



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water power stations (fig. 3) and of the rivers on which these are situated.—Fig. 2 shows the rivers with power stations. The map shows as much as possible of the drainage areas and the existing reservoir lakes. We see plenty of reservoir lakes, but also certain power stations with practically no possibilities of regulating their water supply, for instance the power station in Ickån and to some extent also that in Draggån. Before cooperation was established, each station was run on its own, with the result that the power consumption from stations without reservoir lakes frequently had to be restricted on account of lack of water, while other stations were openly wasteful, in that they frequently had to use stored water while there was still a superfluity of water in rivers without reservoirs. With cooperation, it should be possible to close the power stations possessing reservoirs as long as the stations which cannot store their water have plenty, and these would consequently then also supply power to the reservoir stations. When the water has fallen, the reservoir lakes will be full, and their power stations can then return the power received during flood time. The water which would otherwise have run to waste past power stations lacking storage facilities can thus be utilized.

Other advantages of cooperation are also conceivable, e. g. those arising from a steam-power station cooperating with a water-power station, and from having a reserve available in case of faulty lines or machines, which is a by no means small advantage.

Before any cooperation was begun, most careful investigations had to be made how this had best be arranged, what the cost of construction would be, and what advantages would be gained. These investigations, which were entrusted to my Bureau, indicated that some of the companies included in the investigation were likely to suffer from a noticeable insufficiency of available energy in dry years. Unless cooperation were established between the various companies, certain waterfalls, so far not utilized, must therefore be harnessed to supplement the power stations already built. But if the existing power stations were to cooperate, all requirements of electrical

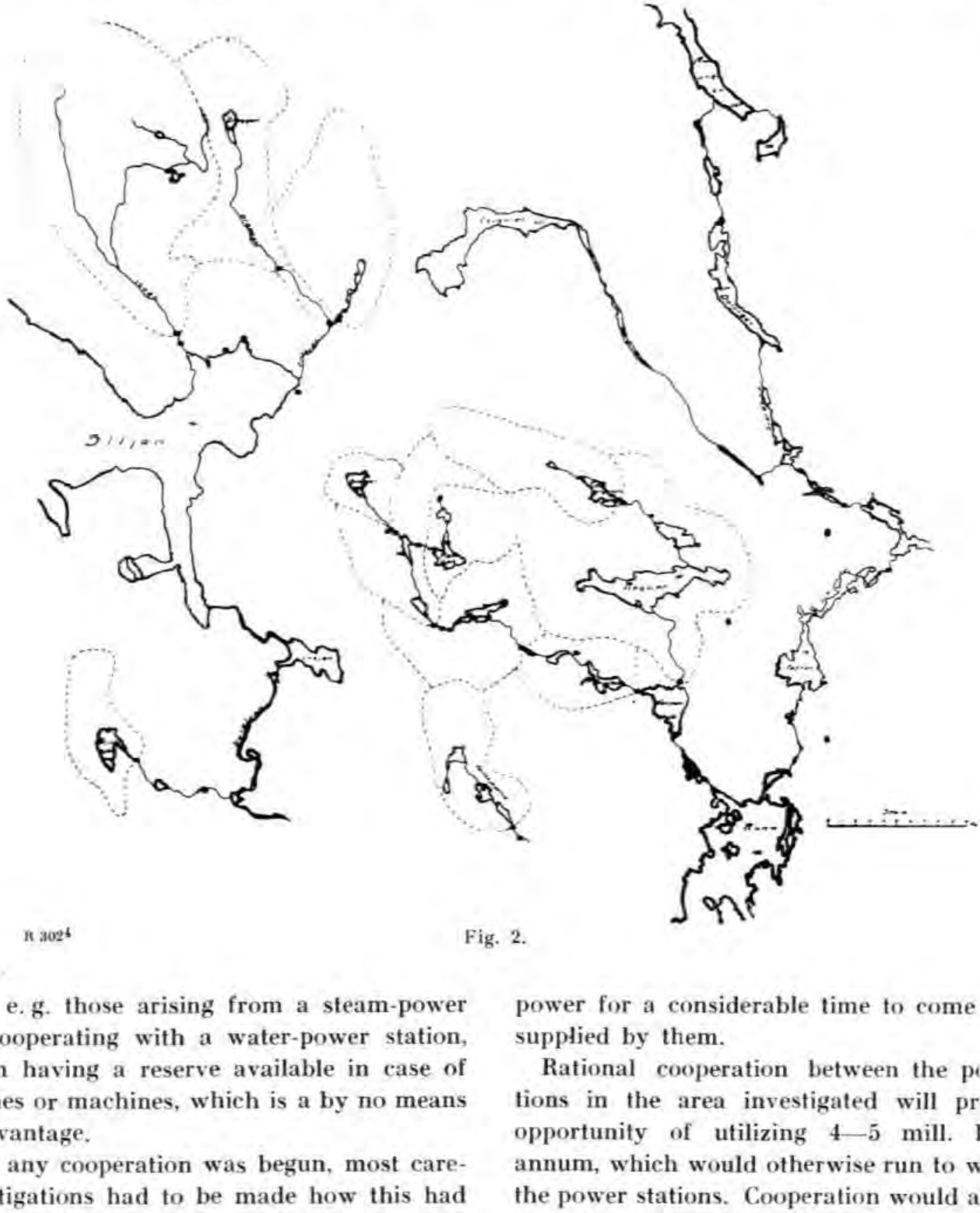

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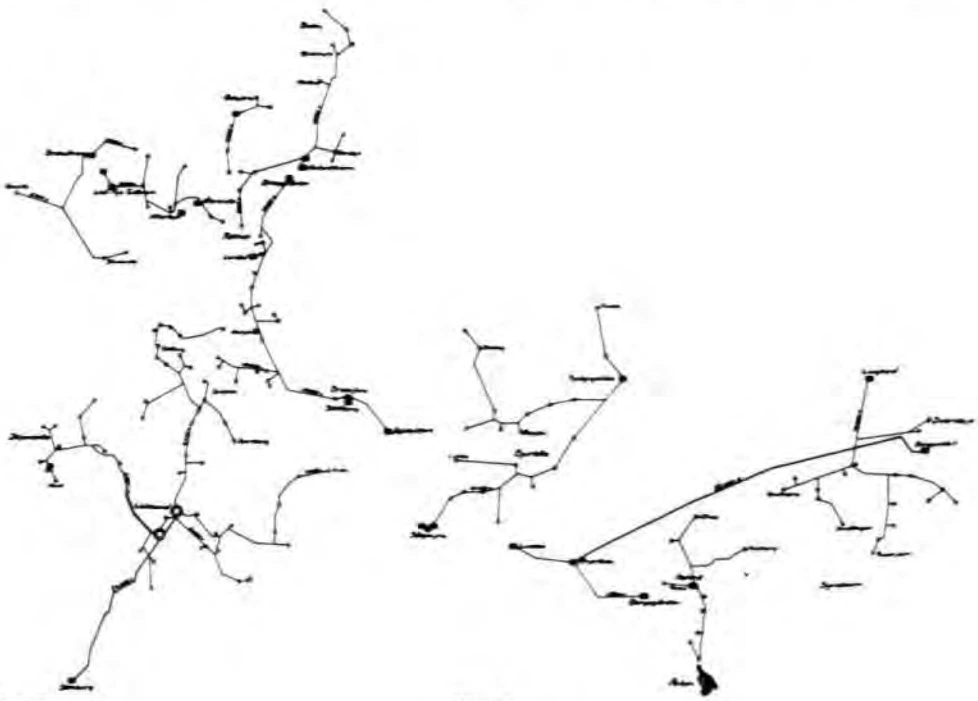
Fig. 2.

power for a considerable time to come could be supplied by them.

Rational cooperation between the power stations in the area investigated will provide an opportunity of utilizing 4—5 mill. kWh per annum, which would otherwise run to waste past the power stations. Cooperation would also result in savings from reduced wear and tear, reduced consumption of lubricants, etc., while advantages from improved working conditions and increased reserves etc. would also accrue. The value of the savings made possible by cooperation, and of the resulting advantages, has been computed, and is 115 000 kronor per annum in round figures. The total cost of new plant has been estimated at 120 000 kronor. An association called the Södra Siljansdalens Kraftförvaltningsförening u. p. a., on a purely cooperative basis, has been suggested for the building and management of this plant.

This was the result of the investigations, and the map (fig. 4) shows the suggested communicating lines and connecting stations. The proposed association, Södra Siljansdalens Kraftförvaltningsförening u. p. a., was immediately formed. The lines were put up on wooden poles, but were strongly insulated by insulators of a wet flash-over voltage of 85 kV and without earth wire or other earthing arrangements. Copper wire of 16 mm² was, however, used in the 20 kV lines also, and railway as well as highway and telephone crossings were made proof against breakages. Figs. 5 and 6 show one of the railway crossings.



R 3023

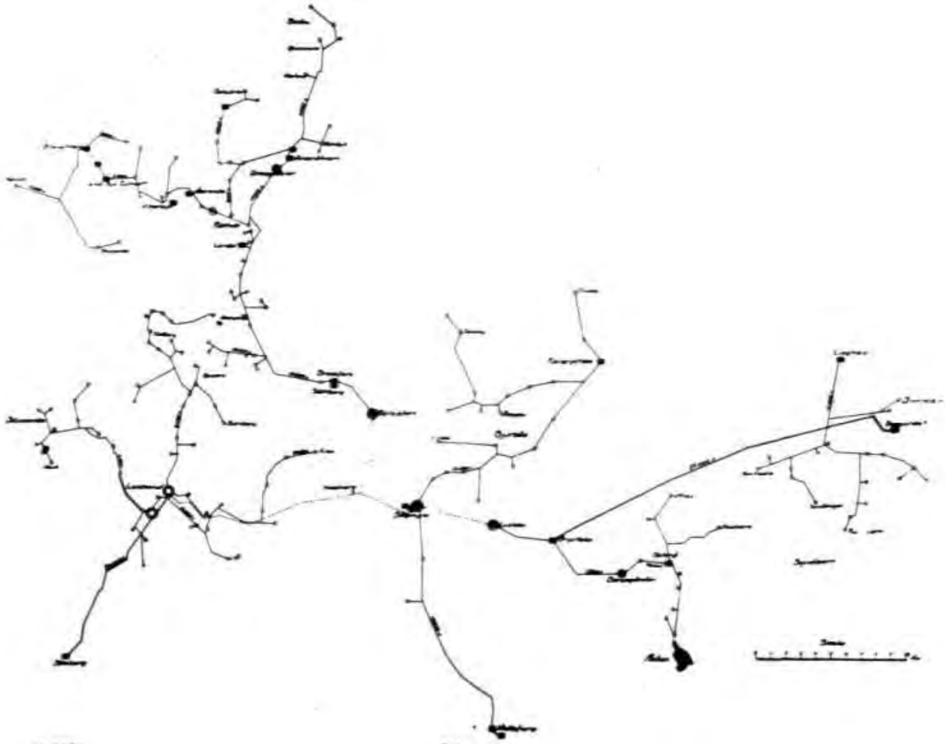
Fig. 3.

The investigation had also included the large steam sawmills at Rättvik as, in order to utilize the water as completely as possible, these mills ought to be driven electrically at times of flood and the waste fuel then be stored, and used at low water not only for driving the sawmill but also to return the electrical energy received from the power station during the floods. By such means part of the water which at flood times would otherwise run to waste can be utilized. By an arrangement of this nature, the sawmill would have its own light and power, and the opposition therefore thought that a valuable subscriber would be lost. The largest sawmill joined, however, and experience has shown that instead of causing loss, cooperation with just this mill was extremely valuable. A steam power station is here provided where we need pay no interest or amortization on an expensive plant, and obtain the fuel at a price which can compete with any coal price.

The technical cooperation was not difficult, but the administration proved harder. Before proceeding to discuss the organization I will, however, in a few words describe such technical details as are often looked at with doubt by engineers and fitters of the older school.

The first problem is that of bringing the currents in phase. Curiously enough this meets with no difficulty at all. We have stations for bringing the currents in phase right out on the line, e. g. in Leksand, where it is consequently impossible to influence the frequency of either of the two systems to be brought in phase. Experience proves that the frequencies are so similar that a wait of a few minutes will usually give a suitable opportunity for phasing. To enable the several stations to keep a constant frequency, we provided them with frequency measuring instruments wherever such were not already installed. The phasing is done by ordinary phase lamps connected to a voltage transformer, which is always put in for the kWh-meters, and although the number of phasings is now approaching 10 000 I know of no case where there has been any difficulty. These phasing stations have always been as completely equipped as possible. Voltmeters with voltmeter switches and frequency measuring instruments have been fitted for measuring both ways when the systems are not connected, a kW-meter has also been installed with zero in the middle of the scale, showing the power supplied in one direction or the other, as well as an ammeter for examining the power factor.

At each station 4 kWh-meters are also fitted, locked in pairs to prevent back metering, two of the meters showing the power supplied in one direction, and the other two that supplied in the other direction. Of these meters, one set belongs to the Power Association and the other to the respective companies. A deviation from current



B 3025 Fig. 4.

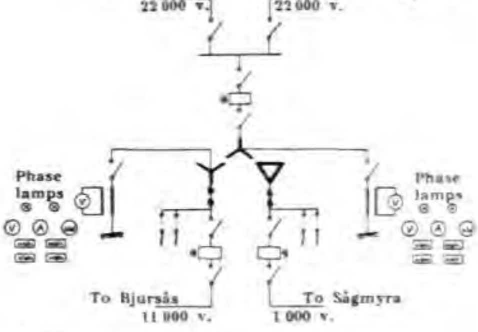
B 3026 Fig. 5.

B 3027 Fig. 6.

practice which has been used here is that each set of meters has been given separate current and voltage transformers, and this has proved very convenient. If a voltage fuse blows, for instance, the other meter set is not affected, and the quarterly readings may be taken from that. If on the other hand, as frequently happens, double meters are connected to the same meter transformer and one of the voltage fuses blows, the two meters will continue to show the same although both are wrong, and it may sometimes be rather difficult to clear the matter up. We decided from the beginning to eliminate as far as possible all causes of friction which might be avoided by simple means, and we therefore indulged in double sets of meter transformers both for current and voltage. We permit, as I pointed out above, the connexion of phase lamps to these meter transformers, as well as the connexion of the instrument boards for current, voltage, power, and frequency measurements.

At some points nets of three different voltages meet, and the circuit diagram of the Sågmyra transformer station (fig. 7) is therefore included. — The lines meeting here have voltages of 1 000, 11 000 and 22 000 respectively. As the lines must be able to cooperate in any way i. e. the 1 000-volt line with the 22 000-volt line, and the 11 000-volt line with the 22 000-volt line, and so on, we selected a transformer with 3 mutually insulated windings, of which the 22 000 and the 11 000 volt were star connected, and the 1 000-volt winding delta connected. All oil switches being provided with incorporated releasing devices, we had to introduce knife switches on either side of them, so as not to have to disconnect the whole plant when changing release current or release time. — A small detail, which perhaps also deserves to be mentioned, is that all the transformers have a device for indicating earth-faults by means of a voltage transformer in the zero tap. The question might be asked why we have not selected an auto-transformer between 22 000 and 11 000 volt, and I wish to reply at once that we have not fallen to that temptation, but have even planned the installation of a 1: 1 ratio transformer at Rättvik also when cooperation is completed there, in order to limit the drawbacks of various kinds, not forgetting disturbances in telephone and wireless apparatuses, which might otherwise easily be very widespread in case of earth-faults in either line.

The connecting stations, however, have as far as possible been placed in some already existing power station, the equipment of which has consequently been increased by what was required for making the connexions. Fig. 8 shows Rällsjöfors Power Station from the outside, with the compulsory tower, which in this instance it has also been possible to use for leading in the new 20 000-volt power line. Fig. 9 is an interior view of the power station, where the instrument board furthest to the right is the only one which had to



R 3028 Fig. 7.

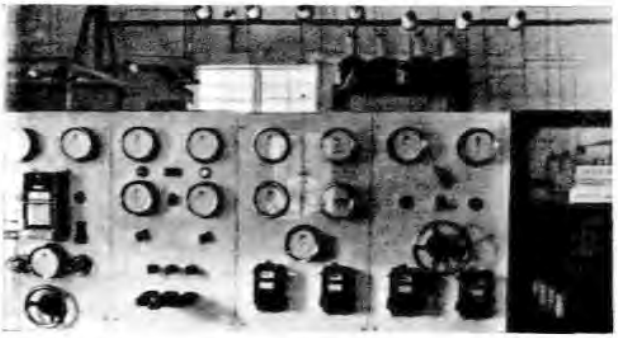
be added, the other boards being those needed for the generator in the power station. There has consequently been no need to alter the building, as everything could be accommodated although space was rather limited from the first.

Fig. 10 shows the exterior of the lower Sågmyra Power Station. This building had to be raised for the introduction of the additional 22 000-volt power lines, but at the same time we were pleased to get rid of the older tower in the centre of the building. Fig. 11 shows the instrument board of the Power Association.

Before concluding the technical description, I should perhaps add that so far everything has functioned excellently.

Passing to the administrative side of the cooperation, the fundamental principle has been that this cooperation should not commit any member to anything. A member has thus the right to deal with his power and manage his power station or stations as he likes, but the price of power is varied with the seasons and fixed by a Board in such a way that it will be to the

R 3029 Fig. 8.



R 3030 Fig. 9.

economic advantage of each member to cooperate. The power will thus be most expensive in times of drought, and cheapest in times of flood. It is thus economically advantageous for the owner of a reservoir lake to save his water, knowing that he will get at least 3 times as much for the power stored as he will have to pay for the surplus power purchased. Somebody might object that sometimes everybody may have power and nobody want to buy. Such a situation is conceivable, and in such an event we must try to find customers for this power. The price could of course be put very low.

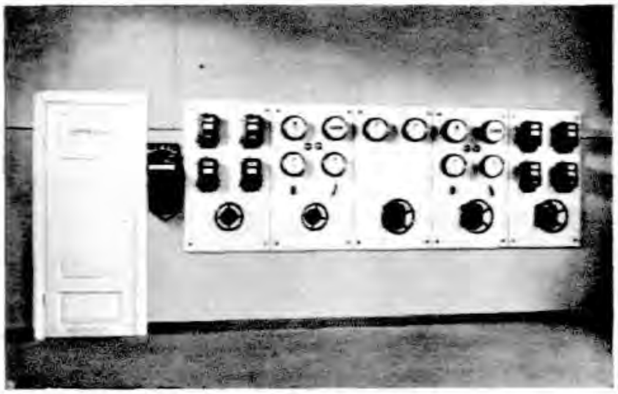
One weakness not yet fully eliminated is that some of the power stations are not on the telephone, and that the others cannot be reached at night. We are now experimenting to find a way of simultaneously using the power lines for telephony, but have not yet got far enough to say how this will succeed. Anyway, the need of such telephonic communication is not very pressing.

We have also considered another alternative, viz. to give working orders simultaneously to the various stations at a certain time, for instance every morning, through the Falun Broadcasting Station. The question is not very pressing, as we said, and has therefore not yet been finally decided.

I have here described how we have been able to arrange cooperation between A. C. plants, but how should cooperation be arranged between D. C. plants, or between D. C. and A. C. plants, without expensive conversion? This is a problem which has lately worried us a good deal, as there is a fairly small district here in Dalarna where there are four A. C. and 10 D. C. power stations. I can easily understand the shareholders of the D. C. plants not wanting to change from direct to alternating current, as all motors, meters, and other instruments must then be changed too. Obviously, alternating current will eventually be distributed, but during the transition period they want to retain the direct current. All D. C. plants are working with a 2×220 voltage obtained by voltage dividers. If the speed of the D. C. generator is selected so that a 50-cycle alternating current is obtained from the slip-ring through the voltage divider, cooperation with an A. C. plant will be possible (fig. 12).

The necessary condition for obtaining a 50-cycle alternating current from the slip-ring is that the speed of the D. C. generator is 3 000

R 3031 Fig. 10.



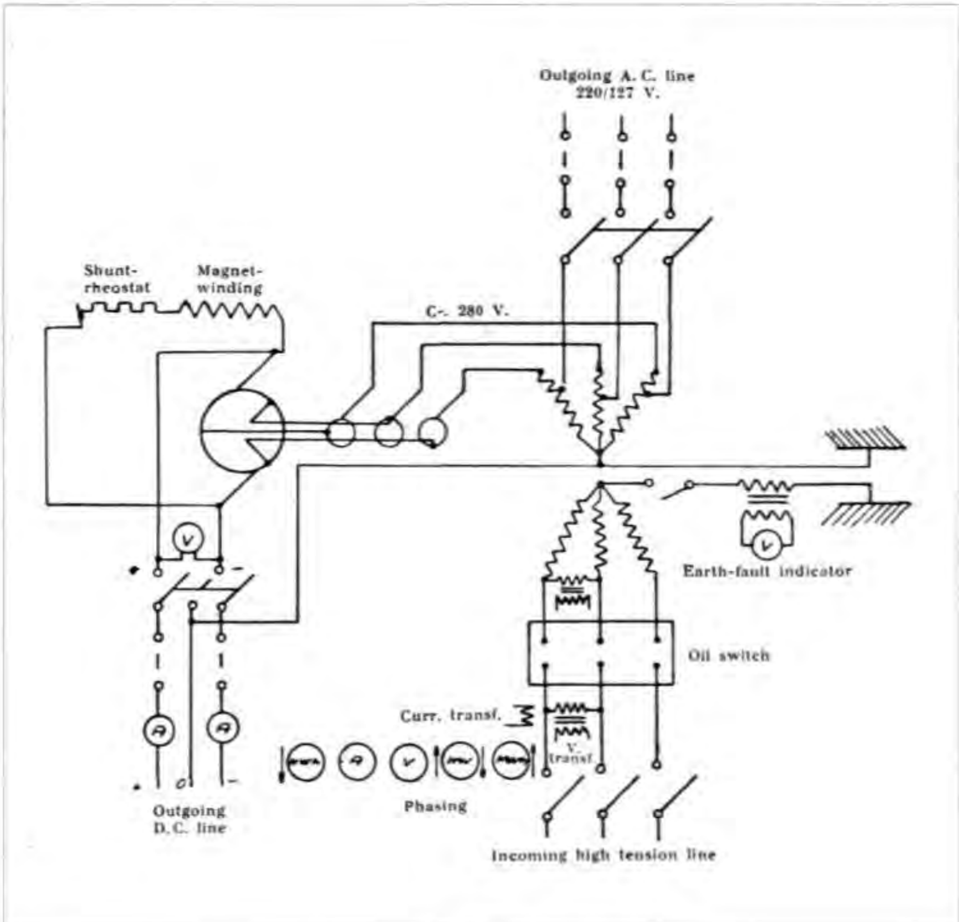
R 3032 Fig. 11.

r. p. m. in a 2-pole generator, 1 500 r. p. m. in a 4-pole generator, 1 000 r. p. m. in a 6-pole generator, 750 r. p. m. in an 8-pole generator, and so on.

Further, it will of course be necessary for the voltage to be divided by 3 slip-rings (3-phase A. C.).

I hope that it will be possible to arrange cooperation in the proposed manner between D. C. and A. C. plants, but at present I lack any practical experience of such cooperation, which, in the interest of truth, I must point out. When new D. C. generators are ordered, however, it would seem desirable that the above mentioned speed be selected, so that future cooperation with A. C. plants may be possible.

Nor should certain points be forgotten in the design of these generators. They must be designed without commutating poles, and will therefore be rather large. The A. C. voltage supplied by the generator will to some extent depend on the design of the machine, but will, at 460 volt D. C., generally be 280 volt. By providing the low tension winding of the transformer with a tap for 220 volt, alternating current of this standard voltage will at the same time be available, and the load nearest to the power station may be connected to this alternating current, which, this should not be concealed, will then gradually spread and completely displace the distribution of direct current.



B 3033

Fig. 12.

Electricity and the Risk of Fire.

A quinquennial Review by Captain *R. Götherström.*

When, after five years, we again meet in Falun, at an electrotechnical course of information and instruction, a fairly obvious question will be: have any great general changes been introduced during these five years, capable of appreciably diminishing the considerable risk of fire which, in spite of exaggerations in the daily press and elsewhere, used to be run in electrical installations during the war and the years following it?

We find that there is much cause of rejoicing, but that in many sections of electrotechnics progress is still hopelessly stagnant, at least as far as increasing the security against fire is concerned. This severe judgement is primarily directed against the slight interest shown by the Government in improving the conditions.

We thus still possess a Government Electrical Inspection which is rather ineffective, and has little authority to interfere in indoor electrical installations. The Government installation regulations are largely out of date, and partly made inoperative by technical progress, which has outrun the general regulations drawn up to guide this progress.

B 1446

R. Götherström.

The indifference and the slight interest shown to the risks of fire and accidents introduced by badly built and managed electrical plants is also regrettable. This lack of interest is particularly striking in those rural electrical distribution areas where electric light and power were installed during the war years.

But on the other hand, electrotechnical progress, particularly in installation methods, has during the last five years been very rapid, and has actively contributed to reduce the risk of fire in a considerable number of plants. Primarily, this encouraging progress is probably due to intense and purposeful informative and instructional activities on the part of a number of organizations, and not least from the Concern whose guests we now are. The number of persons who have attended these courses is well over 5 000.

At the last course of study in Falun, the possibility was discussed of establishing a more permanent organization for the supply of information regarding the most suitable way of using electric current, and during these five years the *Association for the Rational Use of Electricity* and its excellent journal have also been founded.

The *Fire Insurance Offices' Electrical Committee* has also been formed during this period and has done excellent work, all the more valuable as Government instructions regarding indoor installations have been practically non-existent during these five years.

The *Swedish Fire Protection Association* has done intense propaganda work for the reduction of the risk of fire in electrical plants, and the *Swedish Association of Engineers and Architects* and the *Association of Electrical Engineers* have also, particularly by their standards, advices, and instructions, done excellent work in the same branch.

Not the least important news during this five year period, however, is the formation of the *Institute for Control of Electric Materials*, the work of which has already had good results. In my opinion there is little doubt that this Control Institute will under its new management in the near future exercise great influence in eliminating electric installation materials involving a direct risk of fire, and in guiding progress in the right path. It is also to be hoped that the elimination by the Institute of worthless foreign rubbish will provide an opportunity for the extensive manufacture of good Swedish installation materials.

Among noteworthy purely technical tendencies of progress during these five years, which we hope will appreciably contribute to diminish the extreme frequency of electrical fires, I think the following deserve to be mentioned here:

1. An increasing substitution of solid conductors, and above all rubber-lead conductors, for pipe installations, H V G-conductors, and single conductors on studs.

2. Exchanging the H V G-cables, in hand-lamps and other movable appliances and in motor connexions, for solid cables and rubber-tube cables.

3. A more extensive use of encased apparatuses and nonconducting, durable bakelite fittings instead of the easily damaged porcelain fittings and the also easily damaged sheet-metal and iron fittings which are moreover made from electrically conducting materials.

4. The more extensive use of new, factory-made fuse cartridges, instead of home-mended fuses.

5. Automatic regulation of temperature in electrical heating appliances.

6. Substitution of more or less enclosed motors for open.

Considerable improvements are thus to be noted during the last five years, particularly in the towns, while rural conditions still leave much to be desired, electrical lines there having frequently been laid and electrical appliances fitted without assistance of expert workmen.

Immediately after the war the risk of electrical fires was particularly prevalent. Previously, rural electrification was not so extensive, and indoor wiring was generally only used for lighting and usually not so heavily loaded as now, when electricity is increasingly used for *power* requirements in both farms and urban dwelling houses.

The needs of the war years necessitated a far too rapid acceleration of electrification. Very bad materials with zink, iron, and paper instead of copper and rubber were frequently used, and the material was frequently put up by incompetent workmen. This undoubtedly left distinct traces in the fire statistics.

The sums paid out on fire insurance policies before 1918 averaged 15 mill. kr. a year, but subsequently rose enormously, up to 50 mill. kr. The increase was much more rapid than the drop in the rate of exchange or the increase of the amounts insured.

Extensive fire protection propaganda, increased instructional activity in electrotechnical subjects, better electrical materials, and stricter control of electrical plants, have doubtlessly strongly contributed to the relative frequency of damage by fire being now reduced to — and some years actually below — peace time level.

Modern High Tension Cables.

By *Bernhard Ell*, Chief Engineer.

When transmitting electrical energy over large distances, high voltage 3-phase alternating current is generally used, carried by aerial lines. The reasons why underground cables are not used for long distance transmission of electric current are the large charging currents caused by the capacity of the cable, and also the higher cost of such a plant. The charging currents may of course be compensated by connecting inductor coils or synchronizing machines in the cable net at suitable distances apart, but this makes the use of cable still more expensive.

Economical transmission of electrical energy over large distances will only be made possible by the use of high voltage direct current. As energetic efforts are at present made to solve the problem of converting low voltage D. C. to high voltage D. C. and vice versa, it will most likely only be a question of time before all electric power transmission will be made by high voltage direct current. As it is easier to manufacture a cable for high voltage D. C. than for A. C. of the same voltage, the initial cost of underground cables will be less than of aerial lines. An additional advantage is that the plant will be independent of atmospheric disturbances. From a purely esthetical point of view also, and on account of the risk of the high voltage current affecting animals in the vicinity of aerial lines, a high voltage D. C. cable-net will offer several advantages, and, above all, greater reliability of working will be secured by the use of cables.

R 2029

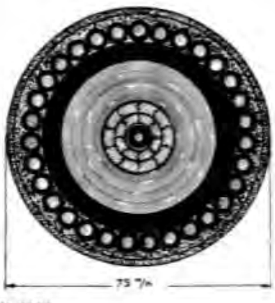
B. Ell, Chief Engineer.

For the transmission of electrical energy from Norway to Denmark and Germany—a problem which is at present very much to the fore—high voltage direct current has been proposed. The idea would then be either to connect Norway and Denmark direct by submarine cables or to lay them along the Swedish coast, placing some of the cable joints on land for easier control of the cables, and to facilitate any repairs required.

The voltage suggested is 300 000—500 000 volt direct current with earthed middle wire. This will of course give rise to certain difficulties on account of stray currents and consequent corrosion of the lead covers and disturbances in the telegraph lines, but this may be obviated by incorporating a middle wire in the cable.

Two cables for the transmission of 300 000 volt D. C. from Norway to Denmark are illustrated on the next page. As appears from the illustrations, their dimensions are not very forbidding, the diameters being 75 and 85 mm. respectively. The thickness of the insulation is only 12 mm. and each armour wire is enclosed in a lead sheath to prevent corrosion. This can also be attained by using flat or shaped armour wires, which are then enclosed in a common lead sheath. This allows a slight reduction of the cable diameter.

The problem of transforming direct current being not yet fully solved, high voltage D. C. cables are perhaps not of much immediate interest, and we will therefore devote our attention to cases where A. C. cables can be used, and to the modern design of such high tension cables. High voltage cables and cables for extra high A. C. voltage can as a rule not be used on greater distances than 100 km. without the devices mentioned above. Their use is, however, well justified for crossing rivers and lakes, in densely populated districts, and in places where it may be difficult to use aerial lines. During severe summer thunderstorms, a length of cable about 1 km. long, connected to the end points of an



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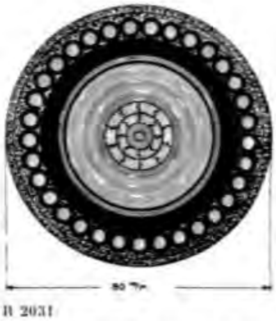
D. C. Submarine Cable, for 150 000 volt, 350 mm², without middle wire.



R 2031

D. C. Submarine Cable, for 150 000 volt, 350 mm², with middle wire.

air line, has in addition proved an excellent over-voltage protection. A cable connected to an aerial net can also serve to compensate reactive effect, as in the Öresund cables. High voltage underground cables, however, are mostly used in large towns for the distribution of current from the power station to the sub-stations. The Stockholm Electricity Works, for instance, has gone in for 33 000 volt 3-phase cables for some years past.

The high transmission voltages, and the great reliability required in present day power distribution, have created a demand for higher quality line materials. This is particularly the case for cabled lines, which are as a rule placed underground, where proper inspection is impossible, and where considerably greater and longer interruptions of service are caused when a fault has to be repaired.

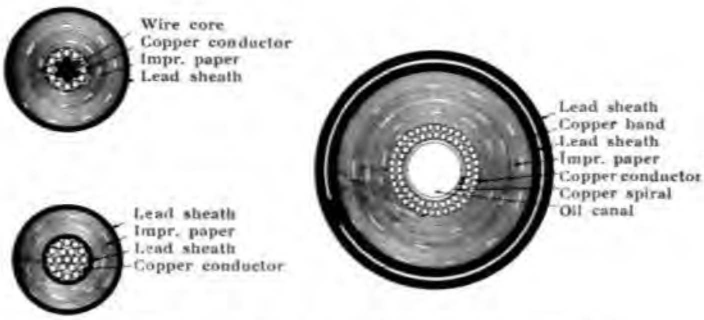
Cable manufacturers, however, have not been outdistanced by progress. Thanks to well directed efforts, consisting partly in theoretical and scientific investigations of cable materials, and partly in improving earlier and devising new working methods, they have kept pace with other branches of electrotechnics. Excellent cooperation has also greatly benefitted the cable manufacturers.

That the difficulties have been many and great will best be understood by a brief retrospect. In March 1899, the ETZ stated that lead cables for a working tension of 10 000 volt had not yet been laid, nor connected in aerial lines. A few years later—1906—we find that 3-phase cables for maximum 10 000 volt were made. For this voltage, insulation of 8.5 mm. thickness was used. With the good materials and improved working methods of today, this thickness could, according to the 1928 VDE standards, be used for a working tension of 19 000 volt. According to present opinion it may even be used for 36 000 volt without risking the reliability. Cables for 132 000 volt have been in use since 1926 with good results, and 220 000 volt cables will be used before long.

Progress towards higher voltages has, we note, proceeded at a record rate. The most important of the principles of modern cable design, the establishment of which has rendered this progress possible, will be described below.

The Conductor.

A cable conductor as a rule consists of copper wires, cabled in concentric layers to a very flexible circular section. To find the cheapest, and from a technical point of view best, cable dimension when designing the conductors of high voltage cables, the relation of the diameter of the conductor to the diameter of the insulated cable must always be considered. This often leads to the conductor of small area having to



Designs of conductors for High Voltage Cables. Top left: steel-core copper cable; below this a lead covered copper cable. Right: Pirelli's design, with copper wires cabled round a supporting spiral of copper band.

be built up to a larger diameter than that necessitated by the copper section, which may be effected by introducing a cabled steel wire core. This core steadies the conductor without reducing its flexibility appreciably, and makes the cable less delicate to lay, partly because of its increased tensile strength, and partly because breakages in the comparatively thick insulating layer are avoided by the steel core preventing too sharp bends in the cable.

In very heavy cables the conductor may be hollow, enclosing a supporting spiral. The canal thus formed is generally filled with oil. Pirelli's 132 000 volt cable is an example of this. In certain designs it is preferable to make the surface of the conductor as smooth as possible. This may be done by pressing a lead sheath round the copper cable.

The Insulation.

Cables for extra high voltages are nowadays insulated exclusively by paper impregnated with some insulating compound. Paper tape, varying in thickness from 0.10 to 0.18 mm., is wrapped round the conductor either with or without overlap. The requisite number of layers are put on to obtain the wall thickness desired. If the cable is to be a three conductor cable, three of these insulated conductors are cabled together. The interstices are filled with spun paper, and the cable is then generally again wrapped round with paper until the same wall thickness is reached as for the conductor.

A few years ago Manilla paper was still considered the only quality which could be used in the manufacture of cables for extra high voltages. Manilla paper is produced chiefly from old hempen ropes. Various impurities are then unavoidably mixed in the paper, causing high dielectric losses in the insulating layer. Even when paper of pure Manilla began to be employed, the losses proved high. Not until pure cellulose was used, which by the way first happened in Sweden, was it possible to reduce these losses. Principally sulphate paper is used, and such paper is nowadays supplied to practically every cable works in the world by Swedish paper mills.

After being spun round with paper, the cable is dried in hermetically closed vessels, which are heated and put under vacuum to remove all moisture from the cable. The impregnating medium, which has previously been well dried, is then introduced under vacuum into the vessel until the cable is completely covered. The vacuum is then removed, and the impregnating medium put under pressure, penetrating and filling up all the empty spaces in the paper fibres. The high pressure applied to the compound hastens this penetration. The cable is then allowed to cool in the compound bath to the temperature of the room.

The impregnating material for high voltage cables nowadays consists practically exclusively of pure mineral oils. Although resins are used in some cable works to limit the movements of the oil caused by variations of temperature, this causes higher losses in the insulating layer.

Rather high demands are put on the oil. It is of course of special importance that its dielectric losses are as low as possible and its disruptive strength as high as possible. A property which to the layman perhaps would not seem to matter much, but which is of great practical importance, is its coefficient of expansion, one of the greatest difficulties in making a cable for high voltages being that the oil when heated expands more than the other materials in the cable. When the temperature rises, the oil therefore tends to expand the lead cover to a larger diameter. Subsequent cooling will cause the oil to contract, leaving cavities with vacuum. Corona discharges are liable to occur in these cavities, and the number and size of these vacuum blisters determine the durability of the cable.

The insulation contains approximately equal quantities by weight of paper and oil. Well dried paper having a very high insulating resistance and small dielectric losses compared with the impregnating oil, the latter might easily be thought to determine the characteristics of the impregnated paper. This is also the case as regards insulating resistance and dielectric losses. The disruptive strength of the impregnated paper, on the other hand, is higher than that of oil, and is also dependent on the density of the paper.

The Lead Sheath.

To prevent moisture penetrating the insulating layer of the cable, the insulated and impregnated cable is provided with a seamless lead sheath, generally composed of pure lead. For extra high voltage cables a cover of lead alloy (3 per cent. of tin) is preferable, as this will have greater mechanical strength and offer greater resistance to distension when the oil is expanded by a rise of temperature.

Armouring.

As a protection against mechanical damage, the cable is armoured with iron strips, round wire, or shaped wire, according to whether the cable will be most exposed to direct impacts or pulls. Several layers of impregnated jute are put both inside and outside the armouring. In high tension cables it looks as if the strip armour would be replaced by shaped wire, as this makes the cable more flexible and consequently easier to lay. In single phase cables, shaped wire armouring alone can be used, as overlapping strips, forming a closed magnetic circuit round the cable, would cause very large losses. The selection of suitable material for, and the design and application of, the armouring is of the greatest importance for obtaining minimum losses.

Some Modern Cable Designs.

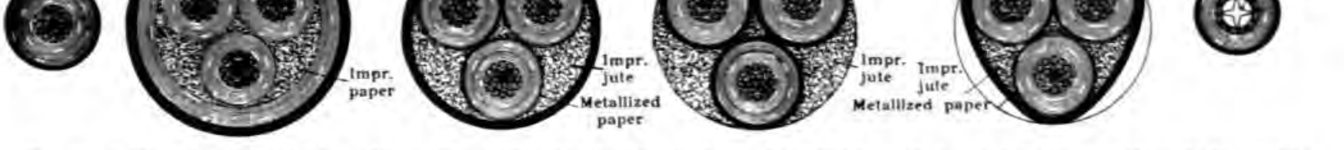
Modern cable making has produced many types of cable of more or less standard design, each with its special sphere of utility. As a supplement to the general notes on the design given above, we will here describe some of the more important of these designs.

The single conductor cable, consisting of one conductor, insulated, covered with lead, and possibly armoured with flat wire, is particularly suitable for extra high voltages, the dielectric being perfectly uniformly distributed between the conductor and the lead sheath, and the voltage distribution is therefore uniform, and there are no tangential potentials. It has the drawback mentioned above, however, that it cannot very well be armoured with strip iron on account of the large magnetic losses which would then be caused. It must therefore either be used unarmoured, or armoured with wire of special quality iron, which will of course be more expensive. Special care must also be given when determining the pitch at which the armouring is put on. Some hard aluminium alloy with great resistance might in future be used for armouring this type of cable.

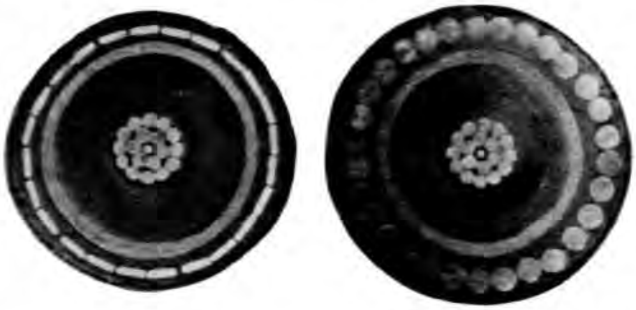
In the type with insulating cover, each conductor is separately insulated. Three conductors are cabled with fillers, provided with an outer insulation, and enclosed in a common lead sheath. This type of cable has the drawback that the electric field is not uniform, and that tangential potentials appear on the surface of the insulating layers of each individual conductor. The design precludes homogeneous insulation, and the cable will contain as much passive oil in the fillers as active oil in the insulating layer. One advantage, however, is that the cable may, without appreciable losses in the armouring, be armoured with strip iron or iron wire for multi-phase working, as the magnetic fields of the several phases will practically neutralize one another in the armouring. The lead sheath losses are also of small importance in this type.

The *Höchstädter-* or H-cable consists of three insulated conductors cabled together, each conductor being first wrapped in a metallized paper over the insulation. The thickness of the insulating layer is computed for the working voltage divided by the square root of 3. The metal coatings on the paper tapes are in contact with each other and with the lead cover. The object is to obtain a uniform electrical field in the cable. This advantage, however, can only be partly utilized, as the heat produced in the cable cannot be sufficiently rapidly transferred from the centre of the cable. The consequent inequalities of temperature also causes an asymmetrical electrical field. The cabled conductors are not surrounded by any outer insulation, but only by fillers and a common lead sheath. Like the cable with insulating cover, the H-cable contains twice as much oil as required for insulating purposes, as the filler, which lies outside the electrical field, must also be impregnated with the same high quality oil used for the actual insulating layer. This cable may be armoured in the same way as the cable with insulating cover.

The *lead sheathed phase-cable* consists of 3 lead covered single conductor cables, cabled together into one cable. It has the same electrical pro-



Types of High Voltage Cables. From the right: Single Conductor cable; Cable with Insulating Cover; Höchstädter cable; Lead-sheathed phase cable; Three-cornered cable, and Expansion cable. The copper section of each cable is 95 mm², and they are designed for a tension of 33 000 volt. Unarmoured cables are illustrated. Scale c. 1 : 2.5.



55 000 V, 120 mm², single conductor cable, supplied to the Gothenburg Electricity Works. This cable is connected in the new power transmission line Marieholm—Lundby (ERA No. 4 1929, p. 78), and is partly land, partly marine cable. The land cable is seen on the left, the marine cable on the right, and the corresponding cross sections are shown underneath.

perties as the H-cable. The lead covers being better able to conduct the heat from the centre of the cable, the electrical field will be more symmetrical. The electrical properties of the filler matter little, and this need not be impregnated with high grade oil. The oil quantity is therefore only half of that in the H-cable, and all oil is active. The vacuums tending to form when the cable cools are insignificant in comparison to those arising in the H-cable. The cable will stand a higher maximum load than the previously described types, with the exception of the single conductor cable. Lead covered phase-cable, like the H-cable, may be used for a working voltage up to 55 000 volt. For higher voltages the dimensions and weight of the cable will be so large that difficulties of transport and handling make its use impossible. Ordinarily, these types are only used up to 33 000 volt.

The three-cornered or SO-cable is in fact an improved H-cable, the quantity of passive oil being reduced by giving the lead sheath a three-cornered shape. Theoretically, the lead sheath should be able to follow the movements of the oil when the temperature varies. Whether it actually does so has not been definitely established. The plane surfaces of the lead sheath are also liable to form folds when the cable is laid, which will cause vacuums in the insulating layer.

The *expanding or X-cable*, British Patent No. 266 385, is characterized by having compressible devices enclosed in the lead sheath to counteract the expansion and contraction of the oil, preventing vacuum blisters in the insulating layer. These devices may be placed either inside or on the conductor, or else immediately underneath the lead sheath. When the temperature rises and the oil expands, these are compressed and make room for the increased bulk. When the oil is cooled down, they assist in driving it back into the insulating layer, compelling the oil to move radially in the insulating layer, along the shortest possible path.

The *screw or S-cable*, Swedish Patent number 67 330, differs from other types in the insulating paper tape being cut in curved strips and wound overlapping, so that the paper layer forms a kind of continous screw-shaped tube. This avoids the small joints between the papers in cable wrapped with ordinary paper tape, which easily cause blisters. This type of cable can be better and more rapidly dried and impregnated, and offers less resistance to the movements of the oil when the temperature changes. The drawback is that the cable is less flexible. This type of cable is used for single conductor cables, and it is then possible to lengthen the cable without ordinary joints, as the screw shape of the insulation enables the cable ends to be pushed into one another and screwed home, when the lead covers, meeting end to end, are soldered together or joined by a simple sleeve joint.

The insulation of the *asbestos or A-cable*, Am. Patent No. 1 665 191, consists of alternate wrappings of asbestos paper and cellulose paper, whereby a better distribution of the potentials in the insulating layer is obtained. Asbestos being a semi-conductor, the asbestos layers cannot form bridges between faults in the insulating layer, and no summation of separate faults can occur, as is the case if a metal layer is used. In an ordinary cable the oil is subject to curious radial displacements. One theory assumes that the electroosmotic pressure arising in the cable drives the oil from the central part of the insulating layer. If this theory is correct, the design with asbestos layers should largely prevent the harmful effect of osmosis. The oil will then collect on these layers instead of settling on the conductor and the lead sheath.

The *Pirelli* cable is a single conductor cable with hollow conductor. The hollow conductor serves as a canal for the movements of the oil when the temperature varies. The oil passes through the canal to the cable joints, where expansion chambers are fitted. The sections of cable form communicating ducts, along which the oil moves when the temperature changes. If these sections are long, so that the oil has a long way to go, there is some risk of it not being able to move quickly enough with the variation of temperature, and vacuums may then be formed. This type of cable is used for up to 132 000 volt.

Recent Theories Regarding the Design of High Tension Cables.

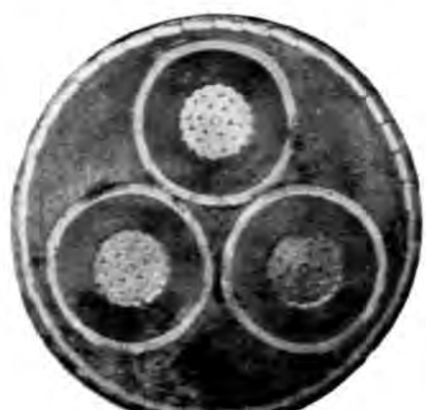
Space does not allow a detailed description of the latest experiences of cable manufacturing. We may note, however, that purely speculative theories have largely had to be abandoned. Apart from purely theoretical factors, a great many practical circumstances influence the design of a cable. Variations of temperature, for instance, which occur in manufacture and testing as well as in transport, laying, and working, play such an important part that special consideration must be given to them.

Theoretically, the voltage gradient next to the conductor is the largest, and should therefore be decisive for the cable design. But if we inspect a cable which has been used for some time, we will find that any charring in the insulating layers has not occurred next to the copper conductor, but in the centre of the insulating layer, and that there is a scarcity of oil here. There may be two reasons for this. The oil may have expanded and pressed out the lead sheath when the temperature has increased, and subsequently not been drawn in again when the temperature dropped. Another explanation is the abovementioned theory that the electroosmotic pressure in the insulating layer squeezes the oil both towards the conductor and towards the lead sheath. The cable should therefore be designed for the voltage gradient in the centre of the insulating layer.

One problem, where opinions will certainly be revised, is the relation of the insulating wall to the working voltage. On the basis of thorough investigations of cable materials and improved manufacturing methods, the Sievert Cable Works are prepared to manufacture cables which are considerably lighter than the specifications of the 1928 VDE standards. The fundamental idea is that by the use of a thinner insulating wall the drying and impregnation of the cable will be improved, and the oil quantity reduced, which in its turn will reduce the risk of vacuum blisters from variations of temperature. In spite of the lighter design, even greater reliability should be attained than in cables according to the German standards. Practical experience of cables made on these principles has fully confirmed this.

It is as yet very difficult to predict the future design of cables for extra high voltages, but one

The new 33 000 V. cable of the Stockholm Electricity Works is a lead sheathed phase-cable of 3×150 mm² section. The land cable, shown here, is armoured with flat wire, and the submarine cable with round wire.



thing is certain, and that is that cables with canals is not the correct solution, even if that design can be regarded as an important advance.

Cables incorporating axial expansion chambers, i. e. cables with hollow conductors where the canal itself is an expansion chamber containing compressible devices, probably hold out better prospects, as the oil quantity in the cable and the distance travelled by it will be reduced to a minimum. Similarly, the laying of dried but un-impregnated cable, the drying and impregnation of which is subsequently completed, will probably be much used in future. British Patent No. 311 774 may be given as an instance of this. In this type the cable, when laid, is embedded in concrete or reinforced concrete, which prevents the lead sheath from expanding. This prevents the oil from moving when the temperature rises, but the pressure is increased, increasing the disruptive strength.

R 3020

Group of members who were present at the first course in Falun Nov. 13th, 1925, taking part in the course March 13—15, 1931.

Swedish Electricity Meters, particularly some special types.

By Mr *O. Jöhnk.*

Introduction.

During the years immediately preceding the war, electrification in Sweden had become so general that the annual expenditure for imported electricity meters amounted to 1.5—2 mill. kronor. The Swedish electrotechnical industry, particularly the electrical engineering industry, was at this time far enough advanced to compete successfully with foreign industries in the supply of many kinds of electric materials, but the manufacture of electricity meters—this indispensable detail of practically every electric plant—had not yet been attempted.

The leaders of some of our large electricity works and others then began to ask whether the demand in our country for electricity meters, at least of the commoner types, could not possibly be satisfied by home manufacture.

Widespread satisfaction was therefore felt when, after thorough preparation, the A.-B. L. M. Ericsson in the early part of 1914 decided to start the special branch of manufacturing discussed here. Many people thought that the foreign meter manufacturers had too long a start and far too large resources for Swedish manufacturers to be able to hold their own in such an unequal struggle. The sponsors of Swedish meter manufacturing, however, were fully aware of the great difficulties they would meet, not least in their sales campaign, from foreign competitors who, having obtained in Sweden a very good and rapidly growing number of customers of great purchasing power, wished to retain this, but they felt sure of being able to compete successfully even in this respect.

R 1450 Mr O. Jöhnk.

When designing the Swedish meters, full use was made of the experience gained up to the time of the war at some of the large electricity works in the country, and the experience of the factory from the extensive activity in allied electrotechnical branches also benefitted the new section for the manufacture of electricity meters.

The manufacture of the multitude of different parts of which every electricity meter is composed was distributed to the respective departments of the Stockholm factory, and new workshops and test rooms, provided with ingenious labour-saving tools and first class testing instruments and control devices, were fitted up for assembling and adjusting the electricity meters.

The usual types of electricity meters for direct, single phase, and 3-phase current, and overcurrent releases, were thus from the very first manufactured according to the best designs and methods of that period, and became extensively used in the rapid progress of electrification which took place in Sweden and the neighbouring countries during and immediately after the war, in both urban and rural districts. The export originally anticipated to foreign countries was of course prevented by the war, and subsequently by other conditions, but in, for instance, 1920, more than 20 000 L. M. Ericsson electricity meters were supplied to Swedish electricity works and distributing organizations alone, and the first 100 000 was exceeded the following year, in addition to which at that time about 15 000 overcurrent releases had been made.

In various countries, and not least in Sweden, the consequences of the war accelerated the attempts at rational simplification and improvement of designs and manufacturing methods in nearly all branches of industrial activity. The production of electricity meters was also largely affected by this development, and many improvements of detail resulted. Simultaneously, new methods of charging for electricity consumed were developed in order to stimulate an increased and more practical use of electrical energy, which also necessitated quite new types of electricity meters.

During recent years, when the difficulties of the post-war years had been overcome, energetic and purposeful constructive work has therefore been done in the L. M. Ericsson electricity meter department, favoured, we are gratified to say, by suggestions and inventions in this branch, made in the meantime by Swedish engineers and designers.

As before, this constructive work aimed at obtaining reliable, lasting, and accessible electricity meters, giving very exact measurements over the greatest possible part of their range, and consuming little power. In addition, special attention was given to making the new Swedish types of electricity meters of small weight and volume, convenient to handle and adjust. They are now manufactured under such rational conditions that, in spite of the drop in the purchasing power of money, they can be supplied at lower prices than the older, pre-war types.

Foreign meter makers have for some time been quoting incredibly low prices, certainly below cost, in the Swedish market, in some cases about half of the low prices charged in their own home markets, in other words pure dumping, but this abnormal condition can hardly last. The leaders of the Swedish electricity meter production, however, are now confidently looking forward to the future, well aware of the value of the Swedish designs, and of the strong economical and technical organization behind them.

Some of the new types of Swedish electricity meters for ordinary single tariffs, protected by a number of patents, are already thoroughly tested in practical use, and rationally manufactured in large quantities at very low prices. The measuring principle, design, and properties of these types are described below. Subsequently, more detailed information regarding some special meters which are also quite ready, and which will probably prove highly interesting, will be given.

D.C. meters.

The L. M. Ericsson electricity meters for direct current are so-called ampere-hour meters, designed on the magneto principle, which makes the apparatus simple and straightforward, with good measuring properties. The number of ampere-hours consumed in the plant is measured by meters of this type, but, provided the voltage is constant and the gear ratio between the armature and the recording device suitable, kilowatt hours are registered.

This type of meter has gradually been improved during the 17 years elapsed since L. M. Ericsson began manufacturing it, and—judging from unanimous testimonals from a great number of Swedish electricity works—it is no exaggeration to say that it is now considered by meter experts to be the best obtainable of its kind. To the Stockholm Electricity Works alone, about 50 000 D. C. meters have so far been supplied of the latest L. M. Ericsson designs, which have fully met the very high demands made by this very large D. C. supply plant.

This type of meter has also been used for some special purposes, e g. as a so-called call-minute meter in the L. M. Ericsson telephone plants, and as a distance meter in the Svenska Aktiebolaget Logg automatic electric logs; time unfortunately does not allow a detailed description of these special designs.

A.C. meters.

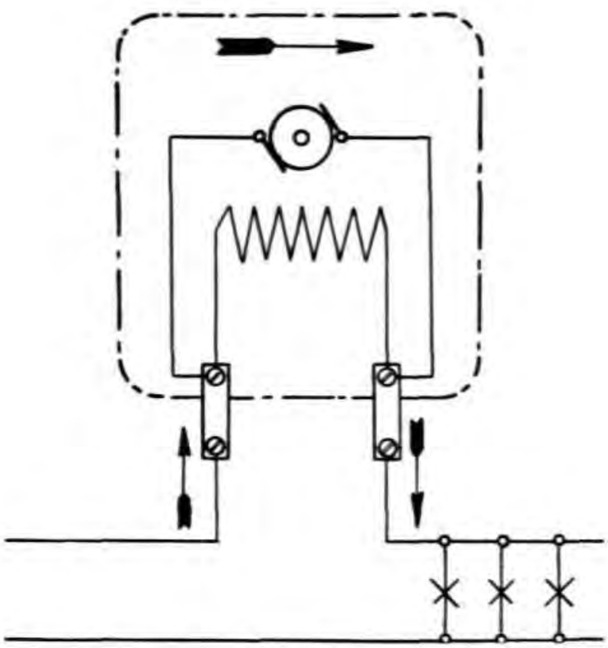
In recent years, the design and measuring methods of A. C. meters in particular have been highly developed.

B 1532

D.C. ampere-hour meter for recording kWh, type L4.

R 1534

D.C. ampere-hour meter for recording kWh, type L4, protective casing removed.



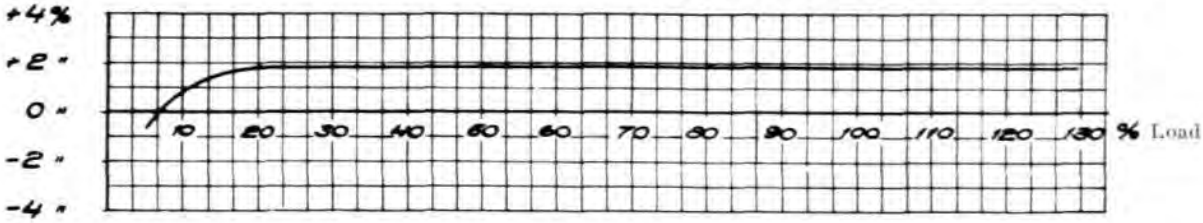
R 1533 Circuit diagram for D.C. ampere-hour meter, for recording kWh, type L4.

The L. M. Ericsson A. C. meters are designed on the Ferrari principle, allowing a meter to be made in which the driving torque on the rotor is proportionate to the power consumption in the plant, and also the sum of the braking torques on the rotor proportionate to the speed of the rotor. The number of turns registered by the meter during a certain time will thus be proportionate to the amount of power consumed during the same time in the plant, i. e. the number of kW-hours.

Before L. M. Ericsson succeeded in producing the new A. C. meters, however, many minor problems had first to be solved, and great difficulties overcome with regard to design, material, and manufacturing processes. It would take us too far to mention in detail all these problems and difficulties, but some of the more important should perhaps be pointed out.

When designing the new A. C. meters, one problem was to diminish the consumption in the meter itself by a suitable design of the field magnet system, allowing nevertheless an increase of the field strength. The new patented design reduces the useless magnetic resistance in the magnet circuit, and thus increases the field strength considerably in comparison with earlier designs, while at the same time the consumption in the meter itself has been appreciably reduced.

The voltage coils in A. C. meters are frequently exposed to great stresses e. g. by atmospheric discharges. For greater protection against these, the voltage coils of the new Swedish A. C. meters are provided with bakelite paper of high insulating capacity between each layer of their windings, and in addition stout copper bands are soldered to the ends of the lacquer-insulated copper wire, and the whole coil is finally impregnated with acid-free insulation compound.



R 1535

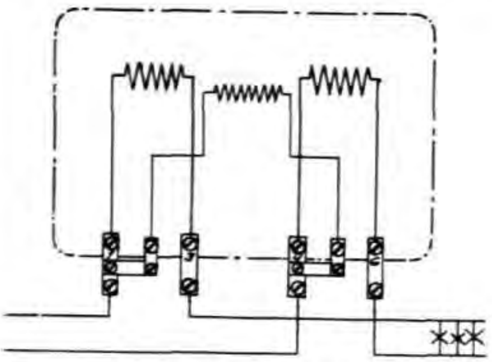
Correction curve for D.C. ampere-hour meter, recording kWh, type L4. The error as a function of the current at normal voltage.

The current coils are also wound with lacquer-insulated copper wire of large diameter, which greatly adds to the large overload capacity of the meter. The wire is wound on a press-moulded bakelite frame, which gives to the coil precision, stability, and a neat appearance, as well as great resisting power to possibly occurring high overloads with consequent heating.

The frame is lightly but strongly made of stamped sheet iron, and the terminal block is of press-moulded bakelite with sleeve terminals, i. e. the wire is introduced in a tube and held there by two stout screws. The sheet iron base is stayed by corrugations, while the cover and the lid over the terminal block are made of sheet brass.

The new L. M. Ericsson A. C. meter is not only characterized by a simple and straightforward design, easily accessible parts, and excellent measuring capacity, but also by small weight and volume. If the weight and volume of the new single-phase meter is compared with that of the next preceding type, we note that the new design weighs c. 1.4 kilos and the older c. 3.3 kilos, and that the volume of the new is c. 1 dm^3 and of the older meter c. 2.5 dm^3. These improvements have largely contributed to reducing the manufacturing costs.

The consumption in the voltage- and current coils of the single-phase meter has been reduced to 0.5—0.6 watt at a torque of 5 gr./cm. on the disc, which only weighs c. 23 grammes and is started by a few milliampères. At normal current and normal voltage, i. e. the values stamped on the meter, the disc only revolves about $^2/_3$ of a turn per sec., and the exactitude of the measurements is so great that there is practically no error between 5 per cent. and 150 per cent. of the nominal current, and very slightly more at



R 1537 Circuit diagram of single phase meter, type V5.

R 1536 Single phase meter, type V5.

either smaller or heavier loads, up to double the nominal load, which may be continuous without any harmful heating of the meter or other drawbacks. Usual variations of power factor, voltage, and frequency, do not appreciably affect this great exactitude of the measurements.

The friction-compensation is adjusted in the simplest possible manner by a conveniently ac-

R 1538 Single phase meter, type V5; pretective casing removed.

cessible micrometer screw, and the more important parts are easily exchanged, e. g. voltage and current coils, driving device, and the rotor with bearings and recording gear.

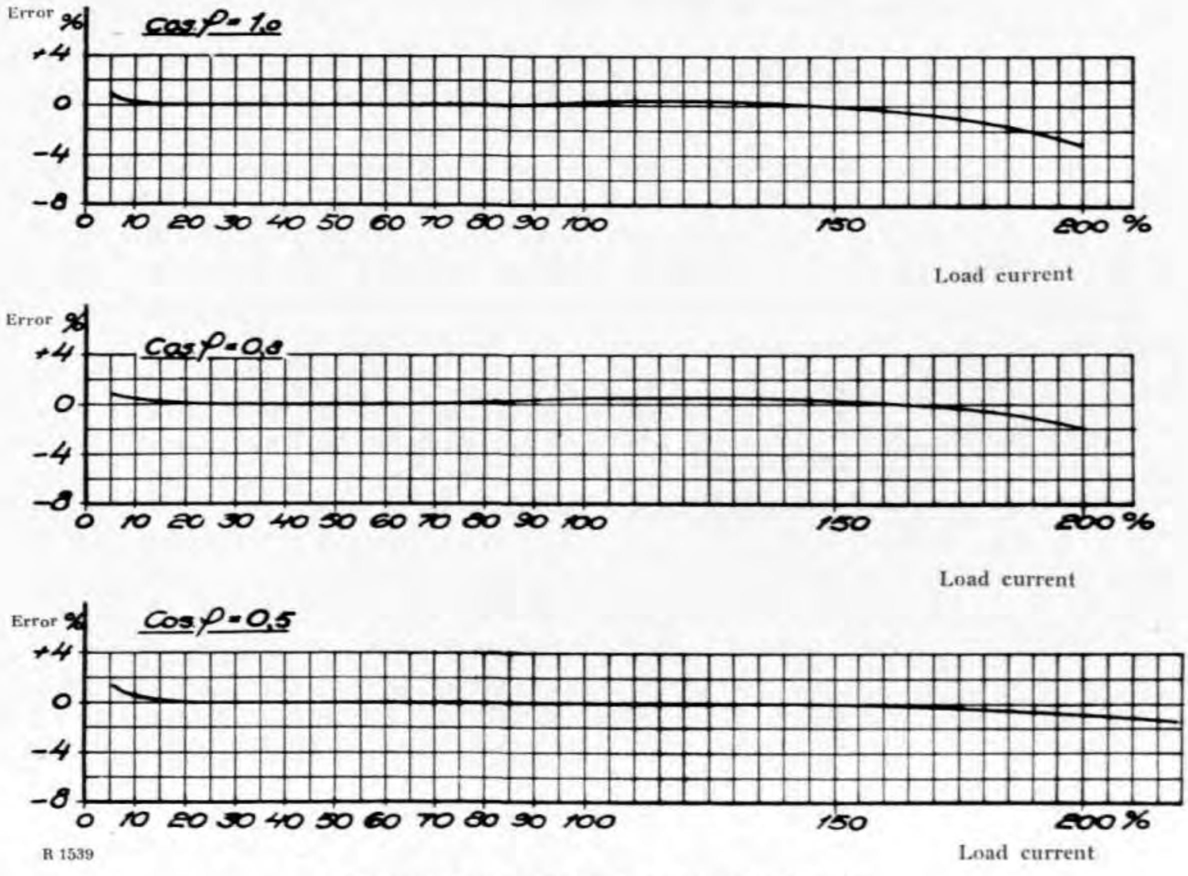
So far, about 10 000 single-phase meters of this new type have been supplied to Swedish electricity works and distributing organizations, which have unanimously praised it as being perfect in every respect.

The same principles of construction and design as are used in these single-phase meters, which after thorough tests are now manufactured on a large scale, are also employed in the new polyphase meters of various kinds which will soon be marketed.

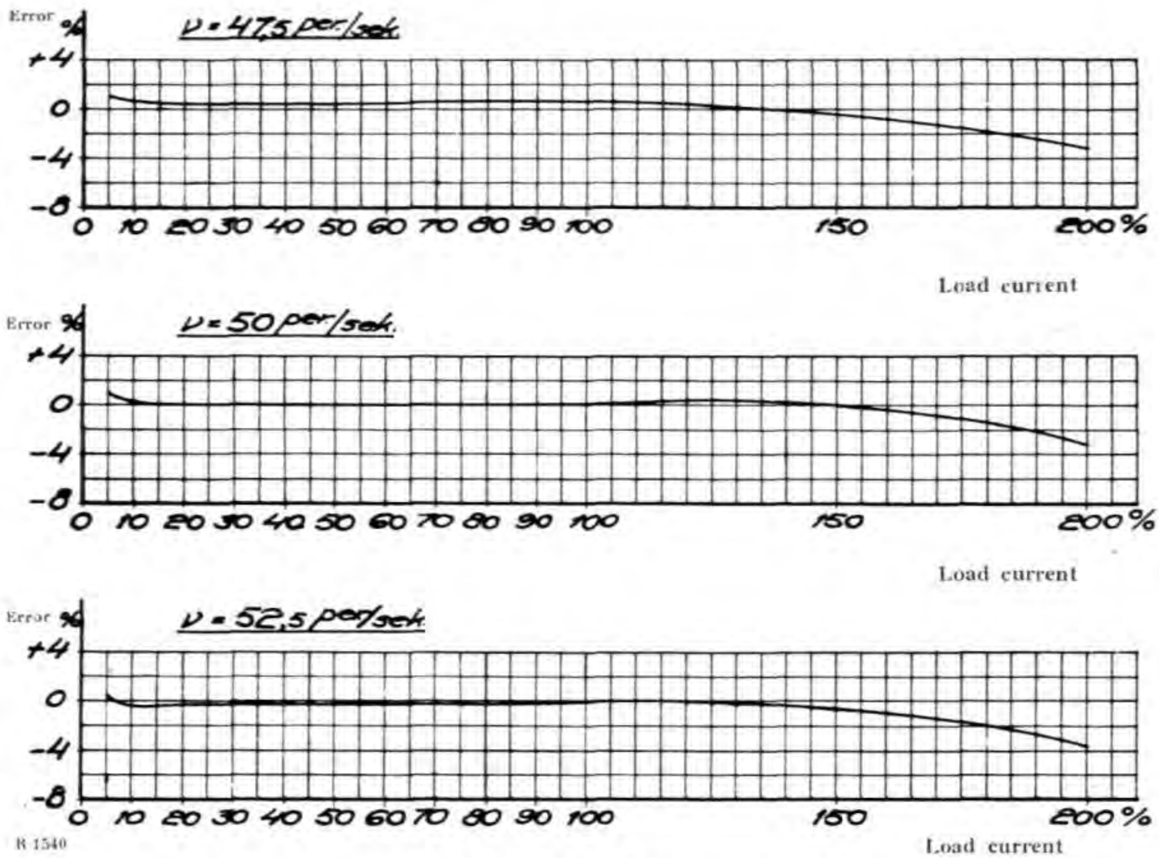
Special meters.

Many electricity works apply special tariffs even to small installations, making it advantageous for the subscribers to avoid load peaks as far as possible, and instead spread their power consumption more equally over a longer period, for instance by not using certain household appliances when a considerable part of the lighting installation or other power consuming device is connected.

For certain tariffs, ordinary so-called subtraction meters are for instance used, which record on a low tariff meter the kW-hours consumed at loads below a certain definite amount, the so-called subscription amount, and on a high tariff meter the portion consumed when the load has been larger. When these meters are used, the subscriber and the members of his household must, however, carefully watch that the subscription amount is not unnecessarily exceeded, and this can only be done by disconnecting by hand one apparatus or another which at the moment may not be absolutely necessary, generally some accumulating apparatus. Great vigilance is obviously required for this regulation by hand as, if one of these appliances is *disconnected* too late when the load is rising, part of the energy will be unnecessarily registered by the high tariff meter, and if the consuming apparatus is *connected* too late when the load is



Correction curves for single phase meter, type V5.
The error as a function of the current at normal voltage, normal frequency, and power factors cos φ = 1.0—0.8—0.5.



Correction curves for single phase meter, type V5.
The error as a function of the current at normal voltage, power factor $\cos \varphi = 1$, and normal frequency varying $\pm$ 5 per cent.

falling, the full benefit of the subscription amount is not gained.

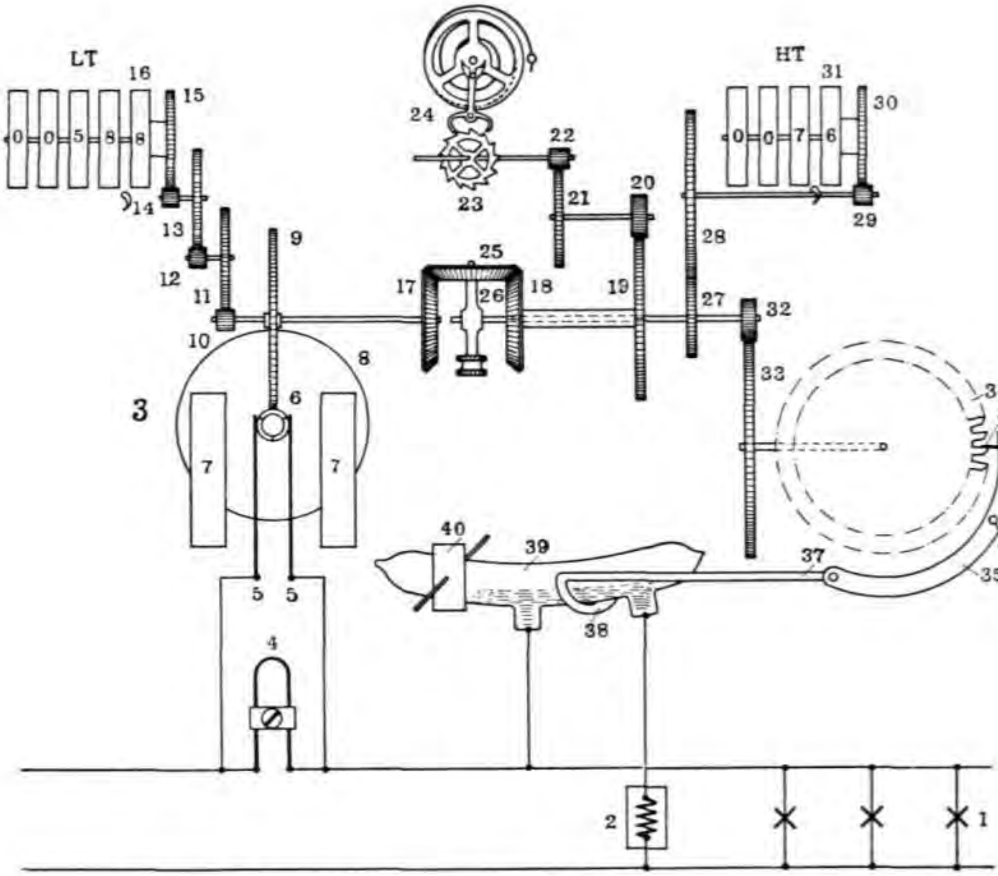
In cooperation between the Stockholm Electricity Works and L. M. Ericsson, a subtraction meter of peculiar design has been constructed, of which one type, with *manual* regulation of the load, is suitable for installations of the type just mentioned, while another ingenious special design automatically connects or disconnects one or more parts of the load as the total load fluctuates round the subscription amount. The subscriber thus has the important advantage that his subscription amount is utilized to the utmost *before* the high tariff meter registers anything, and this without any manipulations on his part. Both these types of L. M. Ericsson subtraction meters are manufactured for direct as well as for alternating current, and one for 3-phase current is now being completed. They are already extensively used, and are probably the meters of the future.

The principle of the first named type, i. e. that designed for installations with manual load regulation, differs from previous subtraction meters only by the necessary clockwork being incorporated in the meter and wound by its rotary system, while in earlier types the clock had to be wound by hand, or provided with a device for electrical winding.

In the type for automatic load regulation, a mercury switch and certain transmission devices are in addition incorporated in the meter.

Both the types just mentioned are provided with two metering devices, on the one hand the so-called total meter, which registers all the power consumed in the installation, and on the other the so-called peak meter, which registers all energy consumed at continuous loads above the subscription amount. To obtain the number of kW-hours consumed within the subscription amount, e. g. to compute the time of utilization of the subscription amount, the amount recorded by the peak meter must thus be subtracted from that registered by the total meter.

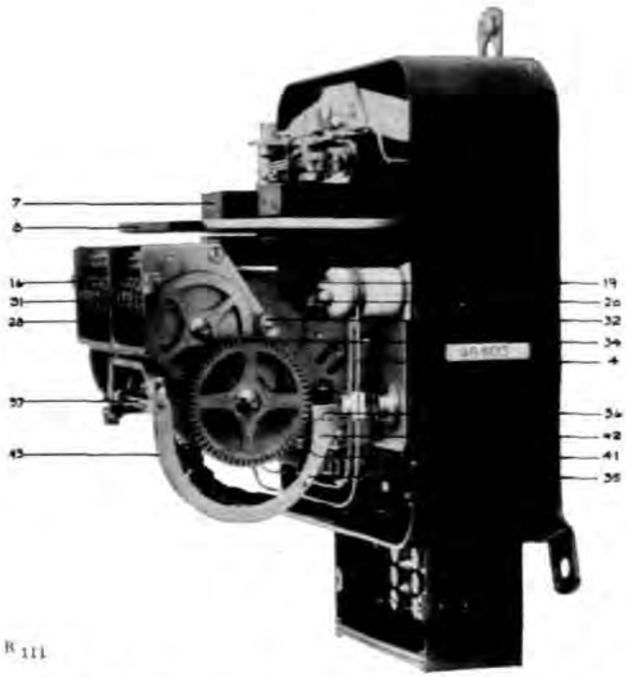
The total meter is driven in the usual manner by a gear from the meter armature, but the peak



R 103

Diagram of a household-tariff meter, type L4H, for automatic load regulation.

1	= Direct-acting consuming appliances.
2	= Accumulating consuming appliances.
3—8	= Parts of the driving mechanism of the meter.
9—15	= Gearing for the total meter.
16	= Total meter
17, 18, 25	= Planetary gear.
19—22	= Gear for the clockwork movement.
23, 24	= Clockwork.
26—30	= Gear for the peak meter.
31	= Peak meter.
32—43	= Automatic regulator.



R 111

Household-tariff meter, type L4H, protective casing removed.

meter is driven by a differential gear, one lateral wheel of which is actuated by the meter armature while the other wheel is moved by clockwork i. e. moves at a constant speed. The intermediate differential gear wheel will thus move at a rate which is proportionate to the difference between the variable speed of the armature and the constant speed of the clockwork.

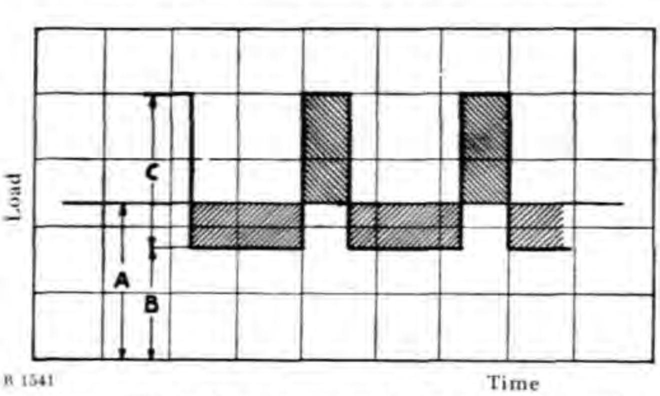
The armature speed corresponds to the total load of the plant, and the speed of the clockwork is geared to correspond to the subscription amount. This can be adjusted by exchanging two gear wheels. The design further prevents the peak meter from going backwards.

The clockwork, being driven by the meter armature, will thus stand still when the armature is still, and is driven continously only when the subscription amount is reached or exceeded.

The mercury switch in the automatic regulation type consists of a glass tube containing an indifferent gas and a quantity of mercury which, when the tube is inclined one way or the other, makes or breaks the connexion between two or possibly more contacts fused in the tube. This switch is actuated by the intermediate wheel of the differential gear.

An example will best illustrate the action of these L. M. Ericsson household-tariff meters for automatic regulation. The subscription amount *A* is for instance 700 watt, the non-adjustable portion of the load, here called the direct-acting load *B*, is at the moment 500 watt, and the adjustable portion of the load, here called the accumulating load *C*, is, for the sake of simplicity, made 700 watt in the diagram.

As long as the direct-acting load is wholly disconnected, which in practice will happen during the greater part of the night as well as repeatedly in the course of the day, the accumulating load remains continually connected. The total meter registers kWh:s corresponding to a consumption of 700 watt, and the remainder of the meter is at rest.



The household-tariff meter automatically disconnects and connects the load C, thus maintaining the average load of the installation at the subscription amount A.

At some time, for instance at night, the subscriber will perhaps have to turn on 500 watt, direct-acting, may be a hot plate of 450 watt and light of 50 watt. The immediate consequence will be that the total load on the meter becomes $B+C$ i. e. 1200 watt, and the subscription amount is thus exceeded by 500 watt. The intermediate differential gear wheel began to move as the load increased, when the ratchet wheel indicated in the diagram turns the mercury switch, which after a given time disconnects the accumulating load *C*. The total load now became equal to the direct-acting load *B*, i. e. 500 watt, in other words 200 watt below the subscription amount. The lateral wheel driven by the armature will now move more slowly than that driven by the clockwork, and the intermediate wheel with its transmission gear will thus be turned backwards until the mercury switch after a certain time again connects the accumulating load, and so on.

The difference between the subscription amount *A* and the direct-acting load *B*, multiplied by the time the accumulating load *C* was disconnected, will always be equal to the sum of *B* and *C* multiplied by the time *C* was connected, and hence the amount of excess power at a total load of 1200 watt will always be equal to the deficiency of power at a total load of 500 watt, at a subscription amount of 700 watt. The meter has thus, in this instance, permitted an average load equal to the subscription amount, 700 watt, without anything being registered on the peak meter, as the intermediate wheel of the differential gear, under the conditions of load just mentioned, has only been pendling backwards and forwards without actually getting anywhere.

If the direct load were increased to a value *higher* than the subscription amount, say to 800 watt, the total load on the meter will of course immediately be 1500 watt, which has the consequence that the lateral differential gear wheel connected to the armature will disconnect the mercury switch quicker than before, and this will now remain disconnected until the direct load is reduced below the subscription amount. Until this has happened, the peak meter will register the total number of kWh used at an overload of, in this case, 100 watt. The total meter has of course the whole time been registering the total power consumption in the plant.

The information just given shows how the household-tariff meter works at certain loads below and above a given subscription amount.

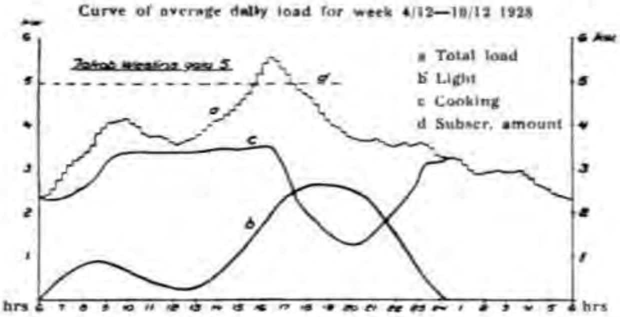
It might also be of interest to learn how these household-tariff meters with automatic load regulation function in practice, and this is to some extent shown by some diagrams obtained in control tests in a Stockholm house where all the flats use the household-tariff.

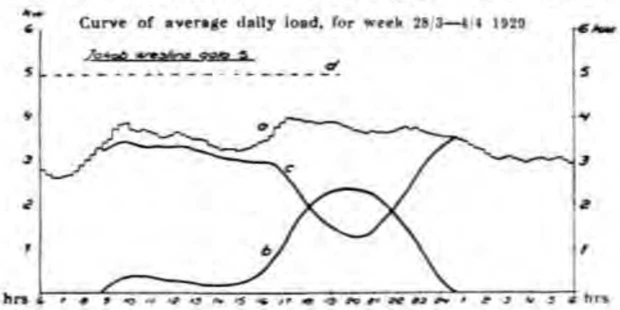
The number of flats in the house is 10, with a total number of 45 rooms and kitchens, and inhabited at the time of the test by in all 53 persons. The total power installed in these flats was 31 kW for cooking, 7.2 kW for light, and 4.9 kW for irons, vacuum cleaners etc., i. e. a total of 43.1 kW. The subscription amounts, however, only totalled 4.95 kW, indicated in the diagrams by the line *d*, thus an average per flat of 495 watt.

The household-tariff meters for automatic load regulation installed have allowed such good equalization that altogether only 4.1 kWh were registered on the peak meters during the week 4—10 December 1928. During the week 28 March —4 April 1929 the highest average load has only amounted to c. 400 watt, that is to say only about 80 per cent. of the subscription amounts have been utilized on an average. They are thus almost too ample.

The information now given, and the diagrams shown, will have indicated the very great importance of this type of meter, as it offers both to the subscriber and to the Electricity Works great advantages above other measuring methods.

This is made still more evident by some statistical information from the Stockholm Electricity Works. During 1928, 400 installations, aggregating a subscription amount of 165 kW, were fitted throughout the year with the L. M. Ericsson household-tariff meter for automatic load regulation. In these installations, 960 000 kWh were consumed in that year, of which 17 000 kWh on the peak meters, and the time when the full subscription amount was utilized was thus over 5 800 hours. During 1929 the number of meters of this type, connected during the whole of the year in Stockholm, had increased to 1325, with an aggregate subscription amount of 500 kW, and these installations between them consumed no less than 2 600 000 kWh, of which only





74 000 kWh, or about 2.85 per cent. of the total consumption, came on the peak meters, and the time when the subscription amount was fully utilized was then 5 200 hours. In 1930, the number of household-tariff meters connected all through the year rose to above 1 800, and the present number is probably somewhere about 2 500. These figures furnish clear and strong evidence that the L. M. Ericsson household-tariff meter is considered by the Stockholm Electricity Works to be a suitable measuring device for installations of direct-acting as well as accumulating appliances such as electrical cooking ranges, water heaters and, in an increasing degree, refrigerators.

When computing tariffs for use with this household-tariff meter, its mode of working must be considered. As a concrete example, we will assume that a customer consumes 300 kWh for lighting etc. and 1 500 kWh for cooking, for which he pays a fixed annual charge of 60 kr. (calculated according to the number of rooms) and a charge of 9 öre per kWh for power consumed. The customer wishes to install an accumulating water-heater of 300 W, and the charge for the power consumed by this will be 5 öre per kWh. The household-tariff meter should then be set for a subscription amount of 300 W. The total meter will then register all the power consumed in the installation, and the peak meter the portion exceeding a load of 300 W. When the load for cooking, lighting etc. is larger than 300 W, the water heater is definitely cut out by the meter.

The simplest way to determine the amount to be paid is to charge 5 öre for the power consumed according to the total meter and an additional 9—5 = 4 öre for all power consumed according to the peak meter. But this would give the customer that part of the cooking and light load which comes below the 300 W. limit at a cheaper rate than before, viz. at 5 öre instead of 9 öre.

The amount of compensation due to the electricity works on this account may be computed in say the following manner. A direct-acting cooking range is usually connected for an average of 3.5 hour a day. The power used for cooking below the subscription amount will thus be 3.5 A kWh per day, if A is the subschiption in kW, or, for 330 days, 330 · 3.5 A kWh per annum. If the surcharge be a öre per kWh, a charge of

$$\frac{330 \cdot 3.5 \cdot A \cdot a}{100} \text{ kr. per annum.}$$

should therefore be included in the tariff. If the figures of the example given are substituted, we get

$$\frac{330 \cdot 3.5 \cdot 4}{100} \cdot A = 46 \cdot A \text{ kr.}$$

or in round figures a subscription of 50 kr. annually per kWh subscribed for. The greater part of the lighting, estimated at $^2/_3$ or c. 200 kWh, will also come within the subscription amount, which justifies an addition of 200 · 4 öre = 8 kr. A certain amount, say 7 kr., should also be paid for hire of the meter. The charge for the meter and the addition for lighting might be added to the fixed charge.

The tariff would thus be composed as follows:

1) a fixed annual charge of 60 + 8 + 7 = 75 kr.;
2) an annual charge of 50 kr. per kW subscribed for;
3) a charge of 5 öre per kWh of the total meter; and
4) a surcharge of 4 öre per kWh of the peak meter.

The subscription amount in this instance being 0.3 kW, the annual charge according to 2) will be 15 kr., and 1) and 2) will thus total 90 kr. which will be the fixed annual charge payable by the subscriber.

If we assume that for various purposes the water heater heats an average of 50 liters of water per diem from 10° C. to 90° C. during 300 days a year, the power required by the water heater may be estimated at about 2 000 kWh per annum.

The total power required in a year by this subscriber would under these circumstances thus be about 3 800 kWh, which are registered by the total meter of the household-tariff meter and charged at 5 öre per kWh, i. e. 190 kr. to which will be added the surcharge of 4 öre per kWh for approximately 1 250 kWh, which are also registered by the peak meter, i. e. 50 kr. The total cost to the subscriber for 3 800 kWh used in one year would consequently be 330 kr.

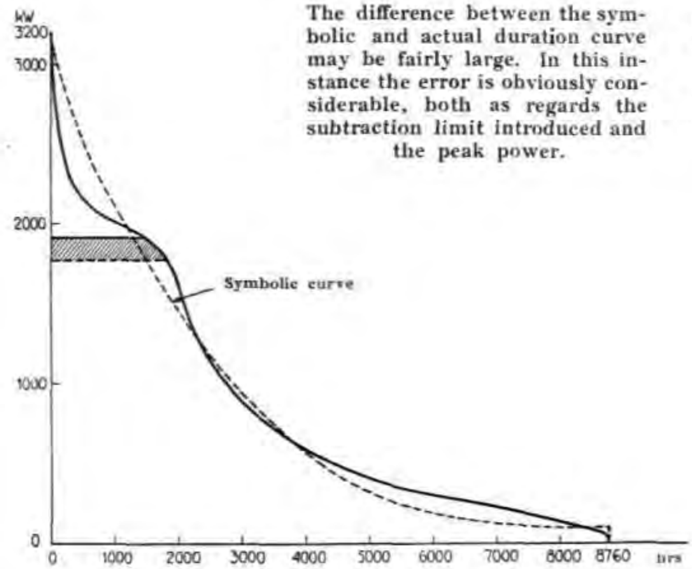
This type of meter also enables rural distribution organizations to let their shareholders or members subscribe for a cheap basis-quantity of power, when the tariffs allow this, without preventing occasional peak loads, which may be charged for at a price to suit each distributing organization.

Duration meters.

Subtraction tariffs have long been used by electricity works and distributing organizations for their larger subscribers. Determination of the subtraction limit of such a tariff required a diagram of duration to be computed and plotted by some means or other.

But the computation and plotting of a real duration diagram is not an easy matter, as anyone who has had anything to do with them well knows. Many different arrangements, measuring methods, and modes of computation have so far been tried, but it would take us too far to discuss them here.

A so-called duration meter has recently been designed and tested in the L. M. Ericsson Works, which in its approved form automatically registers 12 different power-values. The appearance of this duration meter can be seen from

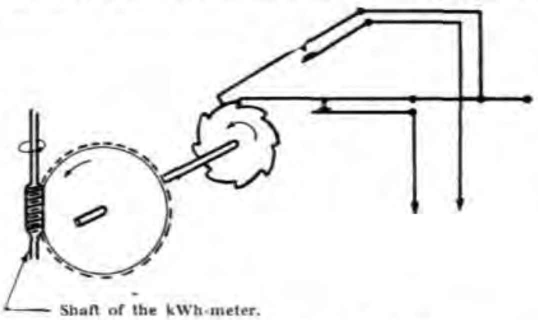


The difference between the symbolic and actual duration curve may be fairly large. In this instance the error is obviously considerable, both as regards the subtraction limit introduced and the peak power.

Actual and symbolic duration curves in an Electricity works.

the model exhibited. It is connected to a motor-type kWh-meter provided with a contact device which gives off current impulses for each revolution, or given number of revolutions, of the meter spindle. A switching-clock, for releases every quarter of an hour or other constant interval of time, is also required.

The duration meter contains an impulse collector consisting of two relays. This impulse collector receives the primary impulses arriving from the kWh-meter, and gives off a secondary impulse when for instance 10 primary impulses have been received, returning to its starting position when this secondary impulse has done its work. The secondary impulse affects an operating device, also consisting of two relays. This



Arrangement of the meter contact.

operating device successively affects 12 recording mechanisms by means of two operating shafts.

The device is so made that the first secondary impulse during each quarter of an hour will move mechanism No. 1 one step forward. The next secondary impulse during the same quarter of an hour moves mechanism No. 2, and so on, until the release takes place at the end of the quarter of an hour, when both the operating device and

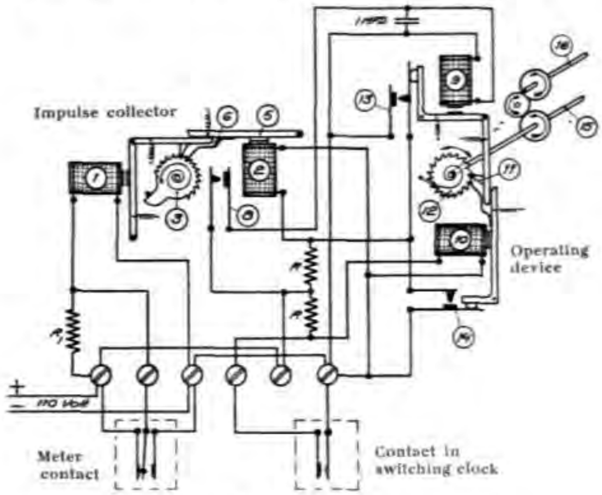


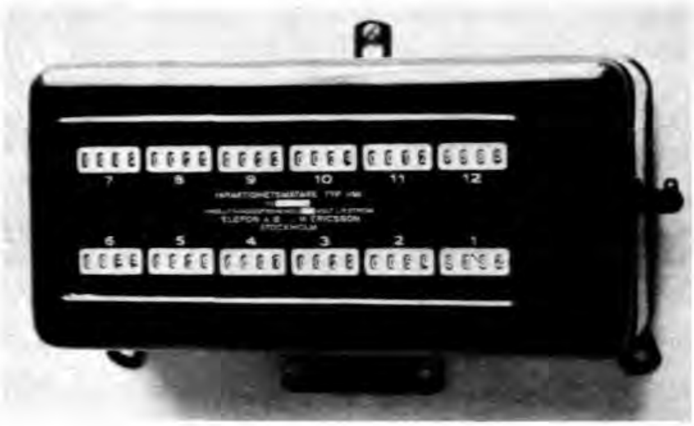
Diagram of duration meter.

the impulse collector return to their starting positions. During the next quarter of an hour the procedure is repeated. We see thus that recording mechanism No. 1 will count all the quarters of an hour when the load has been large enough for at least 10 primary impulses to have been given off. Mechanism No. 2 counts the quarters of an hour when at least 20 primary impulses have been given off, and so on. As all the primary impulses are of the same power, each recording mechanism will register the duration of a certain rate of power consumption per quarter-of-an-hour. The duration of each of 12 rates of power consumption are thus obtained, and the duration curve can be exactly plotted.

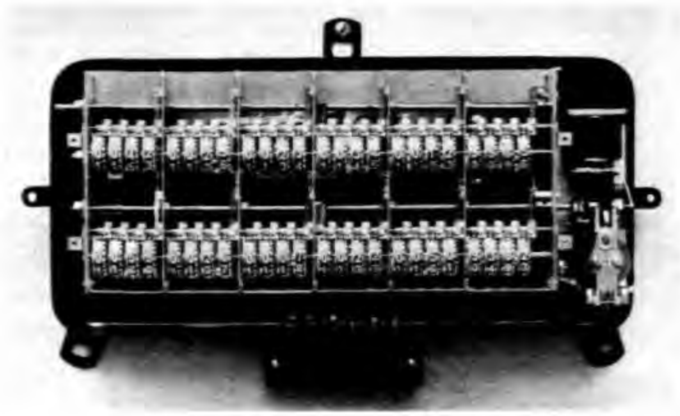
The duration meter is of great assistance to electricity works in the solution of many problems, but it may be profitably used in other ways also, for instance in gas- and water-works for investigations of gas- and water-consumption.

About a hundred duration meters have so far been ordered and supplied to the Board of Waterfalls, to the State Railway Board (for the electrified Stockholm—Gothenburg line), to several Swedish communal electricity works, and others.

Beyond the meters mentioned, other special meters of Swedish origin are designed by L. M. Ericsson, but as they will not be ready for manufacturing until some time this year, a description of them is premature.



Exterior of duration meter.



The duration meter with casings removed.

Summary.

The L. M. Ericsson production of electricity meters thus comprises ampere-hour meters for direct current, watt-hour meters for single- and 3-phase current, and several special meters for various purposes. For almost 20 years the designs and the manufacturing methods have been gradually improved, and the L. M. Ericsson electricity meters, the only obtainable Swedish-made meters, are nowadays without any doubt fully equal to the best foreign ones. They are also produced on a large scale, and supplied at very low prices.

Modern Industrial and Agricultural Installations.

By *E. Jensen*, Engineer.

As electric light and electric power is nowadays a necessity in practically every trade, and in every household also, it is of great importance that the installations are safe in every respect.—But how can this be assured? it is asked.—The reply to that question is best summed up in 5 points.

1. An installation must be carefully planned beforehand.
2. Good and suitable materials must be used.
3. The wiring must be made with care and common sense.
4. The installation must be used intelligently.
5. It must be kept in good repair.

E. Jensen, Engineer.

If unsuitable materials are used, a satisfactory installation obviously cannot be expected. The wiring materials formerly available for industrial and agricultural installations originally consisted of single conductors on porcelain studs, and later also of conductors in pipes. To begin with, both systems seemed to function excellently, but in time they have more and more distinctly proved that they cannot meet essential demands as regards reliability, security, and risks of fire. The weakness of the pipe system is the great difficulty of preventing condensation in the pipes, and the moisture condensed strongly contributes to the destruction of the line. Single conductors on studs may be said to be asking for mechanical damage, and in damp premises the insulation will be ruined.

As early as about 30 years ago, lead-covered conductors were used sporadically in this country in particularly difficult premises. When Liljeholmens Stearinfabrik was altered, for instance, part of the installation was made with lead-sheathed single conductors on porcelain studs. All joints and taps on the conductors were first insulated with rubber, and a lead-sheath was then carefully soldered on, i. e. the joint was made in practically the same way and of the same security as the rest of the line. Lead-covered multi-conductors were tried in Norrland pulp mills, and joined in ordinary armoured boxes which, when the joint was ready and insulated, were filled with cable compound. In southern Sweden similar conductors were used in a number of hospitals, in kitchens, cellars and other damp localities.

Denmark was the first country to make systematic efforts to produce really lasting materials for installations in difficult premises, on account of the large number of fires occurring in electrified farmsteads during the first period of electrification. A lead-covered conductor was manufactured in that country in 1912, the joints of which were made in porcelain boxes filled with ordinary cable compound. But reliability was hardly increased by this new material, as even the installations on this new system frequently were astonishingly shortlived and by no means excluded risks of fire. Work was continued, however, in the knowledge of being on the right track.

The lead-covered conductor first used in Denmark was insulated by impregnated paper, i. e. on the same principle as an ordinary underground cable. This kind of insulation proved far too liable to damage by moisture to be practical for this kind of conductor. The wiring operations required far greater care than could be expected from an average workman, and rubber insulation was therefore considered necessary. As the lead sheath frequently corroded very quickly—sometimes in a few months—an outer cover was considered necessary as a protection against corrosion. This gave rise to a rubber-insulated conductor, protected against all external damage by the airtight cover, and where the cover in its turn was protected against corrosion by an outer, impregnated envelope.

As the insulation had to be removed to make a joint or for connexion to some apparatus, effective protection against all moisture or corrosion was essential in such places. The earlier connecting boxes had not proved equal to this. For various reasons they were, for instance, frequently not filled up sufficiently with cable compound, but the joints were left more or less exposed and accessible to the action of the air. Although many designs had appeared, none of them were satisfactory. A fundamental drawback was that it proved impossible to control the joints or connect new lines when the boxes had once been put up and filled.

In this country, Sieverts Cable Works was the first seriously to tackle the task of effectively raising the installation methods from the exceedingly low level of the immediate post-war period. Extensive research and constructional work were devoted to obtaining a new installation system which might be expected to stand up to the most difficult conditions of industry and agriculture. The problem may be considered to have been solved when in 1923 Sieverts perfected their rubber-lead conductor, now known as the Gebe-system.

Fig. 1. Sievert Gebe-cable with iron band armouring and protection against corrosion.

The characteristic features of the Gebe-system are its cable, the packing used for connecting the conductor to the fittings, and the type of fittings.

The cable, fig. 1, has been made solid by filling all the space between the lead cover and the insulated, spun conductors with rubber. This has eliminated all the condensation characterizing the conduit system. The rubber used being practically non-hygroscopic, moisture cannot be absorbed in the cable from its ends, which on the other hand is possible in a cable where this space is filled with jute or similar fibrous material, e. g. the cable ordinarily used in ships. The Gebe-cable is consequently considerably less sensitive to any moisture possibly penetrating into the connecting boxes, if these should not be sufficiently caulked when put up.

The lead sheath of the Gebe-cable is protected against corrosion by a special protective envelope, consisting of alternate layers of compound and paper, with a final exceedingly well impregnated cotton braiding. As this "chemical" protection is of great importance to the durability of the cable in difficult premises, Sieverts has taken considerable trouble to produce a protection which is really effective in the long run. The layers of compound in the protective covering have been made the subject of special study. That the result of these efforts is good, is best proved by the fact that the resistance between the mantle and a water bath, in which the cable was immersed after having for a long time been exposed to corrosive action under conditions corresponding to the most difficult occurring in actual practice, has still been hundreds of megohms per metre of cable. The resistance was measured both in a straight cable and in one wound in a tight spiral.

The cable is supplied un-armoured, fig. 2 c, armoured with 2 iron bands, fig. 2 b, and armoured with wire wound in a spiral of great pitch, fig. 2 d. The wire-armoured type has great tensile strength, and is therefore primarily intended for pendulums, but is also suitable for use where long spans of wire are desired. The band-armoured type is intended for places where a permanently fixed cable is exposed to mechanical damage. Apart from the wire-armoured type, another pendulum cable, fig. 2 e, is now also made, in the form of a rubber tube cable containing two insulated carrying-wires. The cable is covered with a special lacquered braiding which, being very resistant to corrosion, makes the cable very suitable for use in difficult premises. The lacquer provides a very attractive finish, to which dust or dirt will not adhere.

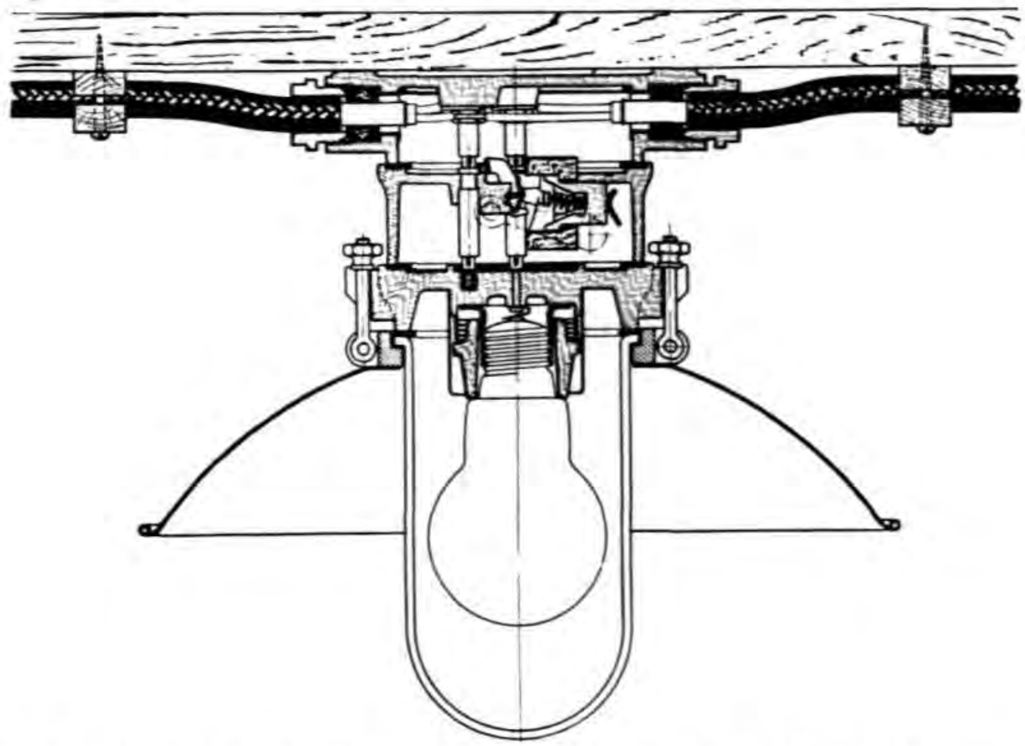
R 1916

Fig. 2. a) Gebe-cable with unprotected lead sheath.
b) „ „ iron band armouring and protection against corrosion.
c) „ „ protection against corrosion.
d) „ „ wire armouring and protection against corrosion.
e) Lacquered rubber-tube cable with insulated supporting wires.

The outer cotton braiding of the Gebe-cable for permanent wiring is impregnated in 3 different ways, viz., with black compound, with red lead, and with white special compound. The black cable is used in premises where appearances do not matter. That impregnated with red lead wherever the wires will be painted the same colour as the room, which is difficult with the black cable, as the compound strikes through both ordinary oil paint and lacquer. The white cable is used in premises painted white. It has the advantage that it is white from the first and thus will need no paint.

When designing the Gebe-fittings, the following stipulations were made:

1. The number of joints in the finished installation should be as small as possible.
2. By placing the switches on the lamp holder, switch loops would be entirely avoided.
3. All joints of a completed installation should be easy to control, and subsequent extensions on the same system should be possible.



R 1928 Fig. 3. Section of Gebe-fitting with switch, provided with glass globe and reflector with 180° angle of illumination.

4. The wiring must be as simple as possible, so that it can be done correctly even by a non-expert man without being botched.

An air-tight fitting, figs. 3 and 4, was made on these lines, the joints of which need not be insulated by cable compound, and which consisted of three principal parts—connecting box, switch, and lamp holder. The cable always has to be connected to the connecting box, but nowhere else. When this is done, the switch and the lamp holder are connected to the connecting box in the same way as a contact plug to a wall socket. Where a switch is not needed, the lamp holder is connected directly to the connecting box, fig. 5. The switch is operated by a string, which can be led to one or more suitable places.

Fig. 4. Gebe-fitting with switch, provided with glass globe and reflector with 120° angle of illumination.

R 1923

If, on account of the height of the room, the lamp holder cannot be put directly on the connecting box, it may be lowered to the desired height by a pendulum section, consisting of an upper cap with contacts fitting into the connecting box sockets, a length of cable, and a bottom cap with sockets like those of the connecting box, in which the contact pins of the lamp holder

R 1924

Fig. 5. Gebe-fitting without switch.

R 1922
Fig. 6. Gebe-pendulum with adjustable reflector of 400 mm. opening.

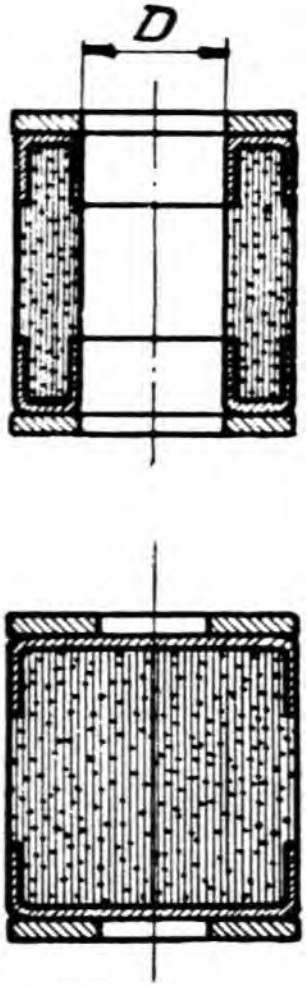
thus will fit. As all the wire entries in the boxes and caps have ordinary armour pipe threads, wall brackets as in fig. 7 can be easily made by fitting an upper cap to one end of an armoured pipe of suitable shape and a bottom cap to the other.

Switches and lamp holders are always made of bakelite. The connecting boxes, originally stamped from sheet iron, are now made of bakelite, fig. 8, and cast iron. The principal measurements of both types are identical, so that the other parts will always fit either bakelite or cast iron boxes. The pendulum caps are also made both of bakelite and cast iron. The advantage of bakelite compared to cast iron for the parts is that the former is lighter and, above, all, insulating. In addition, bakelite is of exceptionally pleasing appearance.

The third characteristic of the Gebe-system is the packing, fig. 9, used for making a tight joint round the cable where this enters the box. The packing consists of a ring of high quality rubber with a lead thimble on each of the plane end surfaces. When the cable and packing have been inserted in the box and the packing screw tightened, the rubber will consequently be enclosed perfectly air- and light-tight. Being in this way protected against all external damage, the rubber will retain its resiliency practically indefinitely, and consequently also its ability to keep the joint tight. The lead thimbles being in contact with both the sheath of the cable and the wall of the box, direct electrical connexion will thus be obtained between the sheaths of the several cables connected to one box, provided the box is of metal. This connexion between the sheaths is of great value for insulation measurements, as it is possible to control at one point of the line whether the whole line has good insulation between conductor and sheath, and consequently also between conductor and earth. The scheath connexion is also necessary because of the demand of the Electrical

R 1921 Fig. 7. Gebe wall-fitting.

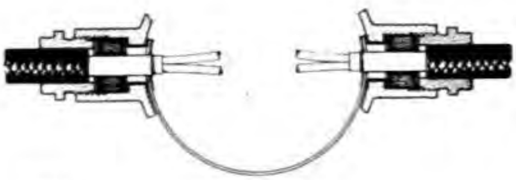
B 1920
Fig. 8. Gebe connecting box of bakelite.



B 1927
Fig. 9. Gebe packings.

Inspection that the sheath should be earthed. The bakelite boxes, figs. 8 and 10, have a special copper band connecting the various entry parts, and the sheaths are consequently automatically connected here also by means of the packing.

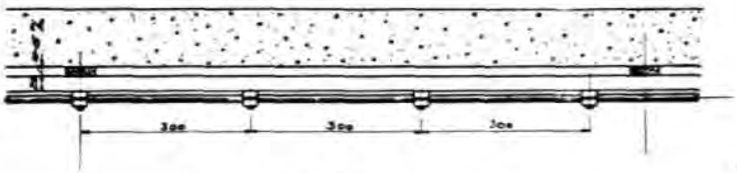
One detail of particular importance is that the packing in the Gebe-system is applied to the



B 1911
Fig. 10. Diagram of lead-sheath connexion.

lead sheath of the cable direct, figs. 3 and 10, i. e. tightening in the packing box is obtained by rubber and lead to lead. The reason for this is the known fact that a really tight fit cannot be obtained by placing the packing against the outer braiding of the cable which, consisting of cotton or other fibrous material, will act as a wick and gradually draw the moisture into the box.

Wiring with the Gebe-cable is a chapter to itself. When the Electrical Inspection directions for wiring with rubber-lead cables were made out, it was considered necessary, on account of previous experience, specially to recommend that the wiring be insulated i. e. that the cable should be fixed to an impregnated wooden board, by means of wood or porcelain clips, fig. 11. Walls and ceilings in farm buildings—and it should be remembered that the directions were chiefly intended for such buildings—are at times very damp. If the cable be laid directly on the wall, it will necessarily be much exposed to the effects of moisture. But if it is fixed some distance from the wall it will be warmer than this, and will remain comparatively dry. The reason for recommending clips which held the cable away from the board was that it was originally thought advisable to paint the cable regularly with protective lacquer. If the cable were fairly free of the wall, it would be easier to paint it all round. Cables are frequently easier to put up by this



R 1912 Fig. 11. Wiring on a board.

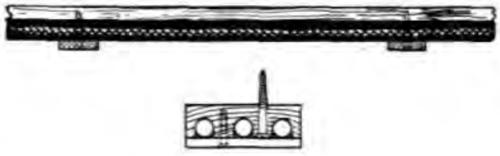
method. If a ceiling is to be wired at right angles to the rafters, it will not be necessary to go round each rafter, and cable will also be saved. When wiring masonry or concrete walls, there will be less plugging to do, as the board will only need to be fixed to the wall at about every second metre, while a cable must be fixed by something like three clips per metre. If several cables are fixed on one board, a corresponding amount of labour will be saved.

As the advantages of the Gebe-system in the course of years has led to its increasing use in all kinds of industrial premises, irrespective of any considerations of risk, the above method of wiring has accordingly been abandoned in favour of other methods, adapted to local conditions.

The objection to wiring on boards has often been made that too little attention is given to appearances. To remedy this, strips of wood grooved for the cable, fig. 12, have sometimes been used. When the strip is fixed and ready for the wiring, it is painted with cable lacquer before the cable is put in. The width of the groove being adapted to the thickness of the cable, the latter will stay put in the groove. As a precaution, bits of wood or sheet metal may be nailed or screwed across the grooves at suitable distances apart. This system is undoubtedly excellent and deserves to be more widely used. One merit is that it is no more expensive than the usual method of fixing by wooden clips on wood strips. The grooving costs little, even if it cannot be done on the spot. The cross strips are cheaper than the ordinary wood clips, and fewer of them will be needed. When several cables are put on the same board, the method will obviously be still more advantageous.

In dry, or at any rate not too difficult, premises, the cable is nowadays frequently fixed direct to the wall with ordinary iron clips, fig. 13. One common clip is used for several parallel cables.

In factories where the roof trusses consist of

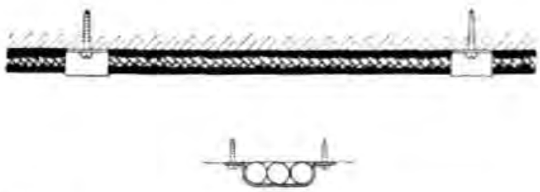


R 1913

Fig. 12. Wiring on grooved board.

two angle irons fixed a few mm. apart, the simplest way is to hang the cable in U-shaped iron strips, fig. 14. The shanks are pushed up between the angle irons and bent round their top edges. Another simple and effective way of fixing cables to these trusses is to knock in oaken wedges between the irons. These will bear a considerable load, and still more when the screw has been screwed into it. For a single cable, the sheet iron strips are probably the simplest way, but for several cables it is usually best to fix a wooden board to the oak wedges. Wedges may also conveniently be used for the fittings.

When large bunches of cables are to be put up together, the simplest way is sometimes to lay them all on a specially arranged cable shelf



R 1914

Fig. 13. Wiring direct on the wall, using a common clip.

wherever the cables are running horizontally. They may lie loose there as long as they are prevented from falling down.

Certain buildings are very difficult to wire at all, as is for instance the case with modern boiler rooms. Some difficulties may be avoided

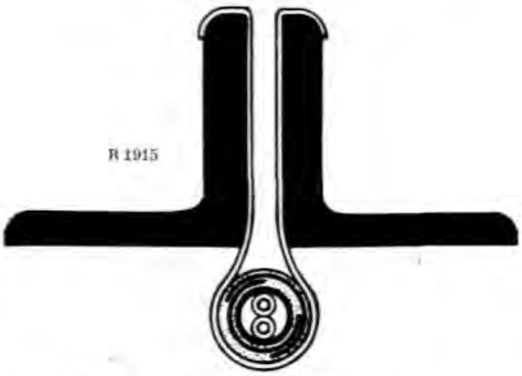


Fig. 14. Cable suspended in a roof-truss by a strip of hoop iron.

by attaching cables and fittings to a steel rope, which naturally must be firmly fixed and sufficiently tightened by a turnbuckle. The cables can simply be lashed to this rope, and the fittings fixed by special clamps.

The same way may often be convenient in modern concrete factory buildings with high girders in the ceilings. The carrying rope should then be fixed to every girder so as not to be exposed to unnecessary stresses. If conditions are suitable, wiring is easily done in this way, and a great deal of cable can be saved.

As long as the cables can be fixed on wood, the wiring offers no great difficulties. But if the wiring has to be done on iron or concrete —and the latter is now very common—the boring of holes for the screws will take a lot of time, if no special arrangements are made. As we have already mentioned, the work is facilitated by the use of wood strips, as the number of holes required is only a fraction of that needed for fixing the cable directly on the wall. Whatever method is used, the work becomes much easier by using electrical or pneumatic tools for boring the holes. In some of the large plants recently built in this country considerable savings, both of costs and time, have been effected by the use of such auxiliary tools. When fixing apparatus or wiring in stone or concrete walls, the holes must be properly plugged. Wooden plugs, notched to make them stick properly in the plaster, were formerly usually employed. In dry rooms this method is usually good enough for small stresses if properly carried out, but it cannot be recommended in damp places and where the strain is great. In recent years the British Rawl-plug, consisting of spun jute yarn, cabled without any central core, has been fairly extensively used. The rope formed is impregnated with glue to hold the fibres together when cut to the proper plug lengths. When the screw is screwed home, the plug splits and if the hole is the right size for the plug the fibres are pressed hard against the sides of the hole and hold the screw well. Another common method is to roll up strips of lead into a plug of suitable thickness for the hole. Such lead plugs are very strong. The quantity of lead required being small, the plugs are cheap, and experience has shown that the labour of making them may be disregarded, as a handy fitter will roll a plug in a moment.

One way which has long been used when fixing large objects in concrete walls is to grout iron bolts into them. The objection, however, is that it is difficult to get the bolts fixed in exact positions, but the method may be considerably improved by mixing the cement with waterglass. One of our sulphate mills has used it with very good results for many years whenever anything, from large motor brackets to Gebe-materials, has to be fixed in concrete, brick, or stone walls.

Even though the Gebe-cable will last under the most difficult conditions, there is no harm in exercising care when passing it through walls. In damp premises there is always some risk of condensation in the holes made, unless special precautions are taken. As it is unnecessary to expose the cable to such risks, draughts through these holes should be stopped. If the cable is passing through a built up wall, the part which will rest on the masonry may suitably be wrapped in a layer of jute fabric (fig. 15) soaked in some compound of low melting point or simply dipped in tar, and the hole filled up with cement mortar, when the cable has been put in. If the cable is taken through a wooden wall, the wrapping should be sufficiently thick to fit tightly into and stop up the hole.

When carrying cable through walls between dry premises, there is of course no need for any extra protection against corrosion.

When the cables are carried through floors, care should be taken that they are not exposed to any damage. The best protection is to select, wherever possible, a position for the opening which is out of reach of accidental damage. It should be pointed out, however, that the cable is very resistant to blows, chiefly because the rubber filling inside the lead covering acts as a kind of buffer. No extra protection need therefore be given for ordinary knocks, but only for

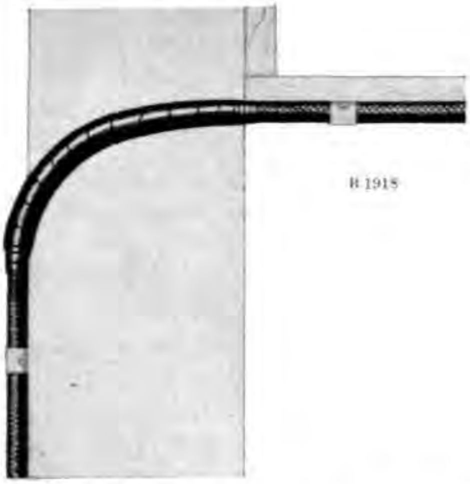


Fig. 15. When passing through a wall, the cable is wrapped in impregnated tape. The bend is inside the wall, and the hole well closed up.

such injury as may tear the cable. This may happen where trucks are passing, and no cables should be put up in such exposed positions.

We have already mentioned that careful planning is essential to make an installation satisfactory. The following points in particular must be given special attention in planning:

1. The installation must be well adapted to its purpose.
2. It must involve no risk to staff or property.
3. Fulfilling these conditions, it must be as cheap as possible.

It is now fairly generally acknowledged that insufficient consideration was formerly generally given to adequate service or safety, but that the chief concern as a rule was to make the plant as cheap as possible. This is regrettable. Low initial cost generally means that the work has been scamped and that troubles will soon arise. A plant of this kind is obviously no good. It will be expensive in the long run, as is amply confirmed by experience. If an installation is to be made, the first consideration must obviously be that it is planned in every detail, and in such a way that all demands for convenience and safety are met. It should then be put up as cheaply as possible.

A badly planned plant is generally impossible to improve except at very high cost. If, on the other hand, it is well planned, odd unsatisfactory details may easily be altered without disturbing the plant as a whole.

It is hardly possible to give any detailed rules for the planning, as this must vary according to circumstances, but certain fundamental rules may always be given.

One general rule is that electrical machinery should not be put up in particularly difficult places if this can be avoided. If therefore an apparatus can do its work equally well if mounted in an adjacent room, it should be put there. This demand is more urgent in case of movable appliances, on account of the greater risk in using these. It is therefore advisable carefully to examine if they might not just as well be fixed. If this is not possible, it may sometimes be necessary to step down the voltage if alternating current is used.

Unless absolutely necessary, nothing but supply cables for the machines in the room should be put up in particularly difficult premises, fig. 16 a and b. The supply lines to each of the several buildings of a factory should be put underground. Aerial lines should normally be avoided. If power is supplied from the outside, the service line, which must be considered the most important line in the plant, must naturally be placed underground up to the main distributing station. If the establishment has its own pumping station for fire hydrants, the pump house should be well away from other buildings, and its supply line run direct from the central distributing station and be wholly underground. If this precaution is neglected, the result might easily be the same as when Matfors sulphite mill was burnt down in 1921 or Kockums Enamel Works in 1925. In both cases excellent pumping plants were provided, but the main supply lines to the pumps were put up in such a way that they

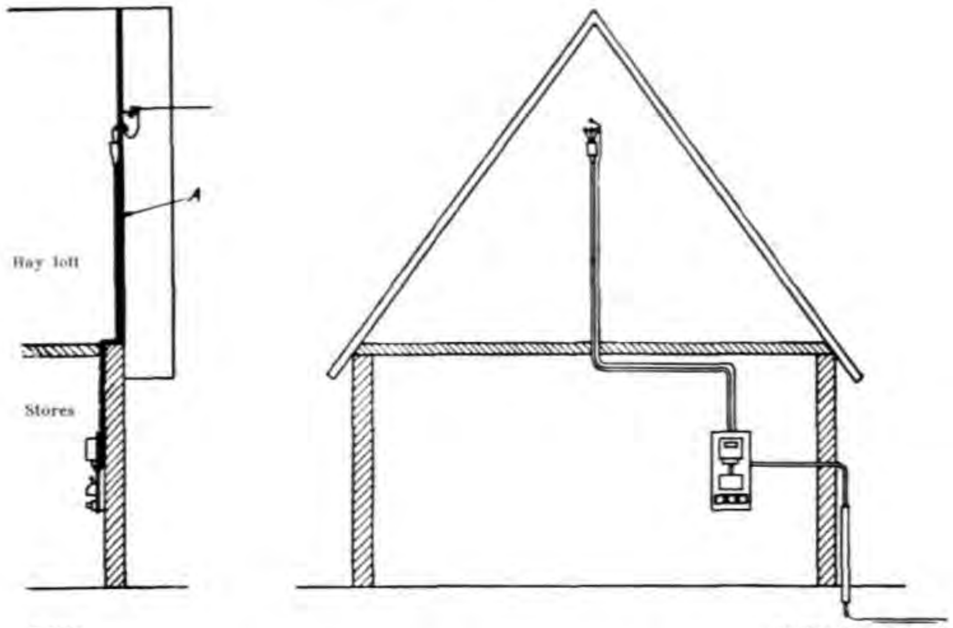


Fig. 16 a. A cable has been unnecessarily introduced in the very inflammable hay loft. It should rather have been placed on the outside of the wall.

were practically the first to be destroyed by the fire.

One conductor should not carry several heavy loads, unless this is necessary, as, the greater the load on the conductor, the more extensive will be the interruption in the work in case of a line fault or blown fuses, and the larger will also be the cost of such interruption. As a small cable can take a higher load per mm^2 than a heavier one, the lines will sometimes be considerably cheaper if several light cables are used instead of one heavier. If for instance 200 A have to be transmitted, one 95 mm^2 cable could be used, but if the load be divided between two, 35 mm^2 will be sufficient. It is therefore always necessary to ascertain that what is saved on line materials and apparatus is not eaten up by increased losses.

Another rule of the same kind is that light- and motor supply lines should if possible be entirely separate right from the main distributing station. It is important, not least from a safety point of view, that the illumination of a factory is not extinguished by a break in a motor supply line.

A puestion which has been the subject of animated discussion in

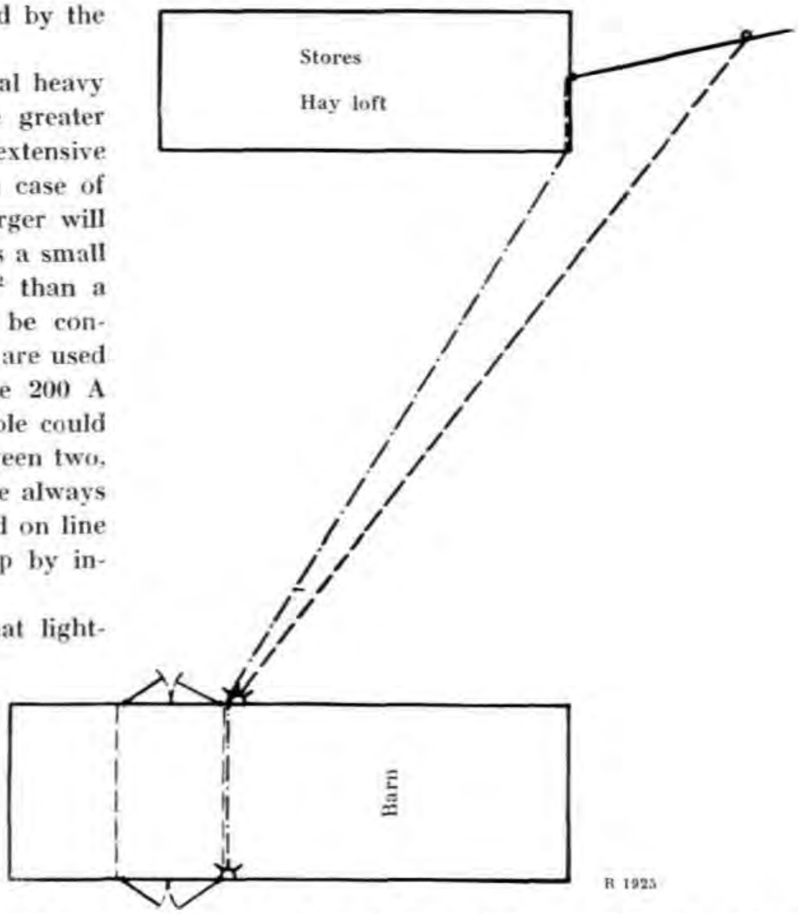


Fig. 16 b. As the cable is not needed in the store house, it would have been better to bring it underground straight from the last pole to the barn, where all the appliances required ought to have been collected in one encased central switchboard.

recent years is that of main switches. According to the insurance conditions of the Fire Offices' Committee, every plant or part of a plant which may at times not be used, must be provided with a conveniently placed main switch by which the current may be cut off from the plant when this is not in use. If this regulation is sensibly interpreted, neither expert nor layman will object to it. But occasionally it has been interpreted in a manner which the Fire Offices' Committee certainly never contemplated. In recent years the inspectors of some insurance concerns, chiefly active in rural districts, have required main switches to be put up not only for the whole plant, but also for its different sections. One main switch is thus insisted on for the stables, another for the byre, one for the pigsties, one for the barn, etc. And even this does not satisfy them. They also demand that these main switches should always be arranged so that a lamp is always lighted wherever a main switch is on. The main switches must further be turned off whenever work is not proceeding in the farmstead, i. e. at nights, on Sundays, etc. When installations are made on the older systems, and with more or less inferior materials, it is understandable that insurance companies would like to see them used as little as possible, and a good many of us would even like them never to be live at all. But one must strenuously object to a demand that a modern installation, made with materials which experience has proved capable of enduring the most difficult conditions—conditions far worse than those which under the most unfavourable circumstances may obtain in any farmstead—should be split up in small sections in a way which is not justified either by the risk of fire or by practical working conditions. It is not enough that this splitting up causes a lot of unnecessary expense. A far more serious consequence is the risk of changing the most valuable properties of electricity—convenience and comfort—into the opposite. The presumed increase of safety against fire may also in reality be reversed.

The question has been discussed whether in farmstead installations the wiring should be placed on the outside of the walls, with short branches brought in to each lamp, or if it is advisable to put the whole wiring on the inside in the usual simple way. In case of the older systems, both methods have advantages as well as drawbacks. If the wiring is placed outside, it may be less exposed to damage from corrosion, but on the other hand there must be many quite unnecessary passages through walls, which should preferably by avoided in these systems. In addition, the installation necessarily becomes more complicated and consequently more expensive. If all the wiring is done indoors, fewer walls have to be penetrated, and the wiring will be easier. This makes for a cheaper and generally more convenient installation. The drawback of indoor wiring would be that the cables will be more liable to corrode, but this is of comparatively slight importance, for when all is said and done it makes no difference if they are partly or completely ruined after a few years. Another point mentioned as a drawback to indoor wiring is that this is more difficult to inspect, particularly in barns and lofts. This statement is hardly correct. In these premises the lamps are usually fixed high up underneath the ridge of the roof. In outdoor wiring, a wire must be taken for each lamp from the floor of the loft right up to the ridge, and it is just this part which at times may be very hard to get at. In the usual method of wiring the cable is taken up to one lamp and then continued along the ridge pole to the other lamps. Even if the loft is fairly well filled with hay it will not be particularly difficult to get at the highly placed cable.

With the Gebe-cable there is no reason whatever to go any roundabout way to avoid a non-existent danger. If anything can be gained by putting the wiring out-of-doors, this opportunity should of course be taken, if not, the wiring should be done some other way. It is frequently easiest to lead the supply line to a group out-of-doors up to the first lamp, and then to continue it indoors. Particularly in new buildings in the country, an exellent place for the cables can usually be found underneath the board which is now generally put up between the lower edge of the roof and the wall, fig. 17.

An exceedingly dangerous point in the older systems is where the wires are taken from one damp or inflammable room to another. On account of this experience, the complete avoidance of direct passages through walls in such instances is sometimes strenuously advocated, not only when the older and inferior systems are used, but also with Gebe-materials. As no single instance of the modern Gebe-cable having been destroyed by corrosion either where it passes through a wall or anywhere else is known, there is no reason to be particularly anxious about these holes, and still less to avoid them where needed. When planning a Gebe-plant, no particular consideration need be given to the passages through walls, but the cable can be laid where convenient.

When the directions of the Electrical Inspection were made out, a recommendation was included to paint the cables at regular intervals with some protective lacquer. To ascertain the strength of the new material, the Sievert cable works in 1923 made an installation in some pigpens near the factory, which have since been inspected at various times. No repairing work has been done in this installation during these years. An inspection in the beginning of 1930 proved the resistance between the conductors and between conductor and lead sheath to be about 25 megohm. Astonishingly enough, however, it was observed that the sheath had full voltage to earth, though this could not be noticed by touching the cable. As the conditions in these premises are particularly difficult, this shows that the cable, even though it has not been painted over with protective lacquer, is not yet damaged in any way. This example has been confirmed in many other places. As the conductor now manufactured is considerably improved with regard to external protection, we might venture to assert that, at least in normal cases, regular maintenance can be dispensed with. A good way to ascertain the outward condition of a cable is to measure the insulation between the mantle and earth. If this is high, it shows that the cable has not been damaged and that repairs are consequently not required.

We have previously mentioned that Sieverts have tried to make the Gebe-system as simple as possible. If we compare what might be called a pure Gebe-installation, fig. 18, with one on some other system, we find that the number of connexions in the Gebe-system is only a fraction

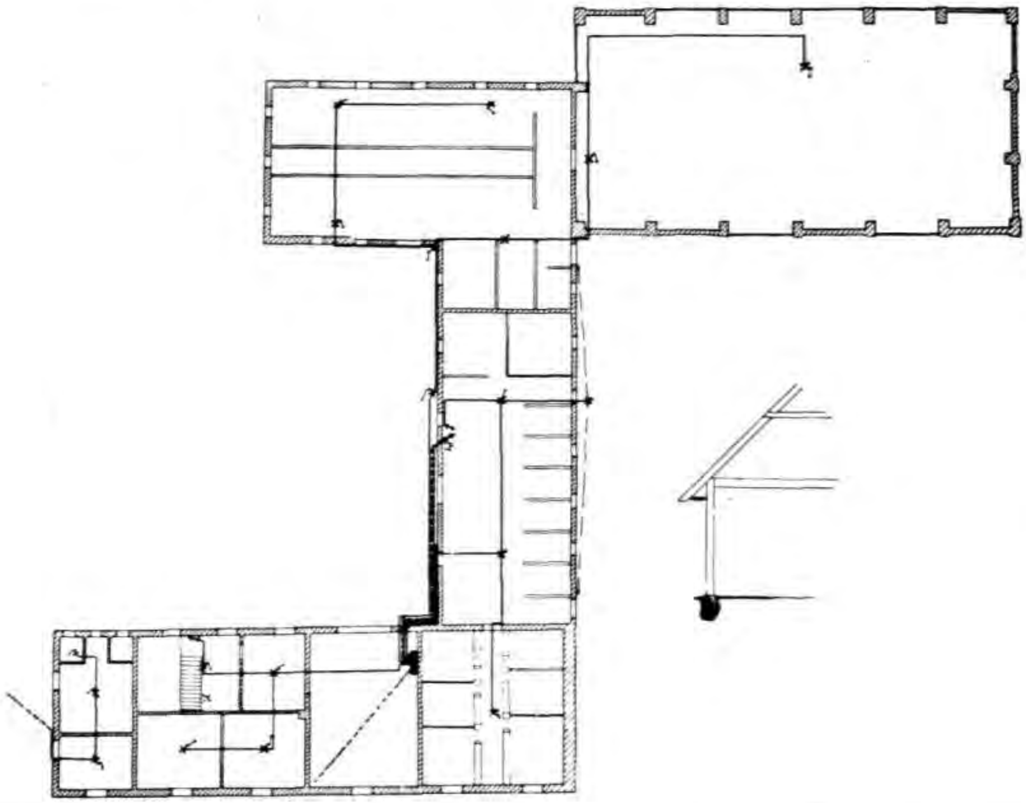


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Fig. 17. Wiring of a modern farmstead. The cables are carried on a board underneath the eaves from the distributing station.

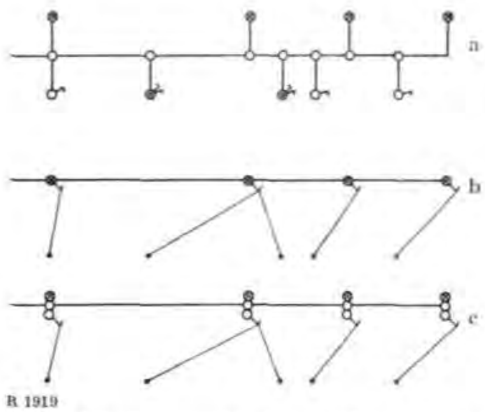

Fig. 18 a. Installation as usually done with armoured pipes.
b. Pure Gebe-installation.
c. "Modified" pipe installation. Switches and lampholders fitted close to the connecting boxes. Switches provided with strings.

of those in other systems, and that the length of cable used is usually less in a Gebe-installation.

The design of the fittings makes the Gebe-system exceedingly flexible, and in this respect superior to other systems. If required, a lamp holder with or without switch may, for instance, be added to any branching-box already put up, without any need of making new connexions. If for some reason a switch for any lamp or group of lamps is required, one may easily be put on at the first lamp. If a fixed lamp holder has been put in originally, and later should be wanted lower down, the fixed holder may without any trouble be exchanged for a pendulum, and vice versa.

This flexibility of the system may also be utilized in other ways. When repairs and altera-

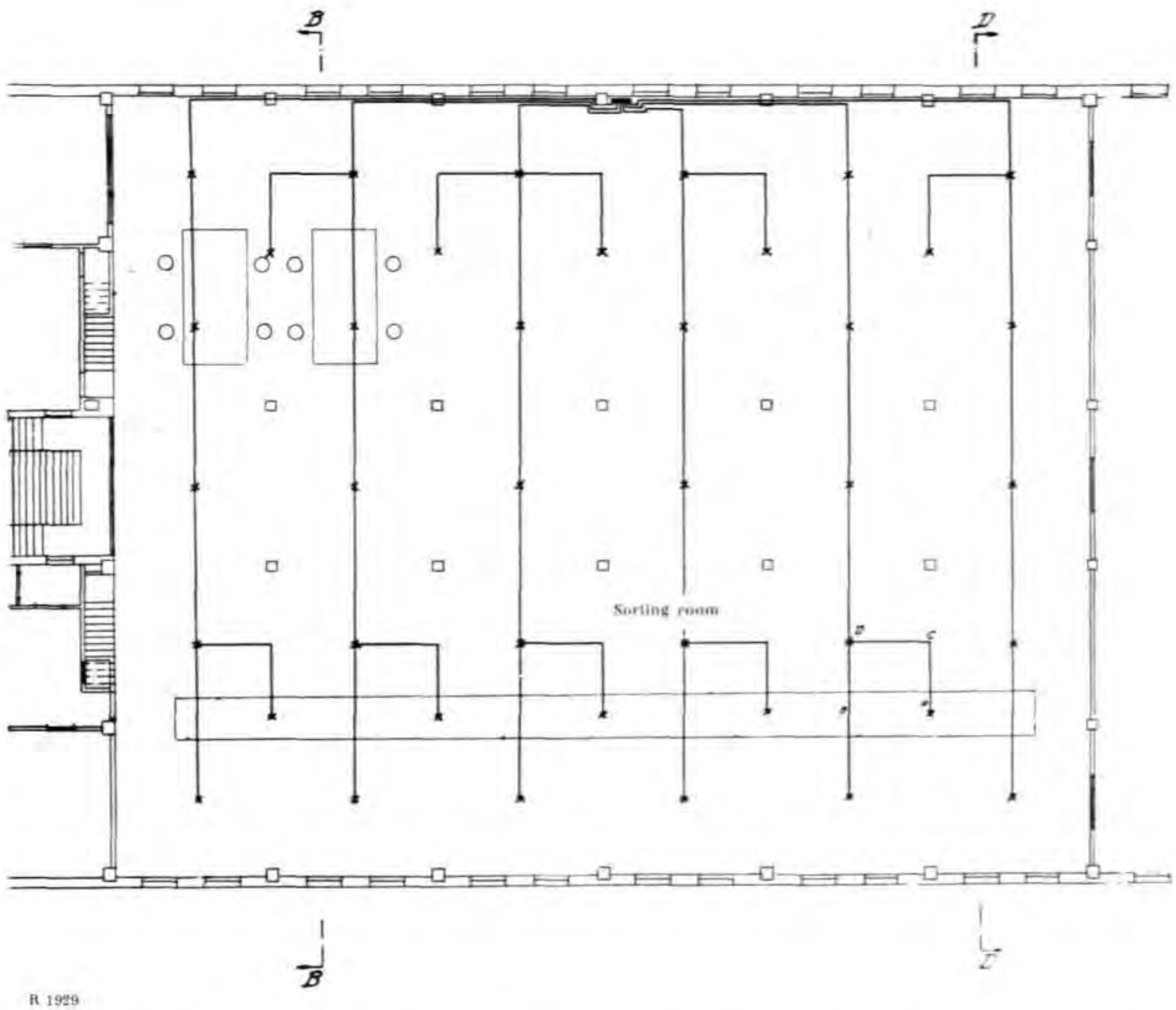

Fig. 19. A Gebe-installation can as a rule be made without any extra connecting boxes beyond those at each fitting.

tions are made in a plant, the fittings will generally suffer considerably. In the Gebe-system they may in such a case simply be removed by loosening the two screws holding them to the box and an ordinary lid be put on the box. When the work is completed, the fittings are again put up. Outdoor fittings which are not used in winter can frequently be removed on the cessation of work in the autumn and put in store to protect them from ice and snow falling from the roofs. If eventual extensions are provided for when planning a plant, and boxes with reserve taps provided in suitable places, such extensions can afterwards be made without disturbing the original wiring. In other words, if a Gebe-plant is planned with a certain amount of forethought, it may subsequently at any time be considerably altered without any necessity of wasting time on altering the original connexions. In practice, this is of great importance in industrial plants which, as we know, frequently have to be altered on account of changes in the production.

Every Gebe-fitting having its own connecting box, no special branching boxes are ordinarily required, but the branches are taken from the boxes which are already put up for the fittings, fig. 19. A separate box need only be employed if a considerably increased length of cable would otherwise be required. Usually, a fitted T-box is reckoned to cost about the same as 5 m. of cable put up. If, in addition, we remember that unnecessary joints in the cable are always an evil, that connecting boxes are not particularly ornamental, and that it is often rather difficult to fix a box, we find that the increased length of cable may be considerably more than the said 5 m. before we resort to an extra box.

Thanks to the design of the fittings, the wiring for a Gebe-installation is very simple. When putting in the permanent cable system, no thought need be given to the fittings, except that a box should be fixed wherever a light will later be needed. There is no connexion of fittings in the ordinary sense of the word, the fitting being simply fixed to the box by two screws. This applies to all kinds of fittings, whether fixed direct on the box, pendulums, or wall fittings.

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