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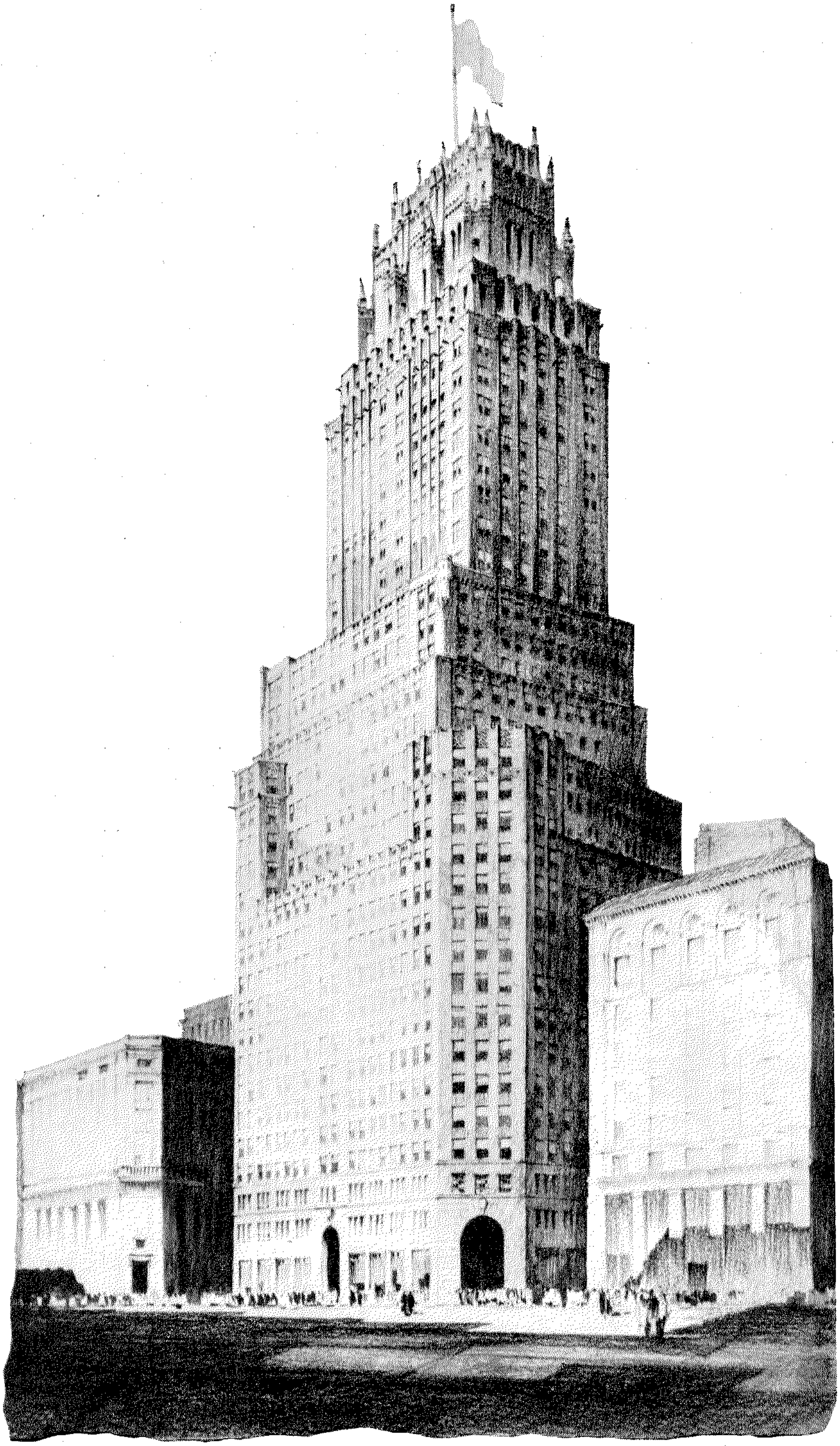


International System Headquarters Building

67 Broad Street New York

*Architect's drawing showing how the building will look after the final half has been added*

# A Rural Rotary Automatic Telephone System Installed at Herrliberg

By W. HATTON

*Les Laboratoires Standard, Paris*

THE demand for rural automatic telephone equipment is becoming more insistent in Europe, and the various Telephone Administrations are at present engaged in studying the special conditions to be encountered in this type of service. Advanced programmes are being prepared, notably in Switzerland. These, when completed, will provide the smallest community with a telephone service of the same high grade as that enjoyed in large towns.

The modern tendency is to consider a large town as the switching centre for the surrounding small rural exchanges, and to provide for full automatic inter-connection between all the subscribers of the network so formed. This general idea is capable of development in several different directions. For example, automatic metering on a zone and time basis may be introduced, or a uniform rate may be charged for connections terminating within the network. Subdivision of the network may be effected with the larger villages as sub-centres. In cases where it is found more expedient to inter-connect the sub-centres on a semi-automatic or manual basis, a second line of development may be followed.

There are many communities, however, where a simpler service would answer, and where the full automatic operation may be restricted to purely local calls. Power driven equipment for this class has already been tried with success in Denmark and Belgium and, on December 1, 1927, an installation of this type was opened for public service by the Swiss Telephone Administration authorities at Herrliberg, situated on Lake Zürich and distant about 15 kilometres from the town of Zürich itself (Figure 1).

## *Equipment*

The installation at Herrliberg is of the type known as the No. 7000 Automatic Rural, which is built up of self contained units completely assembled, wired, and tested in the factory. Standard sizes of equipment are manufactured for capacities varying from 100 to 400 lines. If the development ever exceeds the anticipated figures, the capacity may be increased to 600 lines. At Herrliberg, equipment was furnished for 100 lines, 10 two-party lines, and 6 junctions. At the cut-over, 77 subscribers were connected, including 6 two-party lines. Four main units were supplied, i.e.,

One line and junction relay unit.
Two link circuit units.
One register circuit unit.

Figures 2 and 3 show respectively the front and rear of the link and register unit after installation and with dust covers removed. The plan, Figure 4, shows the floor space occupied, and the disposition of the units.

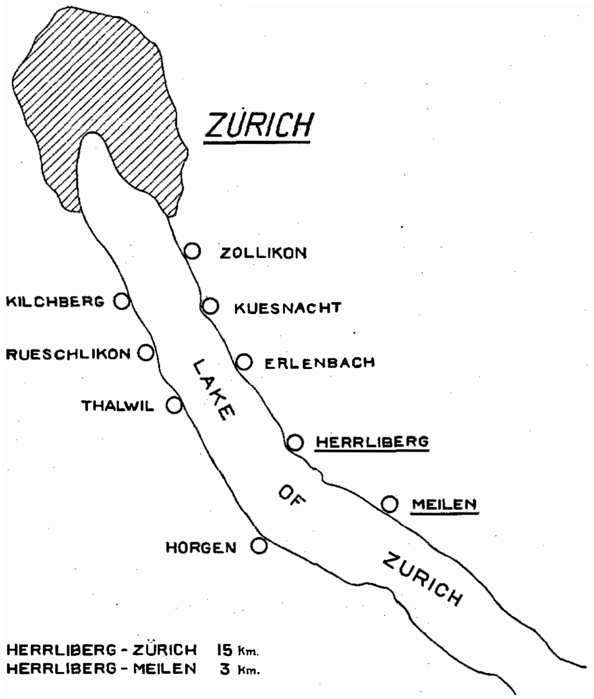



*Figure 1—Part of Lake Zürich.*

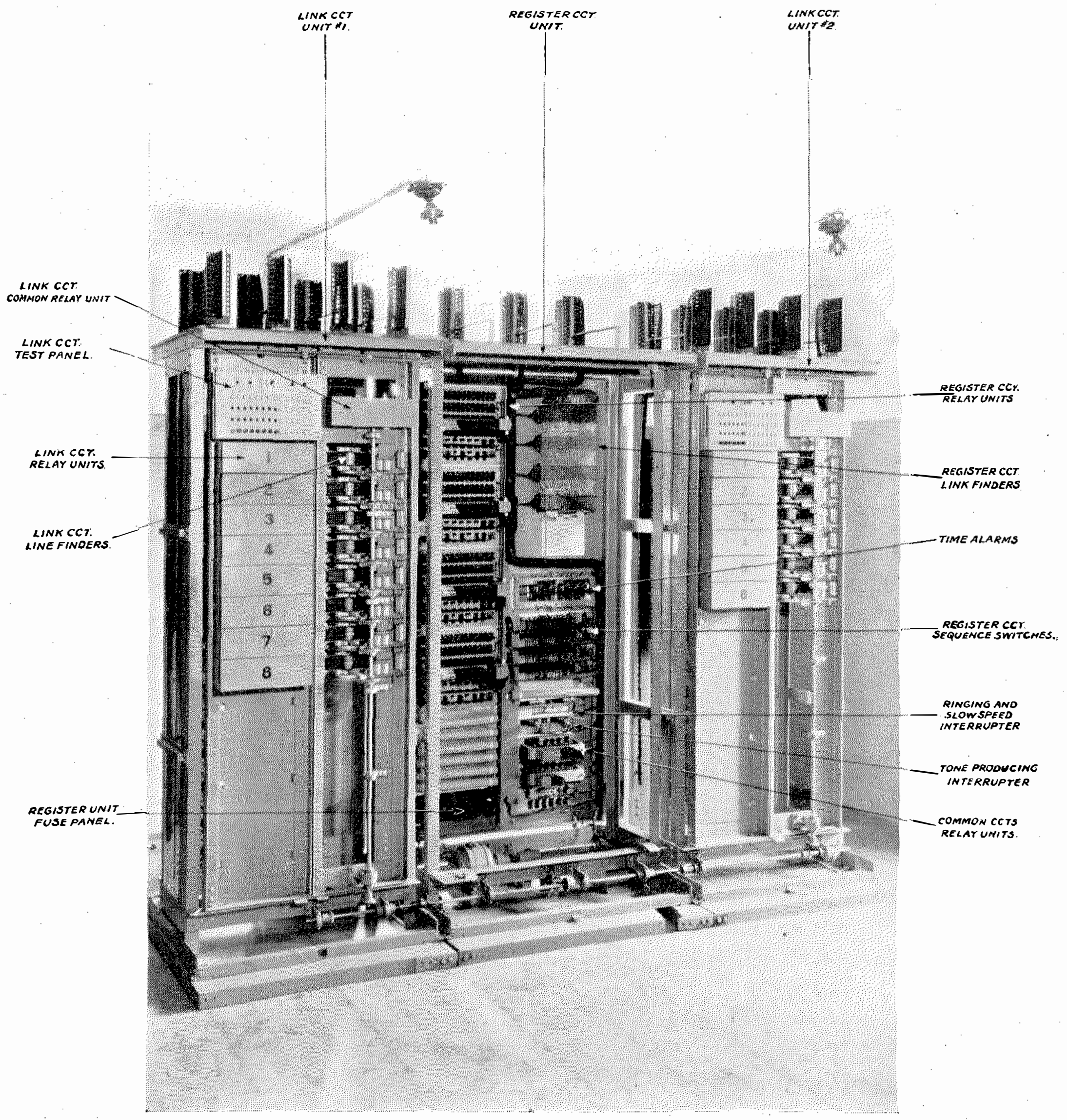



*Figure 2—Link and Register Units, Front View. Herrliberg Installation.*

The line and junction relays are mounted on vertical bays, two bays forming a unit with a capacity of 200 line circuits and 25 junction circuits. The link circuit units have a capacity of 28 circuits, but for the present 14 circuits only are equipped. A single link circuit comprises two 100-point gear driven finders (the construction of which has already been described)[1] and standard flat type relays. One finder is used as a line finder, and the second as a selector. The selector capacity of the circuit

[1] G. Deakin, "No. 7-A Machine Switching System," *Electrical Communication*, Volume III, No. 3, January, 1925.

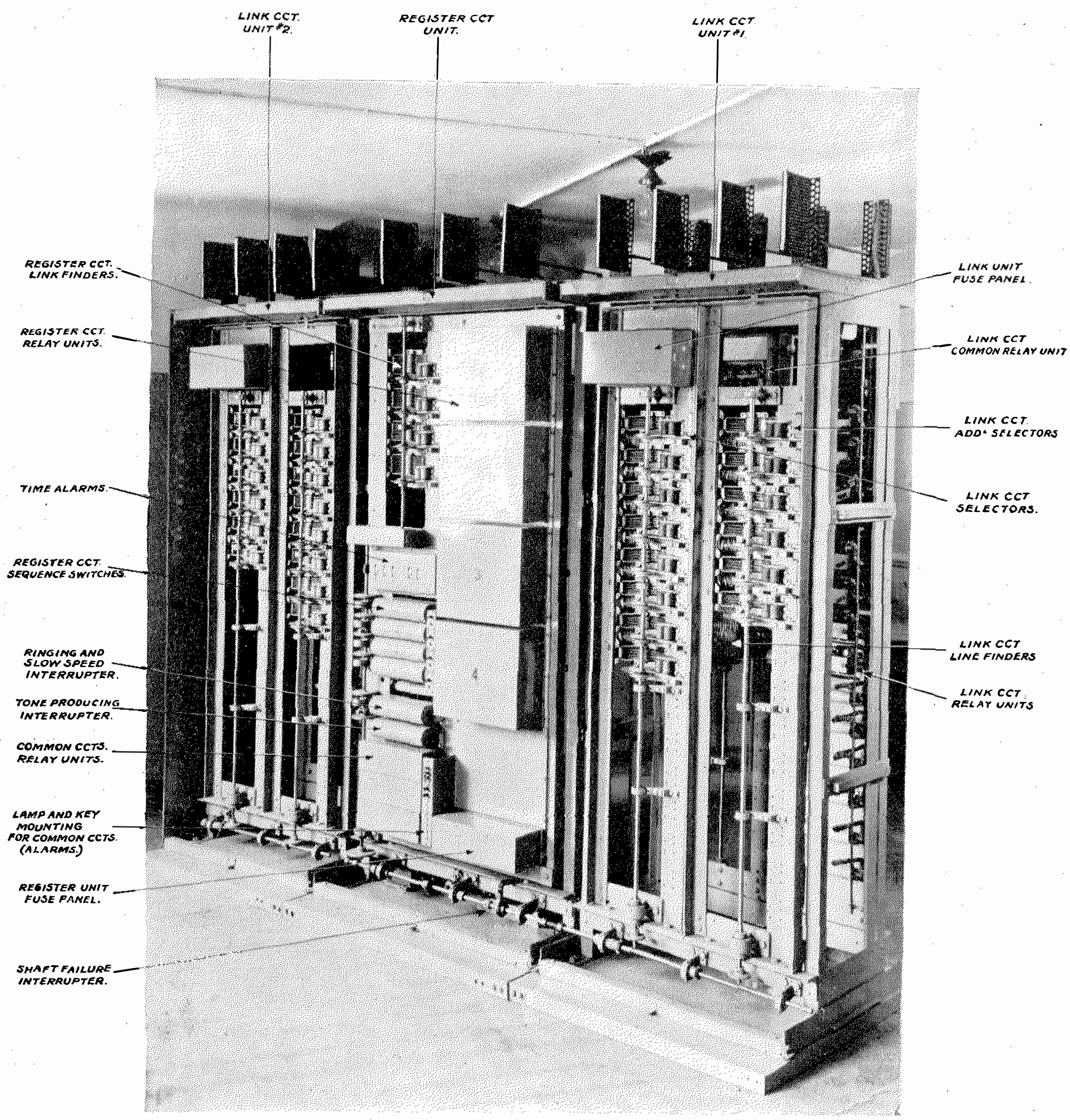



*Figure 3—Link and Register Units, Rear View. Herrliberg Installation.*

may be increased by adding further finders, and space is provided on the link unit for one additional finder per circuit. When the capacity reaches a figure above 200 lines, the additional finders are accommodated on separate bays. Figure 5 illustrates a link unit with covers removed, and it will be seen that the equipment on the front of the unit is mounted on hinged bays, which are shown opened.

The capacity of the register unit is 10 circuits, and the present equipment 4. A complete unit is built up on two vertical bays, each bay accommodating 5 registers. A single register circuit comprises one standard gear-driven sequence switch, one gear-driven finder and flat type relays. The register unit equipped with four circuits may be seen in the centre of Figures 2 and 3. By fully equipping the present units, the Herrliberg installation can therefore easily be extended to carry additional subscribers' lines up to a maximum of 200, including the junction circuits. The three units are driven from a common motor which is fed from the main 48-volt battery, 48 volts being the normal operating potential of the system.

The shaft motor is controlled by a starting circuit which is closed only when the motor is actually required.

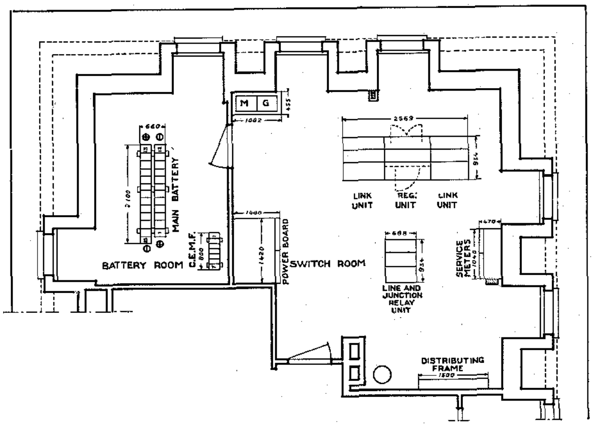



*Figure 4—Floor Plan of Herrliberg Installation.*

The system is provided with a scheme by means of which fault alarm signals are transferred to Zürich. The alarms are divided into two classes: those requiring prompt action, such as shaft failure, ringing failure and main fuse failure; and those requiring deferred action, such as battery discharge, individual circuit fuse failure, and register circuit alarm.

The subscribers' lines are ordinary two-wire circuits, but as the subscribers' line plant of a rural exchange is not usually of the same high grade as that provided on large installations, each subscriber's line is provided with a fault relay. This relay becomes energised on a fault or failure to dial after 30 seconds, and disconnects the line from the automatic equipment. In addition, it makes engaged a certain test number which is periodically called from Zürich, and the engaged condition of this test number indicates the existence of a faulty line at Herrliberg. The guaranteed operating limits of conductor resistance are 1,000 ohms and of insulation resistance 10,000 ohms, but satisfactory service can be given in cases where the insulation resistance is below this figure. The subscribers' instruments are of the standard type as provided for No. 7-A Machine Switching System, and the guaranteed operating limits of dial speed are 8 steps per second, minimum, and 14 steps per second, maximum.

Two party lines with revertive calling are also connected, and secret service is provided, this being a standard requirement for Switzerland. (See Figure 6.)

## *Operation*

*Connections to Zürich*

As is usual with small communities such as Herrliberg, the percentage of local calls is very small, most of the traffic being directed to the nearest centre, which, in this case, is the town of Zürich. Four 2-wire junction circuits are provided to carry the traffic between Herrliberg and Zürich, which terminate at Zürich on the short haul toll position. To gain connection with the Zürich operator, the procedure is as follows:

The receiver is removed from the hook, whereupon the calling subscriber at Herrliberg is connected to an idle link circuit, and thereafter to an idle register circuit. On receipt of the dialling tone, the calling subscriber dials the single digit zero. The link circuit selector is then set in motion and hunts under the control of the register circuit. When a free junction to Zürich is found, the register circuit is released and the through connection is made in the link circuit. The Herrliberg subscriber is now connected through to the Zürich operator who controls the further progress of the connection. At present, all effective connections are "ticketed" in the regular manner.

Automatic metering of the calling party on outgoing calls to Zürich is not introduced at Herrliberg, but this feature may be added later by modifying the junction circuits, in which case the service meter of the calling party would be operated 2, 3 or 5 times at the beginning of each three-minute conversation period. Metering would commence when the called party

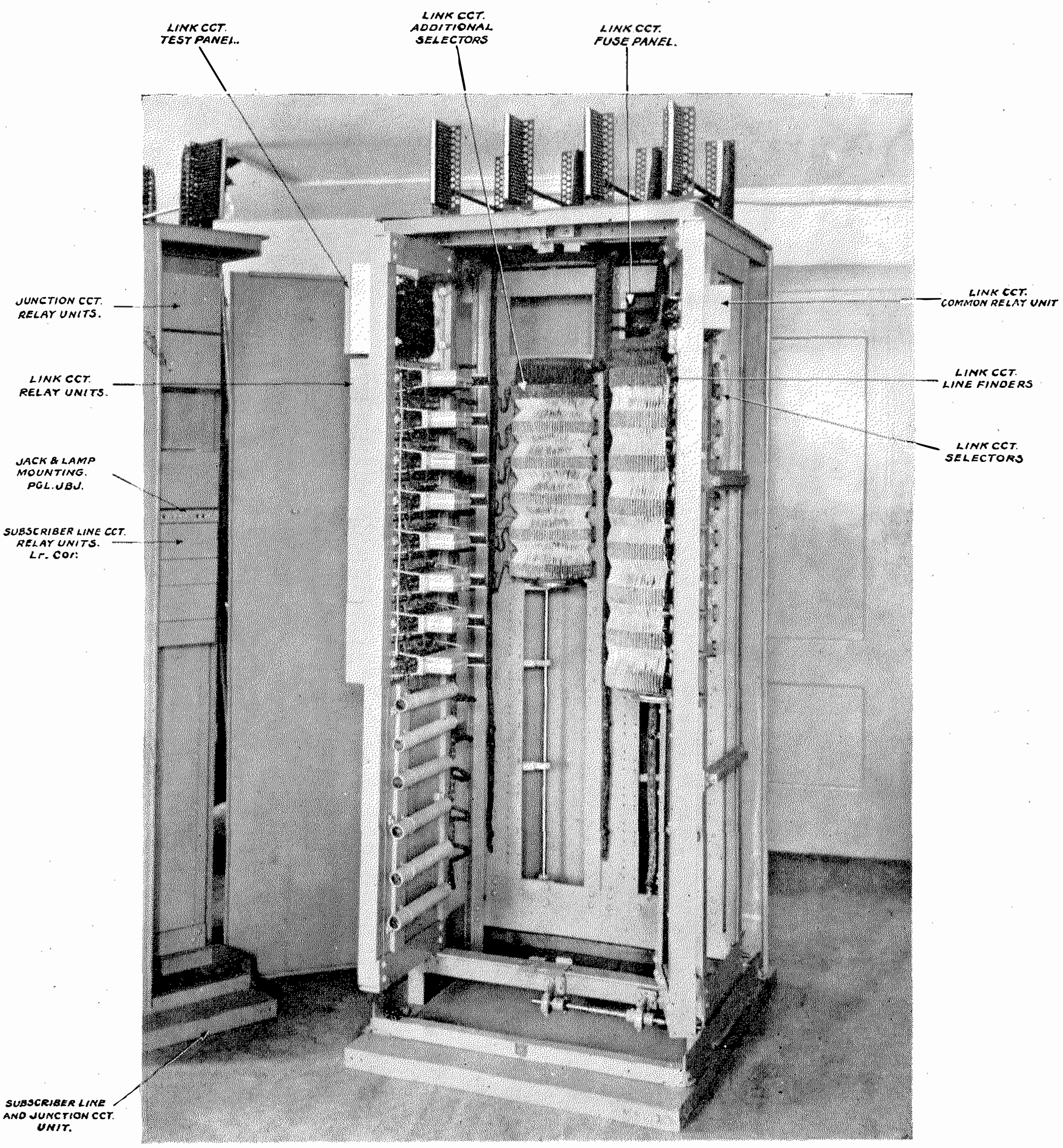



*Figure 5—Link Circuit Unit. Herrliberg Installation.*

replies or, in the case of non-through signalling cord circuits, when the operator depresses the metering start key.

For connections from Zürich to Herrliberg, the toll operator selects an idle junction, and thereafter dials the number of the wanted party at Herrliberg. The junction in this case appears at Herrliberg as a regular subscriber's line, and the toll operator is connected to the ordinary link and register circuits.

### *Connections to Meilen*

Tie line service is provided between Herrliberg and the neighbouring village of Meilen. The

Herrliberg subscriber dials the single digit 9 and becomes automatically connected to the operator

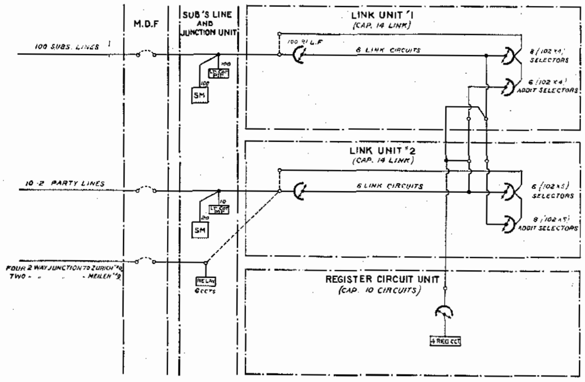



*Figure 6—Junction Diagram.*

at Meilen, who then completes the connection. For connections from Meilen to Herrliberg, the operator selects an idle junction and then dials the number of the wanted party at Herrliberg.

### *Local Connections*

For local connection the calling subscriber lifts the receiver and, on receipt of the dialling tone, dials the three digits forming the number of the wanted subscriber. If the line is free, ringing current is connected and, until the wanted subscriber replies, the calling party receives a ringing tone. The release of the connection is normally under the control of the calling subscriber, but an interesting feature of the system is the provision of delayed back release, that is, the forced release of the connection in the event of the calling subscriber holding for thirty seconds after the called subscriber has restored the receiver. No time limit is provided on local connections; at the termination, the service meter of the calling subscriber is automatically operated once.

### *Maintenance Records*

The subscribers of Herrliberg were, from the outset, in favour of the introduction of automatic equipment. After five months of service, an enquiry was distributed to all subscribers with the following results:

Number of enquiries mailed........... 80
Number of replies received............ 59
Number of subscribers satisfied........ 40
Number of subscribers very well satisfied 17
Number of subscribers not satisfied.... 2

Of the two dissatisfied cases, the first was found to be due to an error in the directory, and the second to faulty installation at the subscriber's premises.

The amount of traffic dealt with during the first six months of service may be seen from the records below:

MAINTENANCE RECORDS
FROM DECEMBER, 1927, TO MAY, 1928, INCLUSIVE

| | Dec. '27 | Jan. '28 | Feb. '28 | Mar. '28 | Apr. '28 | May '28 |
|---|---|---|---|---|---|---|
| Regular Subscribers | 71 | 71 | 72 | 72 | 76 | 77 |
| 2-Party Subscribers | 6 (3x2) | 6 (3x2) | 6 (3x2) | 6 (3x2) | 6 (3x2) | 6 (3x2) |
| Total number of subscribers | 77 | 77 | 78 | 78 | 82 | 83 |
| Total number of local connections | 836 | 1252 | 1045 | 1311 | 1363 | 1528 |
| Total number of toll connections | 3236 | 3161 | 2963 | 3519 | 3457 | 3543 |
| Total faults found and cleared | 5 | 5 | 3 | 2 | 3 | 3 |
| Total man-hours required for maintenance, including battery charging and travelling time | 18¾ | 29¾ | 18 | 26 | 33½ | 32 |

Further particulars on the No. 7000 Rural Automatic Equipment are given in an article in *Electrical Communication,* Volume VI, No. 2, October, 1927, on "An Automatic Telephone System for Rural Exchanges," by L. J. Saltoft.

# Control of Release Time of Relays in Automatic Telephone Systems

By R. St.G. TERRY

*Engineering Department, Standard Telephones and Cables, Limited.*

ALL automatic telephone systems at present in operation use slow-acting relays and a study of their operation shows that the releasing and operating time of any given relay is capable of variation. In addition, it is well known that if a number of relays of any given design made by modern repetition methods are tested, lack of uniformity in timing will be revealed. This variation necessitates large timing margins and these have been provided without much difficulty in the more elementary applications.

Automatic Telephone Systems for large areas such as London or Paris involve an increase in the number and complexity of the time relations which exist between different relays. In some cases the release time of a particular relay cannot be allowed to vary up or down very much, so that some precise method of adjustment is necessary. At times the effect of a faulty adjustment is to derange the working of distant apparatus, possibly in another exchange, in which case the method used largely at the present time of adjusting a relay until it enables associated apparatus to function correctly cannot be relied upon.

To satisfy the new conditions it is necessary to have a method of controlling release time which deals with the relay as a unit. If such a method is forthcoming, the circuit designer will be aided in his efforts to simplify and cheapen automatic equipment by having a more satisfactory instrument at his disposal; and the task of the maintenance staff will be made easier.

Before the methods of controlling release time of relays can be formulated and considered, it is necessary to know how to predict the release time of a particular relay under given conditions. This part of the subject has been considered by Chechelovsky[1], but will be discussed here in greater detail to explain how variations in components of the relay affect its release time.

Consider a relay having a copper ring or slug encircling its core. On opening the circuit of the relay there is, as a rule, little sparking, and the current falls to zero very rapidly. The flux in the magnetic circuit then has a value dependent upon the previous excitation, and it commences to die away. The decay of flux induces an e.m.f. causing currents in any closed circuits which happen to link with the magnetic circuits. The currents thus set up tend to maintain the flux and would do so indefinitely if these circuits had no resistance. Actually the resistance of the slug of a telephone relay is such that the flux falls to a low value in about one second or less and the relay releases. Release occurs at the instant when the magnetising force provided by the eddy currents reaches a value just insufficient to provide enough flux to resist the forces tending to restore the armature to normal. A further period is occupied while the armature moves from the core to the back stop, but this is negligible compared with the time required for the flux decay.

The factors determining the release time are:

1. The reluctance of the magnetic circuit.

This involves:

a. Quality of iron and method of annealing.
b. Thickness and composition of finish.
c. Dimensions of core, polepiece and armature.
d. Operated air gaps, i.e., air gaps present when armature is operated.

2. The conductivity and number of turns of the closed electric circuits linked with the magnetic circuit.

Included under this heading are:

a. Dimensions and conductivity of the slug.
b. Dimensions and conductivity of all parts such as polepiece, core, armature, metal spool cheeks.

[1] C. Chechelovsky, Physical Laboratory, Bell Telephone Manufacturing Company, Antwerp, "Etude sur le Temps de Fonctionnement et de Relâchement des Relais Téléphoniques," Mémoire Couronné au Concours de la Fondation George Montefiore. Bulletin Institut Electrotechnique Montefiore, 1925-1926.

c. Thickness and conductivity of finish.
d. Short circuited turns in the winding.
3. Magnetic leakage.

This depends upon the position of slugs and windings, the shape and permeability of the magnetic circuit and the excitation.

4. Initial excitation.

This is the product of the circuit current and the number of turns on the coil.

5. Excitation at which release takes place.

This is dependent on:

a. Operated load (itself dependent on spring stiffness and adjustment).
b. The size, permeability and coercive force of the magnetic circuit.
c. Initial excitation.
d. Position of the winding or slug providing the excitation.

Each of the quantities above is subject to some variation, and the release time variation is compounded from them all. It is not surprising therefore that large margins are necessary if the natural limits consequent upon the use of commercial materials are allowed. There are two ways of reducing these limits. Each one of the quantities concerned may have its limits restricted, or advantage may be taken of the fact that adjustments may be used to counteract the effect of some of the variables. To accomplish this the adjuster must have some simple means of knowing what adjustments to make; in other words, he needs a test to indicate directly whether the release time of the relay will be within the prescribed limits or not. Moreover, since wear and handling obviously will affect the release time, the maintenance staff must be in a position to make like tests.

When adjustments are used to counteract the effect of variations in components, it is still necessary to limit the dimensions of components; otherwise excessive adjustment may be necessary. Thus whatever plan is followed, limits are necessary on all components, but where an overall limit is imposed individual limits need not be so close.

Examination of the component variables is sufficient in itself to show that no simple theoretical expression can be devised for calculating release time, but if constant permeability and negligible leakage are assumed a simple and interesting formula can be obtained.

Let $I$ = Current in main coil.
$\phi$ = Flux.
$N$ = Turns in main coil.
$K$ = A Constant.
$T$ = Time.
$n$ = Turns in short circuited coil or slug.
$r$ = Resistance of short circuited coil or slug.
$r_c$ = Effective resistance of the core, pole-piece and armature to eddy currents.

And let the suffixes s and r indicate saturated (i.e., initial) and release conditions, respectively.

Then for steady values of flux,

$$\phi = K.\ IN: \tag{1}$$

and if the flux is changing with time,

$$IN = \frac{\phi}{K} + \left(\frac{n^2}{r} + \frac{1}{r_c}\right)\frac{d\phi}{dt}, \tag{2}$$

which is analogous to the well known equation

$$E = RI + L\frac{di}{dt};$$

obviously, the magneto motive force has to overcome the reluctance of the magnetic circuit and neutralize a counter magneto motive force provided by the eddy currents.

At the moment the magnetising coil circuit is broken (assuming no spark),

$$IN = 0;$$

whence from (2) $\frac{\phi}{K} = -\left(\frac{1}{r_c} + \frac{n^2}{r}\right)\frac{d\phi}{dt}$;

and $dt = -K\left(\frac{1}{r_c} + \frac{n^2}{r}\right)\frac{d\phi}{\phi}$;

therefore

$$\int_{T_s}^{T_r} dt = -K\left(\frac{1}{r_c} + \frac{n^2}{r}\right)\int_{\phi_s}^{\phi_r}\frac{d\phi}{\phi};$$

and $T_s - T_r = -K\left(\frac{1}{r_c} + \frac{n^2}{r}\right)(\log_e \phi_s - \log_e \phi_r)$.

From this equation and (1);

$$\text{Time of release} = K\left(\frac{1}{r_c} + \frac{n^2}{r}\right)\log_e\frac{I_s}{I_r} \tag{3}$$

A more accurate expression results if the permeability is considered to vary with the flux density whilst the flux distribution remains constant. Equation (2) can then be restated as

$$IN = \frac{\phi}{R} + \left( C_1 \frac{n^2}{r} + \frac{C_2}{r_c} \right) \frac{d\phi}{dt} \qquad (4)$$

in which $C_1$ is the leakage factor corresponding to the size and position of damping winding or slug,

$C_2$ is the leakage factor for the core, and

R is a variable.

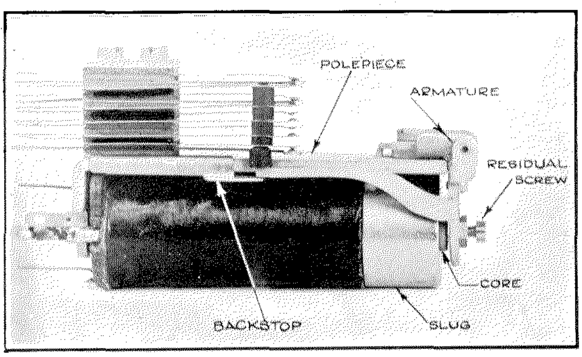
$$\text{Then} \int_{T_s}^{T_r} dt = - \left( C_1 \frac{n^2}{r} + \frac{C_2}{r_c} \right) \int_{\phi_s}^{\phi_r} R \frac{d\phi}{\phi};$$

$$\text{and time of release} = \left( C_1 \frac{n^2}{r} + \frac{C_2}{r_c} \right) f(I_s, I_r) \qquad (5)$$

Experimental results will now be described and related to the theory. Taking any particular relay there are three things that can be altered:

1. Initial excitation.
2. Operated load.
3. Operated air gap.

The last two clearly fix the releasing excitation; and if we can measure the latter directly, it will be possible to replace two variables by one. The actual release excitation is that provided by the slug, and its value will depend upon the excitation obtaining just before the circuit is broken. This quantity cannot be measured directly but we have a nearly related variable in the release ampere turns measured by means of a resistance and milliammeter in series with the coil. If the release currents for a given adjustment are measured after different values of excitation and the results are plotted, curves as in Figure 1 are obtained.




*No. 4700 Type Relay, as Used in Step-by-step Automatic Telephone Systems.*

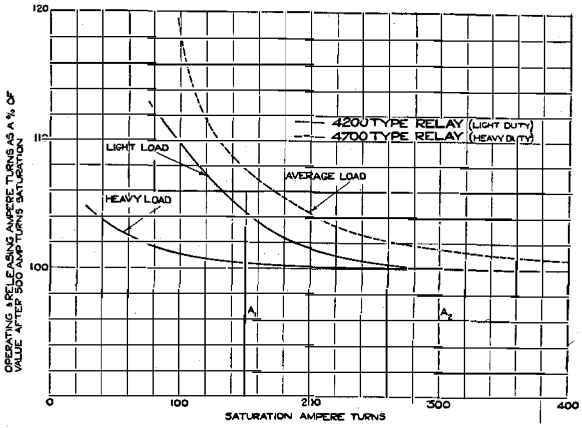



*Figure 1—Effect of Initial Excitation on Release Ampere Turns.*

Above a value, A, the value of the release ampere turns is practically independent of the previous excitation. A convenient definition of release current is therefore the value obtained after an excitation A. In the case of 4700 type relays used in the step-by-step automatic system, this can be taken as 300 ampere turns.

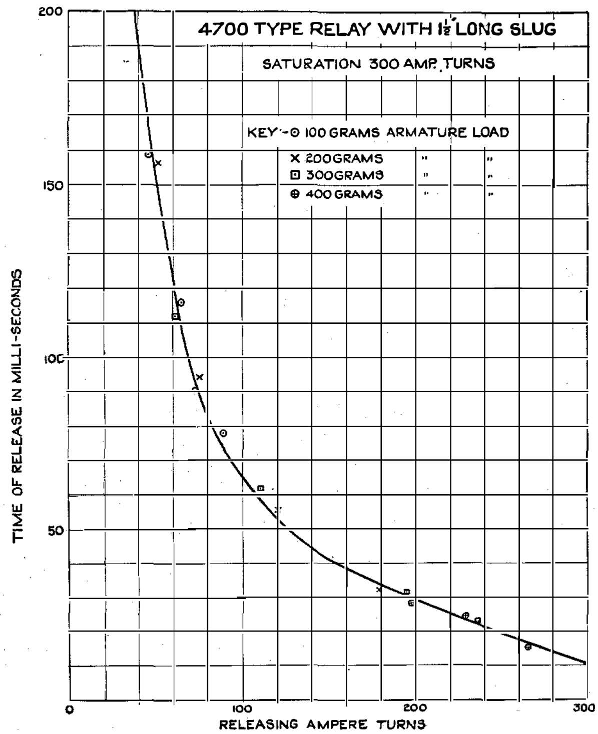



*Figure 2—Variation of Release Time with Release Ampere Turns.*

The curve in Figure 2 is typical of the results when release time is plotted against release ampere turns, measurements being made after one value of excitation. It will be noticed that although each value of release ampere turns has been obtained with a wide range of load and air gap, the points all lie on one smooth curve. This means that relays similar in all respects, except load and air gap, tested under the same conditions will have the same release time provided that their release ampere turns measured in the standard way are identical. The air gap may be due to the residual screw, oblique armature contact, or surface finish, such as zinc plating, without affecting the result.

Taking the release ampere turns measured after standard saturation as the criterion of adjustment, we can proceed to explore the release time characteristics of any given relay. A typical set of curves is shown in Figure 3. If a number of such sets of curves from relays having different slugs or short circuited windings but the same magnetic circuit are compared, it will be found that curves such as Figure 4 can be drawn.

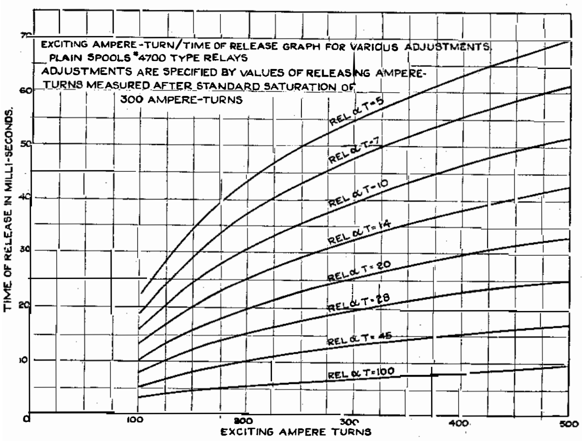



*Figure 3—Release Time Characteristic of a Relay.*

Starting with a length of slug = −E instead of 0, the release time is proportional to $\frac{n^2}{r}$. The value E is the size of a short circuited winding to fit relays similar to those tested, but composed of iron having infinite electrical resistance, to give the same release time as

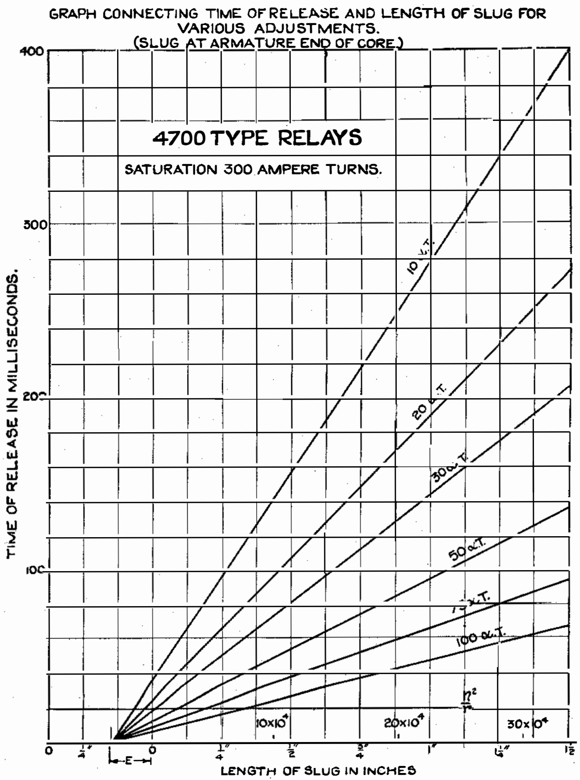



*Figure 4—Variation of Release Time with Length of Slug.*

the actual relay. It can be called the "slug equivalent" of the core, polepiece and armature; and depends upon the resistivity of the magnetic material. Thus, the release time of a relay can be made very small by the use of nickel-iron alloys, silicon-iron alloys, or by laminating the structure.

The slug equivalent for a given relay is not a constant but varies with release ampere turns and saturation ampere turns. Figure 4 does not show this because the scale is small and the saturation ampere turns were kept unchanged. The reason for the variation is that the flux distribution in the iron parts of the relay changes with the flux density so that the distribution of eddy currents is not the same for high densities as it is for low ones. Thus $C_2$ in equation (5) is a function of $I_s$ and $I_r$.

It is also found when using slugs at the terminal end of the spool that the lines on graphs connecting time of release with length of slug curve downwards very slightly. This shows that $C_1$ is also a variable, decreasing a little with an increase in slug length, but the error introduced by considering $C_1$ to be a constant is negligible.

The time of release of a relay having any size of slug therefore can be determined if graphs similar to Figure 3, drawn for two values of $\frac{n^2}{r}$, are available.

The fact has thus been established that release time can be predicted and that the release time of any *given* relay can be kept within any desired limits by controlling the excitation and release current. To ensure that any one of a large number of relays also releases within the desired time limits, certain other requirements have to be observed.

Taking the five groups of quantities previously cited, it is necessary to examine them in detail to see whether they can be kept constant and whether commercial variations will affect the release time to an important extent.

1. *Reluctance of the magnetic circuit.*

The simple formula (3) suggests that the release time is approximately proportional to the reciprocal of the reluctance. It is necessary therefore to take great care to keep the quality of iron and the annealing process in close agreement with those employed in making the experimental relays. Ordinary piece part limits will keep the value of $\frac{\text{length}}{\text{area}}$ (the dimensions governing reluctance) to within about $\pm$ 3% of standard. The thickness of finish, obliquity of contact between armature and core and the operated air gap do not cause trouble so long as the relay can be adjusted to the current tests imposed.

2. *Conductivity and number of turns of the electric circuits linked with the magnetic circuit* $\left(\frac{n^2}{r} + \frac{1}{r_c}\right)$.

This quantity appears as a multiplying factor in the time equation and is therefore important. Ordinary piece part limits will keep the value of the ratio $\frac{\text{length}}{\text{area}}$ for the various parts within about $\pm$ 1%, and the conductivity of copper can be kept within $\pm$ 2%. The conductivity of the iron used is less easy to control but merits careful attention, especially in the case of relays without slugs. The effect of finish also is quite important on plain (unslugged) relays and the easiest way to deal with it is to use a form of plating having high resistivity, avoiding the use of too thick a coat. In this way the inevitable large percentage changes in plating thickness will have little effect on the release time, since they will be second order variables.

An impedance test at voice frequency shows up short circuited turns, changes in plating, and iron resistivity very well on unslugged relays. On relays with slugs it is difficult to detect faults of this kind, but the effect of change in thickness of plating and of iron resistivity upon the quantity $\left(\frac{n^2}{r} + \frac{1}{r_c}\right)$ is always small compared with the effect of the slug upon that quantity. The number of short circuited turns in slugged relays is rarely great enough to have important detrimental influence upon release times.

3. *Magnetic leakage.*

No changes in release time due to alterations in magnetic leakage have been detected. The only way leakage can be modified when the components of the relay are satisfactory for other reasons is by adjusting the residual screw. The effect is to change the release excitation by varying both the reluctance of the magnetic circuit and the leakage. Figure 2 shows that the relationship of release time to release ampere turns is independent of this effect, for in obtaining this curve, a range of residual gap of 0—20 mils was used. Additional evidence of the small effect of commercial differences in piece parts on magnetic leakage is provided by the previously mentioned fact that there is not more than about 5% difference in release time between relays having equal length slugs, one relay having its slug at the armature end of the core and the other having its slug at the terminal end.

4. *Initial Excitation.*

The limits of the two components, current and turns, are easily evaluated.

5. *Release Excitation.*

This is brought within prescribed limits by adjustment. It is necessary to ensure, however, that the hold (upper limit of release) and release tests are made in the same way as those used in the experiments, i.e., after an excitation equal to or greater than A in Figure 1.

After reviewing the steps necessary to ensure a known degree of uniformity for a quantity of slow releasing relays, it must be remembered that most of the work is done during manufacture. The actual tests used by the maintenance staff would be the same as those usually employed with the addition of two current tests. Thus, in the case of a 4700 type relay as used in step-by-step automatic exchanges, the following tests would be given:

a. *Current Tests.*
   1. Saturation.
   2. Hold. } Additional tests to control minimum and maximum release times.
   3. Release. }
   4. Non-operate.
   5. Operate.

b. *Mechanical Tests.*
   1. Gauging.
   2. General Clearances, etc.

"Saturation" is not really a test but is a measure which should be taken to standardise the condition of the relay before making *any* tests. The current employed for saturation is usually the normal circuit current so that no measurement is necessary.

A better idea of the advantages of the use of these additional tests may be obtained by considering the case of relays with which the same care has been taken in regard to dimensions, materials and processes, but which have been adjusted to operating and non-operating currents only.

For a given relay and method of tests, release current, governing release excitation, depends upon:

a. Operated air gap.
b. Operated load.

In step-by-step system relay practice, the operated load will depend upon the contact separation and upon the "follow," the stiffness of the springs, and the contact pressure on the break contacts. Usually the operating current is fixed by the load at the beginning of the armature stroke, so that the amount of load applied later in the stroke by front contacts, etc., can be varied considerably without changing the operating current. Thus, the only help the operate and non-operate tests give is in controlling the back contact pressure. Even this is done very imperfectly because the contact separation also affects the pressure.

The operated air gap on slow releasing relays is usually "zero." This means that it consists of a certain amount of zinc or nickel plating and air bounded by two surfaces which may be neither flat nor parallel. It is in fact subject to changes which, although small, are a large percentage of the average value.

The combined effect of these causes is that the release current of ordinary (i.e., without hold and release tests) slow releasing relays may be anything from zero up to about half the operating current, and the release time varies correspondingly.

In design, the hold and release test values are normally fixed so that a reasonable adjustment margin exists when all the piece parts, etc., are at either extreme. It is possible, however, to restrict the range of release time to a much smaller amount than this allows, by making the hold and release tests more nearly equal. If free use of the residual gap adjustment can be allowed, as is usual, these tests can be made to differ by no more than 10% and a constancy of release time can thereby be achieved, quite impossible by the other method. The value of the ratio $\frac{\text{Maximum Release Time}}{\text{Minimum Release Time}}$ of course depends upon the exchange voltage limits and the spring combination to some extent, but the following figures can be taken as representative of good practice:

| | Ordinary Operate and Non-operate Method | Hold and Release Method: Full Margins | Hold and Release Method: Minimum Margins |
|---|---|---|---|
| $\frac{\text{Maximum Release Time}}{\text{Minimum Release Time}}$ | From 3 to 4 | 2.5 | 1.2 |

In the first two cases above, the windings have been assumed to be of the form:

N turns minimum of No. X gauge copper wire.
Resistance = R ohms ± 5%.

In the last case the winding has been taken as N turns exactly of No. X gauge copper wire made up to R ohms ± 5% by resistance wire.

From the point of view of release time control, it is better and cheaper to wind coils to exact turns and to within ± 10% resistance limits than to have a minimum turn requirement and ± 5% resistance limits. Additional advantages of this practice are that it is simpler to detect short circuited turns, and adjustment is a little easier.

The case here considered has been the release of a relay from a steady excitation when there is no external magnetic field to influence it. In actual practice, it is usual to find that the current has not quite reached the steady state, and moreover that external magnetic influences may be present.

Experiment shows that if a relay is energised for a short period and then released, the length of time of energisation profoundly affects the release time. It is also found that so long as the operating current is small compared with the exciting current (say less than a quarter of it) its actual value has no influence on the release times. Figure 5 shows how the release time varies with the period of energisation for different values of excitation and release ampere turns. It will be noticed that an increase in excitation is relatively more valuable for very short periods than it is for long periods of energisation. Also a short slug gives better results than does a longer one when the period of energisation is short.

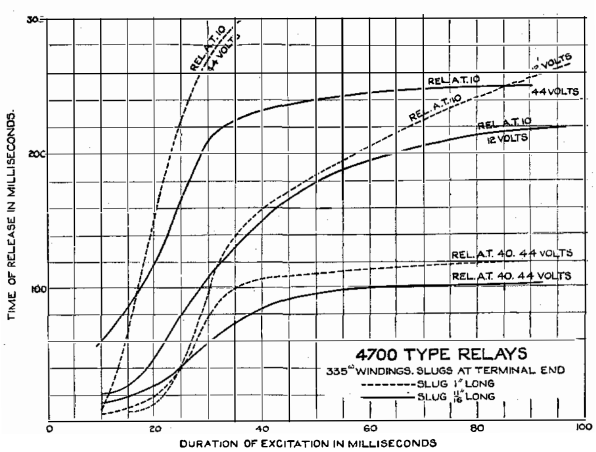



*Figure 5—Variation of Release Time with Duration of Excitation.*

When a certain release time is wanted from a relay which is energised for a short period, the corresponding release time for full excitation is determined and the appropriate hold and release tests are specified. This ensures uniformity of performance in the same way as it does for fully excited relays, but it is evident that, in addition, any changes in the period of energisation must also be allowed for or eliminated.

External magnetic fields, commonly referred to as cross fire, have an important influence on the release time of relays. A relay magnetised to the same polarity mounted beside the test relay will reduce its release time. If the polarity of the adjacent relay is opposite to that of the test relay, the release time of the latter will be increased. Such disturbing effects are usually present without being sought, but they may on occasion render useful service. In addition to these influences, there are several other electrical means of modifying the release time of relays which are employed either to augment or replace the effect of a slug. The following are examples of these methods:

1. Shunting the relay with a condenser in series with a resistance.

2. Shunting the relay with a non-inductive resistance.

3. Shunting the relay with an inductive resistance.

In all these cases some means is adopted for delaying or accelerating the fall of the flux from the initial value to the releasing value, and in consequence the "hold" and "release" current test is the logical way of ensuring the desired degree of uniformity.

# Intercall Selector System on the Swedish State Railway

By IVAR BILLING

*Byrådirektör, Electrical Department, Royal Swedish State Railways*

IN AN article appearing in "Teknisk Tidskrift," Stockholm, in 1923, a complete description was given of the train despatching system with selective calling of way stations from a central point, as supplied by the Standard Electric, and to a large extent adopted by the Swedish Railway Administration. This system is also extensively in use in Great Britain, Belgium, Spain, and in other European countries as well as in India, South Africa, the Federal Malay States, Australia, America, and other parts of the world. It has the merit that any of a number of way stations connected in parallel to a metallic line can be called easily without the other stations being simultaneously called or otherwise disturbed, a feature which renders it particularly suitable for railway application. As is well known, this type of service requires facilities for the rapid delivery of messages over great distances with full guarantee of safe transmission between the responsible persons, and without employing expensive trained telegraph operators.

The system is in constant use by the State Railways and has expanded greatly, so that the 3,500 km. of lines and 440 way stations equipped with selectors in 1923 have increased in 1928 to 6,150 km. of lines and 730 way stations. During this time the use of the selector system has increased also on the privately-owned railways of Sweden. In addition to the Railway Companies mentioned in the previous article, i.e., the tunnel railway of the Luossavaara-Kiirunavaara Company comprising a section of 3 km. of line and 10 selector sets, and the Stockholm-Roslagen railways, whose 55 km. line Stockholm-Rimbo has 18 selector sets, there now exist, in the Västergotland-Göteborg Railway with 130 km. of line, the Göteborg-Skara line with 33 selector sets, and the Eskilstuna-Oxelösund line of the Trafik A/B Grängesberg-Oxelösund Railways with 103 km. line and 32 selector sets. The private railways in Sweden accordingly have at present a total of 291 km. line with 93 selector sets in use.

As is well known, there are two systems supplied by the International Standard Electric Corporation:

(i) The "traffic control," "train despatching" or "centralised" system. All ringing is done by a single traffic controller, who can call up any station. In this system, stations cannot call one another directly, but only through the agency of the controller.

(ii) The "Intercall" system, in which by individual selection any station on the same telephone line can call, directly, any other on that line, without a controller.

Most of the lines in Sweden are in accordance with (i). The Eskilstuna-Oxelösund equipment, however, is in accordance with (ii). As this is the first time that the "local calling" system (ii) has been used in Sweden, as it was developed to cover the demand for a system not disturbed by power lines, electric railways, etc., and as new types of apparatus have been introduced into it, a more detailed description of it will here be given.

The signalling arrangements of the intercall system (ii) are similar to those of the traffic control system (i), i.e., selectors are operated by means of A. C. impulses through condensers. The means of producing the impulses is, however, different. In the train control system the impulses are obtained by connecting a signalling battery to the circuit through a smoothing circuit, and then making a series of reversals of the connections of the battery in accordance with some predetermined code. In the intercall system, the A. C. impulses are produced in exactly the same manner that speech currents are produced in the well-known retardation coil cord circuit. The signalling battery is permanently connected to the line through a network of comparatively high impedance at signalling frequency, the function of the microphone, in the case referred to, being performed by a clockwork key which periodically short-circuits the line in accordance with the predetermined code.

As in the system (i), only the selector at the one station which is set to the code signal in question moves forward to the ringing position. The bell is operated by a local battery.

The particular form of the intercall system above described is known as the non-grounded system. There is also another form of the system in which the signalling battery is applied between the two wires and ground. This form requires less battery power, but is more subject to interference from electric power or railway lines.

### *Non-grounded intercall selector system*

The way stations on an intercall selector system communicate through a metallic loop to which they are all connected in parallel. For selective calling one battery supply set is installed. This can be placed where desired along the line, preferably, however, at the middle, in order to reduce the voltage of the line battery necessary for reliable operation. Way station equipments are installed at the various points, each consisting of a table or wall set fitted with an adjustable selector key to make calls, and a selector set with selector to receive calls.

Where it is found necessary, a special key for "common signal" and "time signal" is added as for the Eskilstuna-Oxelösund line. The battery supply set shown in Figure 2 consists of the following parts: (1) Two ballast lamps, whose characteristics are adjusted for properly limiting the signalling current; (2) Condensers connected in parallel with an ohmic resistance and a retardation coil, which together with the ballast lamps have high series impedance at signalling frequencies essential for the operation of the system; (3) A repeating coil with windings evenly divided and connected to the telephone line, to give high impedance between the wires for the speaking current; and (4) Three double-throw knife switches of which two are for connecting the lines in two different directions, and the third is for connecting the line battery. The wiring of this apparatus is shown in Figure 1. All parts are static, i.e., not subject to wear. Regulation of the battery voltage is not necessary after the system is in operation, except, of course, that at regular intervals the battery must receive a proper charge.

The line battery consists of accumulators or dry cells. The voltage is adjusted according to

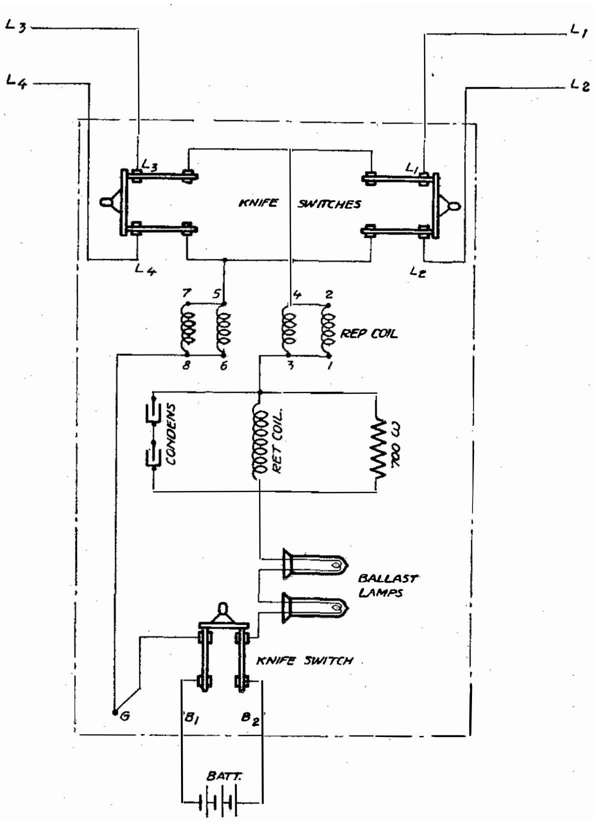



*Figure 1—Schematic Diagram of Battery Supply Set.*

the length of the line, and to the number of way stations connected. When the battery is placed near the middle of the line, the voltage may be calculated only for the longest of the line branches on either side of the battery supply set and the number of way stations connected to this branch. On the Eskilstuna-Oxelösund line, 103 km. long and with a total of 32 way stations, for instance, the battery is placed at Flen. The longest section of the line is then Flen-Oxelösund, 62 km., with 18 way stations. The "normal" voltage of the line battery is fixed at 280 volts. This includes a certain margin for drop in voltage, possible low insulation, etc., as the minimum voltage required for this part of the line is about 180 volts. If the battery had been placed at one end of the line, it would have been necessary to use a "normal" voltage of 360 volts.

In order to protect the battery if short circuits should occur on the line mentioned above, an arrangement with a thermo-electric relay has been installed near the battery supply set and

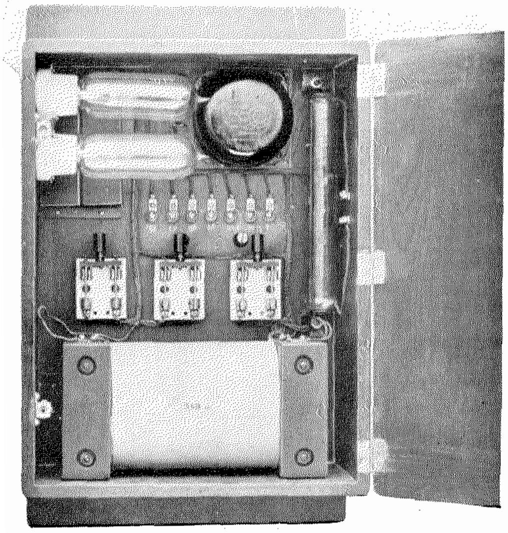


*Figure 2—Battery Supply Set.*

adjusted to disconnect the battery if the line wires at the farthermost end should be short-circuited for eight seconds or more. The maximum current required for a call from the way station nearest to the battery supply set during a period of two seconds—corresponding to the time required for giving a calling signal to a way station—is, however, not sufficient to disconnect the battery.

### *Equipment of the way stations*

The way stations are equipped as shown in Figure 3. To the terminal block, indicated, are connected: The two line wires ($L_1$ and $L_2$), two wires to the ringer and transmitter battery ($B_1$ and $B_2$), and the necessary connecting wires between the table set and the selector set ($L_1$, $L_2$, $B_1$, $B_2$, $K_1$ and $K_2$). Wall sets can be supplied for use at the way stations. These wall sets are self-contained, comprising not only the telephone equipment and the selector key, but also the selector itself.

### *The selector set*

The wiring of the selector set is shown in the upper part of Figure 3. It contains (Figure 4) the selector itself, above which are a condenser of 1.25 microfarads, and the two symmetrically arranged retardation coils, each of 0.55 ohm, connected to the line $L_1$ and $L_2$. In the same set is the 8 ohms ringer, which is connected to the local ringer battery $B_1 - B_2$ by means of contacts on the selector when the latter moves to the ringing position. A special contact in the ringer, connected in series with a condenser, 0.01 microfarad, causes a ringing tone signal to be sent out on the line, as a check that the call is properly received.

The selector, which is hermetically enclosed in a glass cover, consists of a polarised magnet with an armature which operates a stepping mechanism by means of a lever when the magnet coil receives alternate current impulses of approximately $3\frac{1}{2}$ cycles per second (Figure 5).

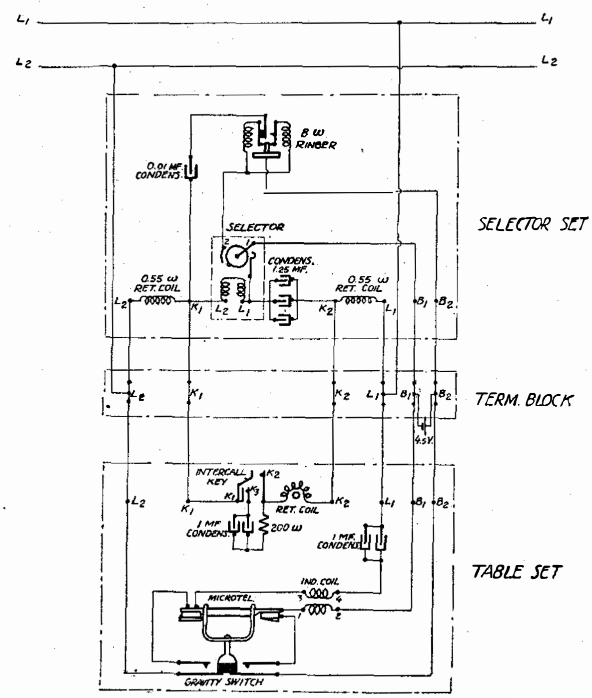



*Figure 3—Schematic Diagram of Way Station Equipment.*

It is non-operative at other frequencies. The selector is accordingly not influenced by ordinary telephone generator current, or current induced from electrified railways or power lines of higher frequencies.

The same shaft on which is mounted a stepping wheel carries the so-called "code wheel" which is provided with small circumferential holes into which are fitted three code pins. These pins are located at different intervals at different way stations, thus forming the code. A contact "ringing spring" is carried round on the code wheel. The corresponding contact is fixed below the wheel. It requires seventeen impulses to rotate the code wheel sufficiently to bring the ringing contacts together. The total number (17) of impulses is broken into three different groups at each way station code wheel, depending upon the relative positions of the pins. The number of possible combinations of this kind is 78.

Current impulses coming from any calling key pass through the coils of the selector and through the condenser connected in series thereto. The motion of the armature steps the code wheel. Consider a selector 5-6-6 to be operated. The first five impulses from the selector key step the code wheel round five teeth. There is then a period of rest at the key, during which time there is no current charge or discharge through the condenser; consequently, the selector armature returns to its position of rest and releases its hold from the stepping wheel. Code wheels at all stations now tend to return to their normal position; but at the particular stations that have 5 for their initial number the code wheel is held by the code pin, and therefore cannot return. After the pause, the sending key sends six more impulses. The operation is repeated at all stations. The code wheel at the station that has 6 for the second item in its code is again held, all others being released. There is now only one selector that is in an advanced position. After the second pause, the key sends out six more impulses which carry the code wheel to the ringing position, whereupon the selector bell rings for two seconds. During this ringing time, a "tone" is produced on the line by means of an extra contact on the bell at the station called. This assures the sending operator that the called selector has operated. At the end of the ringing period the calling key gives one more impulse which restores the selector to normal position.

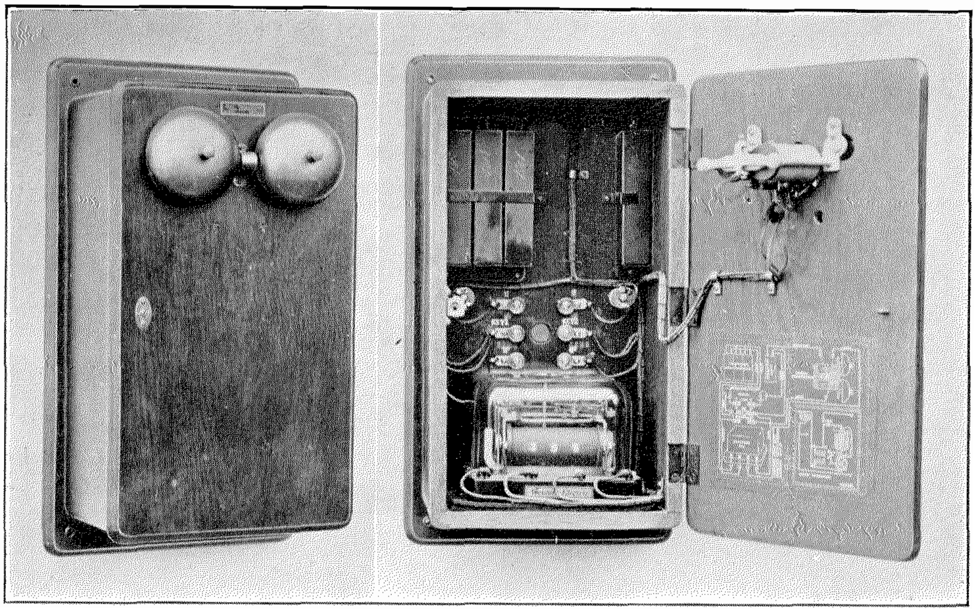


*Figure 4—Selector Set.*

The magnet coils of the selector have a D. C. resistance of 21,000 ohms. The selector and the condenser connected in series have a total impedance of 35,000 ohms at the calling current frequency of $3\frac{1}{2}$ cycles and more than 1 megohm at the speaking current frequency of 800 cycles.

The circuit diagram of a Table Set is given in the lower part of Figure 3. This set is shown in Figure 6. At the top is the microtelephone resting on a movable cradle, which operates a switch when the microtelephone is removed (Figure 3). This switch connects the microtelephone to the line and closes the circuit of the transmitter battery. It also connects the

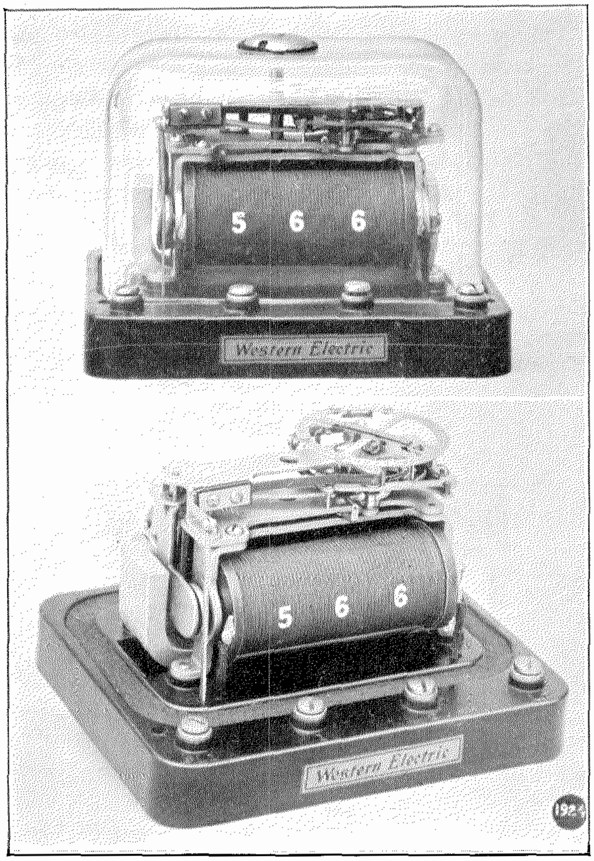



*Figure 5—Selector.*

receiver and the induction coil to the line through a condenser. The Table Set further contains an adjustable (universal) key for originating calls by setting up the special code signal for each of the way stations. This adjustable selector key is characteristic of the intercall selector system. In the system with centralised calling a special central key case contains as many keys as there are way stations on the line, each key being permanently set for a certain signal.

### *Adjustable selector key No.* 2196-*A*

One key is installed in the telephone set at each way station. It consists of a governor controlled clock for the setting of certain calling signals and corresponds to the individual keys at each station in the centralised calling system.

At the front of the key two insulated buttons are arranged coaxially, each associated with a plate sector, one of which is to be seen on the left of the vertical springs in Figure 7. The positions of these sectors, which are controlled by the buttons, are indicated by two pointers with openings (Figure 7) showing the calling signal to which the key is set. In order to set the key to a certain calling signal, for instance 8-4-5, the smaller button is first moved until its pointer arrives at the number 8. Then follows the setting of the larger button until the right pointer is set on 5; in other words, the buttons are used only for the setting of the first and the last (third) impulse group of the calling signal. At the same time the key is automatically set also for the middle impulse group of the calling signal—in this case 4.

Below the two buttons on the front side of the set (Figure 6) is a key handle which can be turned through 90° to the right for the winding of the main spring. When the handle is released, it returns to its normal position, and at the same time the main spring gives the main spindle of the mechanism one turn in $7\frac{1}{2}$ to 8 seconds. Regulation of the speed of the main spindle is obtained by an adjustable governor (Figure 7).

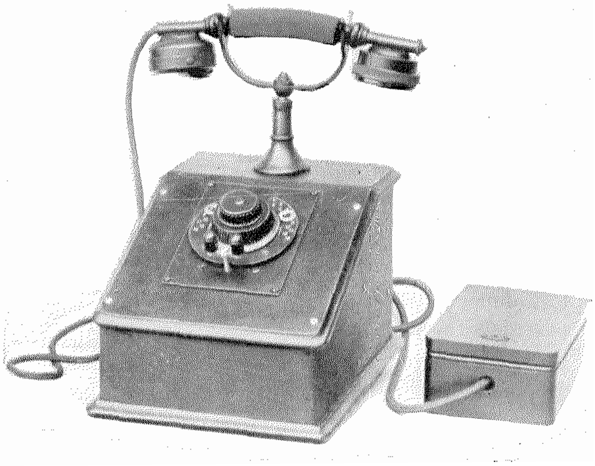


*Figure 6—Table Telephone Set.*

To the main spindle is fixed a lever which follows the movement of the main spindle and is arranged with a ratchet and spring combination. This ratchet fits into a ratchet wheel which moves freely on the main shaft. The lever is fitted with a pin which, when passing the before mentioned sectors, is pushed outwards, so that the ratchet cannot bring the ratchet wheel along in its motion.

The ratchet wheel is associated with a toothed code wheel, which can also move freely on the main spindle. This code wheel moves accordingly, with an even speed, together with the ratchet wheel, i.e., as long as the ratchet runs freely. When the ratchet wheel, as described, stands still because the ratchet is pushed outwards by the sectors, the code wheel is accordingly also held stationary.

The teeth of the code wheel open and close the contact between the springs ($K_1$, $K_2$, $K_3$) which are connected to the selector circuit (Figures 3 and 7). These three contact springs constitute the impulsing mechanism, and by their alternate opening and closing allow the condenser associated with each selector on the line to charge and discharge. The corresponding charge and discharge currents from these condensers operate the selectors. The contact between $K_1$ and $K_2$ is closed with each passage of a tooth of the code wheel. At the same time the contact $K_1$ and $K_3$ is also closed for the purpose of bridging over contact $K_1$ and $K_2$ by an arc-quenching device consisting of condensers and resistance coil. The three groups of impulses necessary for the sending of a call are brought about as indicated above, and the interval between the groups is caused by the two sectors. At the receiving selector, the three groups of impulses cause the mechanism to operate as described and to bring it into a ringing position.

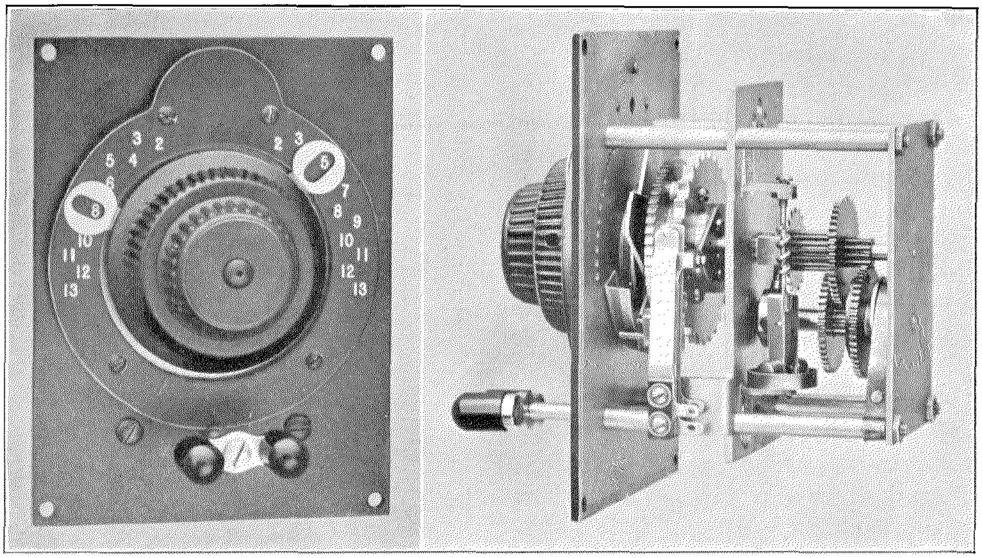



*Figure 7—Adjustable Selector Key (Intercall Key).*

To provide for holding the selector in the ringing position, the sending key has a plate segment corresponding to somewhat more than one-quarter turn of the main spindle. When the lever passes this segment, the ratchet wheel and code wheel are held in such a position that the contact springs $K_1$ and $K_2$ make contact. As the called selector is then without current, the code wheel remains on its ringing contact, and ringing continues until its release by another impulse from the sending key. When the lever has passed the segment mentioned, its pin drops into a notch and takes the ratchet wheel along until the code wheel gets a tooth gap just in front of the contact spring $K_2$; this breaks contact $K_1$ and $K_2$ and a current impulse passes through all the selectors and effects their release and return to normal. Thereafter the pin of the lever slides out again on the segment in such a position that the code wheel has a tooth gap just in front of $K_2$, the contact between $K_1$ and $K_2$ being still broken, and the key stops, whereby contact $K_1$ and $K_3$ is broken and the system has returned to normal position.

### *Special Key for Common and Time Signals*

For the traffic authorities it may often be of importance to call by a common signal a selected group or all stations on the line. An important instance is the giving of the time signal for the daily adjustment of the clocks of the traffic stations. For this purpose the selector telephone plant here described for the line Eskilstuna-Oxelösund has a separate box installed (Figure 8) in the telegraph office in Eskilstuna. This contains three keys, i.e., in the middle, one adjustable selector key No. 2196-A, as described above, by which selective calls for any station can be sent. On each side of this key is a special sending key. These keys are so adjusted that each of them, when used, first sends out seventeen alternating impulses in succession, causing all the selectors on the line to move to ringing position. The key for common signal is so arranged that five short rings follow on all way stations of the line. The key for time signal gives one long and six short rings. On the former signal, all stations have to give an answer in a certain fixed order.

When the time signal is given, however, the way stations do not answer in the telephone, but instead prepare to take the actual time, which is given one minute later, by the repetition of the same time signal, exactly at 9 o'clock.

### *Characteristics of the Intercall System*

The intercall system as supplied to the Trafikaktiebolaget Grängesberg - Oxelösunds Järnvägar has certain features which can be summed up as follows:

(1) All stations have the same equipment.
(2) Each way station can call any of the other way stations.
(3) The battery equipment can be placed wherever desired on the line. It contains no relay or other apparatus requiring adjustment.
(4) As the battery supply set can easily be cut out during tests by means of knife switches, line tests are easy to make.
(5) The system is protected against interference from electric power lines and electric railways, it being evenly balanced and insulated from ground.

The features (2) and (3) are common to both the grounded and non-grounded system for intercalling. In the system with centralised calling as used by the State Railways, however, each connection between two way stations must be established by the despatcher station, i.e., this station is first called and then sets up the selective call. In the United States, Belgium, and other countries where the train despatching system is fully carried out, a person is always present at the despatcher station, the so-called "Despatcher" with his head telephone always on the line, so that the way station need only go in on the line and ask for the desired station. This arrangement, of course, gives considerably quicker service. With the centralised calling system, it is further necessary to place the line battery at the despatcher station.

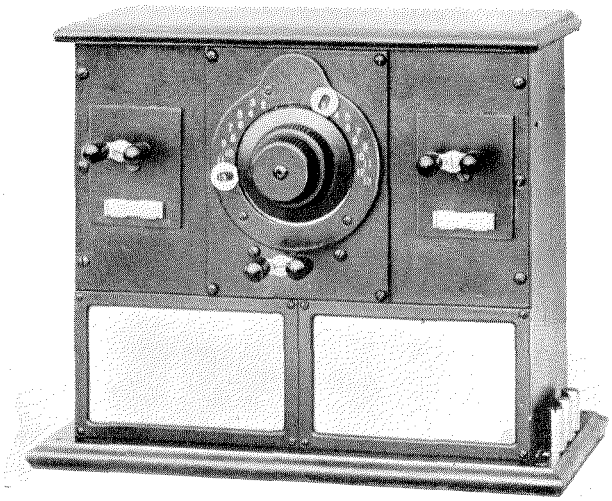


*Figure 8—Special Keys for "General Call" and "Time Signal."*

The non-grounded intercall system has the advantages mentioned under (5) in common with the system for centralised calling used by the State Railways in comparison with the grounded system for intercall.

The advantages here given for the non-grounded intercall system, however, must be offset against what may possibly in some respects be considered a disadvantage, i.e., that the main battery must have a higher voltage than with the other systems. There will be required, for instance, for a 50 km. long 6 mm. copper line with twenty way stations, figured from the battery station to the furthermost end of the line, 110 volts in the system for centralised calls, 192 volts in the grounded intercall system, and about 275 volts in the non-grounded intercall system.

The disadvantage of the comparatively high voltage, provided well insulated material is used for the station wiring, etc., should not be considered as of too great importance; the risk which might possibly exist for the attendants by touching the wires is very small, as the system is insulated from ground, and it is rather unlikely that a lineman would touch simultaneously both line wires. The condition mentioned regarding the voltage of the battery is in any case of minor importance in comparison with the advantages of the system which, among others, avoids the necessity for the presence of an attendant who would be required if the traffic control system were used. In cases where a person is not required for other purposes, as, for instance, attending to a manual switchboard, the system here described always has the advantage over the centralised calling system, which requires one person for attending to the despatcher station. Through the use of the intercall system, this person is not required.

The non-grounded intercall selector system here described, which makes possible a call from one station to any of a number of other stations, could therefore apparently be used to great advantage and should be used extensively, not only by railways which by the introduction of the system would be able altogether to go over to the use of the telephone instead of telegraph and thus effect a considerable saving on account of not requiring trained telegraph personnel, but also by canals and automobile transportation companies, mines, sawmills and other traffic and industrial enterprises requiring a time-saving telephone connection between various points situated at a distance from each other and wishing to save the cost of a switchboard or other central exchange with attendant personnel.

The new type of table telephone for the intercall system has for the first time been used by the above described plant for Trafikaktiebolaget Grängesberg-Oxelösund. All the equipment is manufactured by the Bell Telephone Manufacturing Company, Soc. Anon., Antwerp, with the exception of the selectors, which have hitherto been manufactured by the Western Electric Company, United States of America, but which are now manufactured by the Standard Electric in Europe.

### *The Selector System in Europe*

In addition to the above-mentioned uses by the Swedish Railways, the system is used extensively in England and in the following other European countries:

In Holland, a grounded intercall selector system for communication between eleven way stations over a 30 km. telephone cable has been supplied. The system is used for the regulation of the traffic of an electric railway.

In Norway, the system is used for centralised calling on the lines Oslo-Drammen and Narvik-Swedish Frontier, totalling about 125 km. and 56 selector sets.

In Denmark, an intercall selector system is employed for the lines Copenhagen-Roskilde and Ringsted-Haestved, altogether about 70 km., 16 selector sets.

In Belgium, the train despatching system for centralised calling is used extensively and to great economic advantage. The Belgian State Railways had in May, 1928, 4,800 km. lines, of which the most important sections upward to 1,800 km. were equipped with the Western Electric despatching system. Including way stations, sub-stations, etc., about 1,100 selector sets were in use.

In France, train despatching systems for centralised calling as well as for intercalling are used on several of the largest railways; for instance, Paris-Lyon-Mediterranée, Chemin de Fer de l'Est, Chemin de Fer de l'Etat, Chemin de Fer du Midi and Paris-Orléans. Altogether, more than 2,600 selector sets are probably in use.

In Spain, the selector system is introduced or is being introduced on several of the most important lines, as, for instance, on the Madrid-Zaragoza-Alicante lines, and for the Norte and Cataluña railways—altogether, about 225 selector sets.

In Portugal, the non-grounded intercall selector system is partly introduced, so far with 26 way stations.

In Italy, in the State Railways as well as certain private railways both centralised and intercall selector systems are found, the latter systems grounded as well as non-grounded. According to information available, a total exceeding 1,300 km. railway lines are equipped with more than 300 selector sets. Of this, the State Railways own about 760 km. lines with 65 selector sets after the grounded, and 100 sets after the non-grounded intercall selector system.

In Roumania, the train despatching system is used for centralised calling on, altogether, about 600 km. lines with 72 selector sets.

In Czechoslovakia, the last mentioned system is used on about 200 km. lines with 60 selector sets, and further lines are projected.

**The Editor regrets that through a last-minute printer's error, the authorship of the article, "The Brussels International Telegraph Conference," page 280, Volume VII, No. 4, *Electrical Communication,* was ascribed to Siffer Lemoine, Chief Engineer, Swedish Telegraph Administration.**

**This article should have appeared without credit line.**

# Salesmanship in Telephone Development

By R. M. REINOEHL

*Commercial Engineer, International Telephone and Telegraph Corporation*

SINCE 1875, the year of the invention of the telephone, the art of selling telephone service has progressed as soundly, even if not as conspicuously, as the development of the science of telephonic communication. In fact, sales efforts probably have gone through as many vicissitudes as any other phase of the telephone business.

From the first struggling days of the telephone, when the pioneer promoters carried crude portable sets about with them, forcing demonstrations upon unwilling friends in a determined attempt to obtain supporters, until the turn of the century, the telephone sales job consisted almost entirely of such haphazard promotional salesmanship. Success, during this period, depended largely on promoting the conception among those skeptical people that the telephone was no longer merely an interesting experiment, not a mere toy or scientific novelty into which it would be undignified to be found talking in more serious moments, but the source of a vast enterprise. Furthermore, the burden was upon the shoulders of those early telephone salesmen of impressing the public with the thought that the benefit to be derived from the telephone depended largely upon their appreciation of its possibilities and the aid which they would contribute toward its development.

For many years it was an uphill fight, growth remaining slow and of limited scope, in spite of all efforts that were put forth to arouse interest. For that reason the value of the service continued to be rather limited and the general public was not entirely convinced that it was worth what they were asked to pay. A great many owners of large and small business establishments were very doubtful as to whether telephone service would be of value to them. There was, for example, the case of a very prominent physician. It was believed that if he would subscribe it would greatly assist the company to induce many others to take service. He ridiculed the idea, giving for his principal reason the fact that people would get into the habit of calling him by telephone for advice which he would have to give free of charge.

Compare this attitude, if you will, with that of the present intensive period in which the physicians not only subscribe for their own service, but also arrange for secretarial service to be furnished by large private branch exchanges in order to make sure that all calls for them are properly handled during all hours of the day and night.

Then there were those who had some conception of the telephone's possibilities but were reluctant to introduce it into their establishments because it meant radical changes in their methods of doing business. Even though they admitted that these methods were often crude and frequently involved delays and inconveniences to themselves, as well as to their patrons, yet, since they were established and time-honored customs, they preferred to let the existing conditions continue.

This promotional salesmanship by a few individuals was then largely superseded by special squads making house to house campaigns, with a fair measure of success. As a natural outgrowth of this selling method, the plan was developed of having all employees participate in the contest for new subscribers. This proved to be a profitable move, for the results exceeded even the most optimistic predictions. For example, in Philadelphia during the year 1906 the net station gain exceeded the total number of stations in service when this drive began. It is interesting to note that even today this is recognized as a very successful way of selling telephones. Such periodic sales campaigns not only make large additions to the number of stations in service, but they also arouse the interest of the employees which, at times, is apt to lag. It should be noted that these efforts were expended for the purpose of increasing the number of subscribers in the system, thereby increasing the value of the service—a view which was fundamentally correct. At that time, the value of extension stations and other associated equipment, which today make the service so flexible and useful, was not appreciated. Up until the World War, growth was steady but was not secured without much difficulty, because much education of the public was still necessary.

The War, bringing other radical changes, did not fail to exert its influence on the telephone business in the United States. The demand for service by business concerns grew in leaps and bounds, and extensions of subscribers' equipment were made which up until that time had hardly been thought of. Enormous private branch exchanges, covering miles of area with private lines and many other kinds of equipment, grew over night, so to speak. Later came an unprecedented demand for residence service. Soon a condition was created which, in a way, had been hoped for but which had not been expected or desired so suddenly; the companies virtually employed their equipment up to capacity and service had to be denied to thousands of applicants, not only during the War years, but in many places for several years thereafter. If it had not been for the faith and optimism of the officials of the Bell System who were in charge before the War and who had adopted a policy of continuous and liberal expansion of plant with an eye to great future development, the War growth would have found them totally unprepared.

Selling, as commonly understood, ceased to exist. Salesmanship of the immediate post-war period consisted of restricting growth rather than encouraging it. Applicants were invariably told that there would be an indefinite delay in furnishing service. There was even a dearth of instruments and other auxiliary equipment. This was a most unfortunate situation because all of the selling momentum which had been built up during more than forty years of effort completely died down. When facilities again became available it was not easy to arouse the selling enthusiasm which had previously existed; no concern, obviously, can look forward to a prosperous future by complacently assuming that business will come of its own accord.

This inertia fortunately has been overcome, and there is no doubt that the sales spirit again pervades the personnel of the telephone companies in the United States, bringing with it new problems to be faced. During the past five years not only have new subscribers been sought, but the plan has been to make sure that from the beginning they are adequately furnished with service and equipment. In other words, a new conception has been gained of what should constitute service. For residences it is thought that the telephone equipment should be in proportion to the value of the property and the financial condition of the dweller. It is believed that luxurious homes should accordingly be equipped with such telephone service as inter-communicating systems with telephones liberally distributed. Almost any residence, it is thought, should at least have an extension telephone on the upper floor. Business houses more generally appreciate the telephone's possibilities and a very great responsibility is accepted by the companies by continually offering assistance to subscribers in the solution of their telephone problems. In the United States, Commercial Service Work, as it is called, is an important feature of both sales and customer relations activity.

The sales function of to-day is, accordingly, no longer one of merely inducing people to subscribe for service. It has become far more complex than that. The telephone salesman must be able to familiarize himself with all kinds of business to an extent sufficient to put him in a position to prescribe for the telephone needs of these various concerns. He is really selling the intangible article of "service" rather than so many telephone instruments and associated equipment.

With this broadening of the local use of the telephone, the natural result has been a great widening in the scope of use of long distance service as well. Every day there are increasing numbers of business concerns which are making selling by telephone, both local and long distance, a very definite part of their programs. "Key" towns are selected and their salesmen travel from one to another and call the prospective customers within a certain radius by telephone. Sales are made in this manner at a remarkably low cost.

It is virtually impossible to forecast just to what extent the telephone will be used in the future. Some idea of it may be gained from the fact that some department stores have recently subscribed for facilities which permit their customers for miles around to order by telephone without any toll cost to them. When the scope of usefulness is extended in this manner it is not difficult to realize that the successful telephone salesman of to-day must also be a resourceful and imaginative person. Business houses are eager to hear of any new ideas which are presented by the telephone companies, a fact which is further evidence that the telephone is now recognized as an indispensable part of our scheme of things and its vast potentialities are not nearly exhausted.

The United States of America, with one-sixth of the world's population, had until recently approximately two-thirds of the world's telephones. This is no longer true. The percentage is gradually growing downward, not because of retarding development in the United States but because of the rapid expansion which is taking place in other parts of the world; an expansion which has evolved from those early discouraging days to the present-day international scope, in which latter activities the International Telephone and Telegraph Corporation and its Associated Companies throughout the world are playing a not unimportant part. More and more countries are recognizing increasingly the benefits to be derived from the telephone development of the past fifty years, a development not only in the art of telephony but also in the art of distribution—two factors which have combined to produce the new conception of subscribers adequately equipped with telephone service and using it increasingly over an ever widening area.

Keeping pace with the rapid growth of local service throughout the world is the remarkable use of intra- and international service. Intranational service breaks down the barriers of sectionalism which, in turn, is one of the greatest factors toward national achievement. International service, as has often been said before, without doubt, will be one of the greatest instruments for creating better understanding and, consequently, promoting lasting peace among the nations of the world. This achievement has been made possible by the coöperation of those engaged in all branches of the telephone industry, and surely, in these endeavors, the art of salesmanship has not played the most inconspicuous part.

# The Modern Plant of the Nippon Electric Company, Limited, at Tokyo

By A. G. JILLARD

*Far Eastern Director of Manufacture*

A DESCRIPTION of the plant and work of the Nippon Electric Company, Limited, would not be complete without reference to the situation at the time of the Great Earthquake[1] of September 1, 1923, and the very radical changes it brought about. At that time the plan for the ultimate development of the plant included the construction of buildings up to the property lines, and the five buildings which had been built in accordance with that plan were of reinforced concrete. Four of these buildings were three stories high, and one was partly two stories and partly three stories high. (Figure 1.) The total gross floor area in these reinforced concrete buildings was 185,750 sq. ft., and the total gross floor area of all buildings then on the compound was 293,753 sq. ft. The earthquake completely ruined the reinforced concrete buildings down to the level of the second floors, though it has been practicable to use the ground floors of these buildings, after proper repairs, until new buildings could be built. As all of the other buildings on the compound were small, and old structures marked for demolition, the earthquake resulted in a situation calling for the reconstruction of the entire plant.

Prior to the Great Earthquake, manual telephone equipment only had been used by the Department of Communications; but since fourteen of the nineteen exchanges in Tokyo and both exchanges in Yokohama were destroyed by the earthquake and fire, the Department of Communications very wisely concluded that it was a most propitious time for the adoption of an automatic system.

The Company therefore faced a situation calling not only for disposal of wreckage and the repairing of buildings, equipment, and apparatus, but also for immediate preparation for the manufacture of a complete line of automatic central office and subscribers' equipment and the rebuilding of the entire plant with a minimum of interference with production.

While this was a gigantic task fraught with difficulties and commenced under most depressing conditions, it has been handled in a manner which has brought forth much favourable comment, and the company is justified in feeling proud of what has been accomplished.

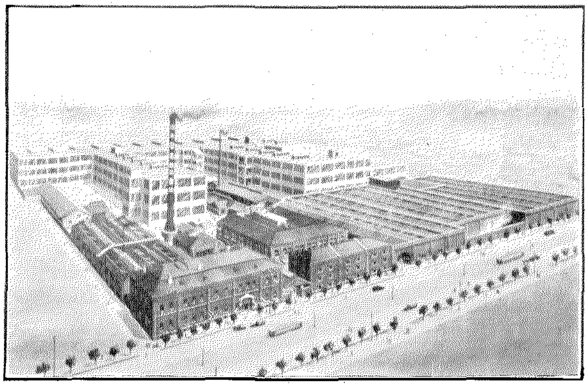


*Figure 1—The Nippon Electric Company Plant at the Time of the Great Earthquake of September 1, 1923.*

Demolition of the wrecked portions of the buildings and the salvaging of materials, parts, apparatus, and equipment, were started simultaneously on the seventh day after the quake, and twenty-seven days later the Manufacturing Branch began delivering fully repaired apparatus. Remains of buildings were made usable, and regular production was resumed with remarkable speed, while at the same time plans were being made for new buildings and preparation was commenced for the manufacture of automatic apparatus.

Including a two-story steel-frame warehouse in a detached compound, the Company now has more floor area than at the time of the quake and eighty percent of it is in newly constructed

[1] S. Inada, "Description of Damage Done by the Earthquake to Wired and Wireless Telegraph and Telephone Installations of Japan," *Electrical Communication*, Vol. III, No. 2, October, 1924.

buildings. Fifty percent of the ultimate building plan has now been realized. (Figures 2 and 3.)

### *The New Plant*

After very careful study of all types of buildings throughout the earthquake zone, the Company decided against the construction of reinforced concrete buildings and adopted steel-frame construction with reinforced concrete walls, floors and roof slabs. At the same time there was developed an entirely new ultimate plan (Figure 4) in which the buildings are set back from the property lines on the sides and back of the compound, thus greatly reducing the fire hazard and permitting all building entrances, except the main entrance, to open within the Company's property instead of to the public streets. The structures are built to the property line on the front street, which is sufficiently wide to permit of this without undue hazard. (Figure 5.)

The three connecting buildings at the front of the compound are sixty feet wide and four stories high. Buildings in the parallel wings which join the front buildings are partly four and partly three stories high, being eighty feet wide on the first floors and sixty feet wide on the floors above, thus providing light courts for the illumination of the second, third, and fourth floors. Skylights in the roofs over the first floors at the bottom of the light courts provide additional illumination for the first floors. This plan gives a large proportion of first floor area which is of great importance in a country regularly visited by earthquakes, because it permits keeping all heavy loads on the ground floor.

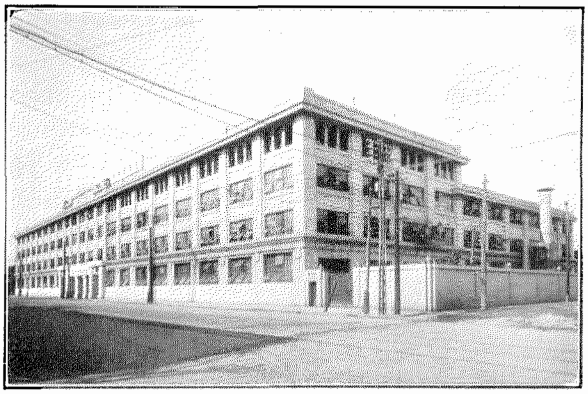


*Figure 2—Some of the New Buildings, Showing the Main Entrance and the Completed Frontage on the Main Street.*

As the building and floor areas are limited by Municipal Ordinance, one of the paramount aims of the designers was to utilize the entire floor area allowed while producing a group of buildings pleasing in appearance, capable of withstanding severe earthquake shock and fire exposure, and so laid out as to efficiently meet the requirements of a modern manufacturing plant.

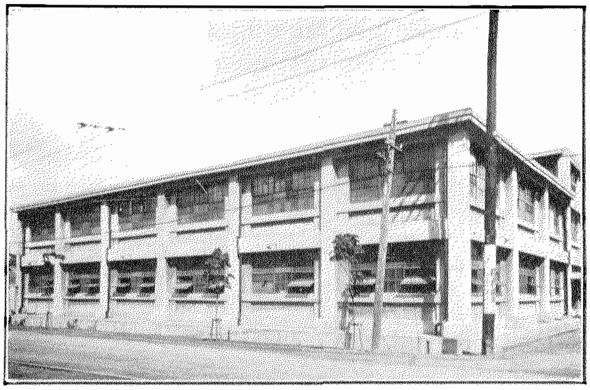


*Figure 3—Warehouse in the Detached Compound.*

The total gross floor area in the main buildings in the ultimate plan is 441,940 sq. ft., while that in detached buildings to be used for the storage of highly inflammable materials, automobile garage, etc., is 5,876 sq. ft.

The buildings were designed through coöperation of the architects of the Nippon Electric Company, and Japanese and American consulting engineers, all of whom had made studies of the effect of the earthquake and fire on all standard types of building construction, and were therefore especially qualified for the task set before them.

Borings to a depth of 100 ft. were made at various parts of the compound to determine the nature of the underlying strata; various test piles were driven and bearing tests were conducted with the result that reinforced concrete piles of the pedestal type were adopted. The foundations consist of individual footings under interior columns and continuous footings under outside and special columns. All foundations are of reinforced concrete and are connected by structural steel tie-beams encased in concrete.

In designing the buildings, the assumed seismic coefficient was .15, although municipal regulations require but .10, and the assumed stiffness ratio between exterior and interior bents was three to one.

The structural frame of the buildings consists of steel of rolled and built-up sections, riveted completely. All members are encased in reinforced concrete. A safety factor of four was used in designing the steel frame, and all stresses in the frame both from vertical load and earthquake shock are resisted by the structural steel. Specially designed connections of extra strength are used between columns and beams, and knee-braces are used between columns and beams in exterior bents.

In the concrete design, a safety factor of four was used, and all concrete was prepared in accordance with Professor Abram's method. Periodic tests on 6″ cube samples, seven days old, showed a consistent compressive strength of over 2000 lbs. per square inch. Concrete, except in reinforced slabs and footings, is considered only as fire-proofing for the steel; but the concrete design covered special features, including extra heavy walls on both sides of exterior columns, diagonal reinforcing at the four corners of all wall openings and diagonal reinforcing in all floor slabs around columns.

In addition, the roof slabs of the light courts were made sufficiently heavy to transmit stresses between adjacent wings.

Steel window sash glazed with ¼″ wire glass is used throughout the plant, while doors are of steel and are fitted with closing devices which operate automatically in case of fire.

Modern hydrant and automatic sprinkler systems were adopted for installation throughout the plant. As severe earthquakes sometimes break the city water mains and as suppliers of electric power open their switches when there is a quake of unusual severity, outside sources cannot be depended upon for water and electric power at times of greatest need. Provision for enabling the company to operate its fire protection system efficiently without aid from outside sources, was therefore important, and to this end the system includes an artesian well and extra large storage reservoir, together with an auxiliary oil engine for operating the pumps when the power supply is cut off.

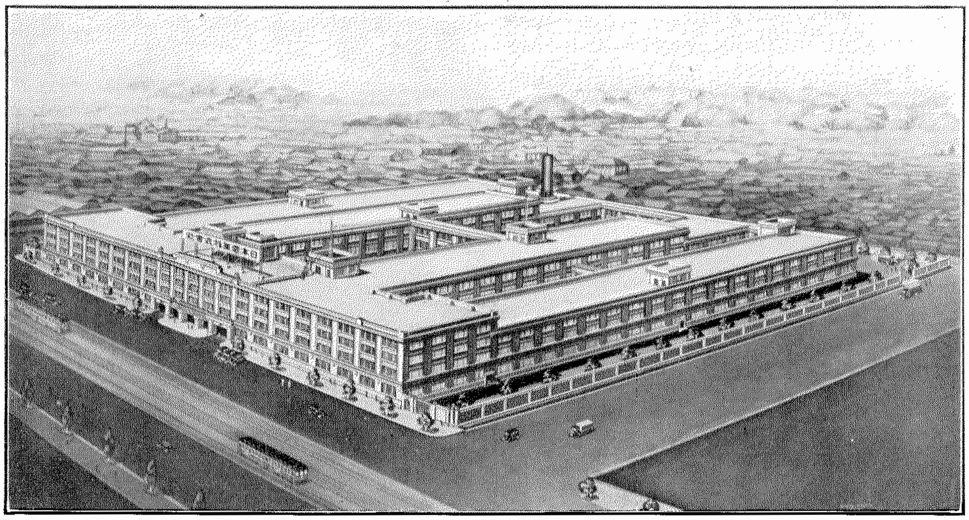
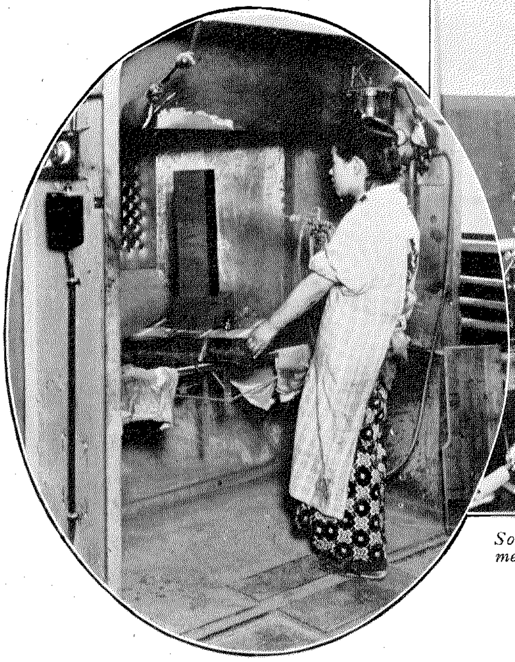


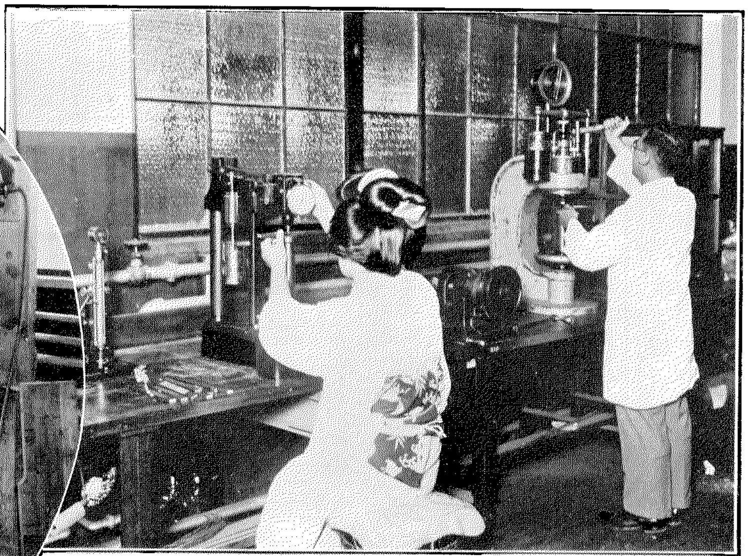
*Figure 4—Architect's Drawing of the Ultimate Development of the Main Compound.*

## *Manufactures and Equipment*

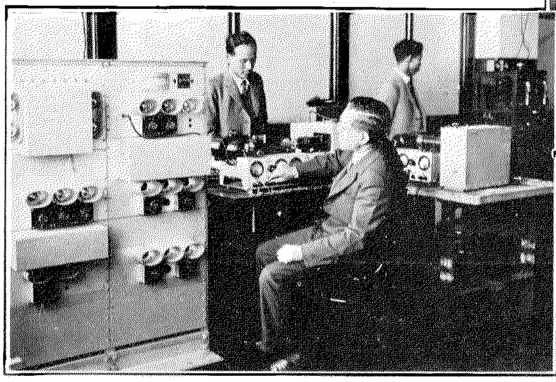
Manufactures of the Nippon Electric Company comprise central office and subscribers' equipment for both manual and step-by-step automatic telephone systems, and include telephone repeaters, loading coils, special communications appliances, electric meters, and switches.



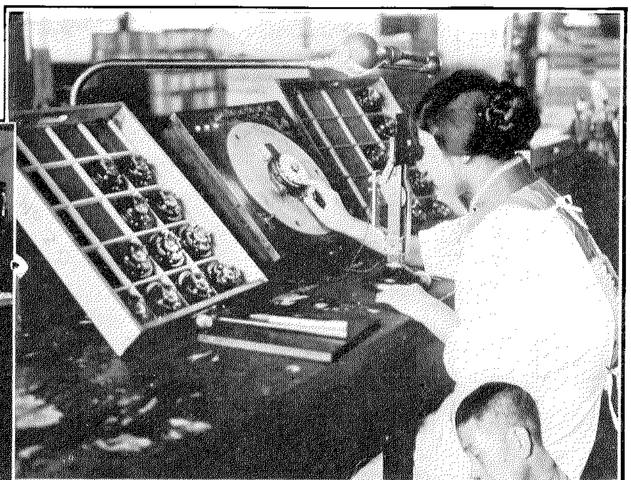
*Teru Tanabe Spraying Varnish in the Wood Finishing Department*



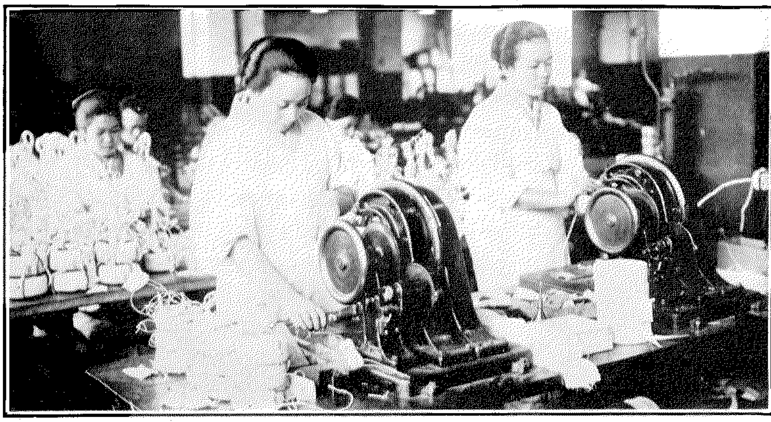
*Some of the Testing Equipment in the Raw Material Inspection Department. Shigeaki Sumikawa Operating the Brinell Testing Machine and Tsuyu Takahashi Operating the Rockwell Hardness Tester*



*Development Laboratory. Masatsugu Kobayashi (at the left), Kinichi Ito (centre), and Yasusuke Inokuchi (right), Testing Picture Transmission Equipment*



*Aki Hasegawa Testing the Speed of Automatic Telephone Dials by Means of the Stroboscopic Fork*



*Tei Kondo and Iwano Ishioka Operating Toroidal Winding Machines in the Loading Coil Department*

*Kakuzo Nakagawa, an Expert Steel Treater with Twenty-eight Years of Service with the Company, Operating Electric "Hump" Furnace in the Tool Making Department*

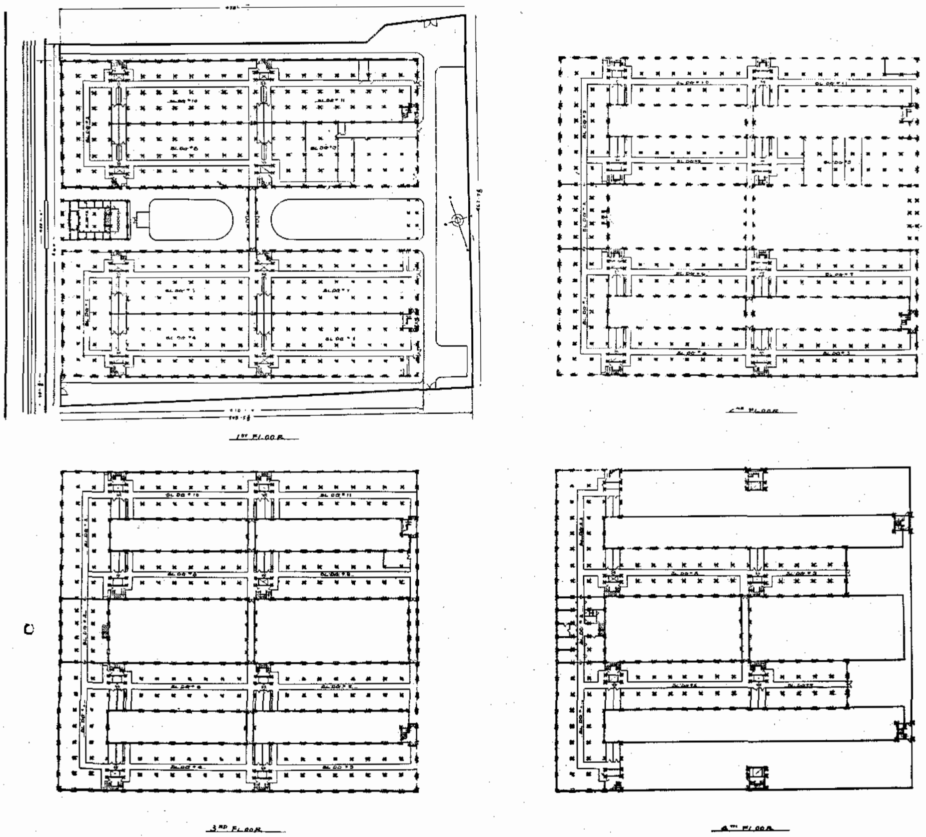


*Figure 5—Floor Plans of the Buildings in the Ultimate Development of the Main Compound.*

Manufacturing equipment is modern and includes screw machines, lathes, milling machines, power presses, wood working machinery, composition molding equipment, miniature lamp equipment, machinery for the manufacture of bare and insulated wire, switchboard cable, black enamelled wire, telephone cords, etc.

The Tool Making Department is manned by expert toolmakers and is equipped with modern precision machines, including a jig boring machine of extreme accuracy and a measuring microscope of most recent design. (Figures 6 and 7.) Modern tool making and heat treating practices are employed.

### *Inspection Methods and Engineering*

A completely organized inspection department maintains a rigid inspection of raw materials, parts and completed apparatus, and is amply provided with precision testing and measuring equipment. The Company's product is carefully and minutely inspected in order to maintain the highest commercially practicable standard of quality.

A well equipped chemical laboratory is provided for analytical work and the control and supervision of chemical processes.

Studies covering the improvement of existing manufacturing methods and equipment, the development of new processes, methods, equipment, etc., and the preparation of manufacturing and material specifications are also carried on by Manufacturing Development Engineers.

The Engineering Department includes a staff of trained engineering specialists with expert knowledge of modern communications systems and equipment. In addition, information is regularly received on improvements in manufacturing and inspection developments from the Western Electric Company, Inc., and from the

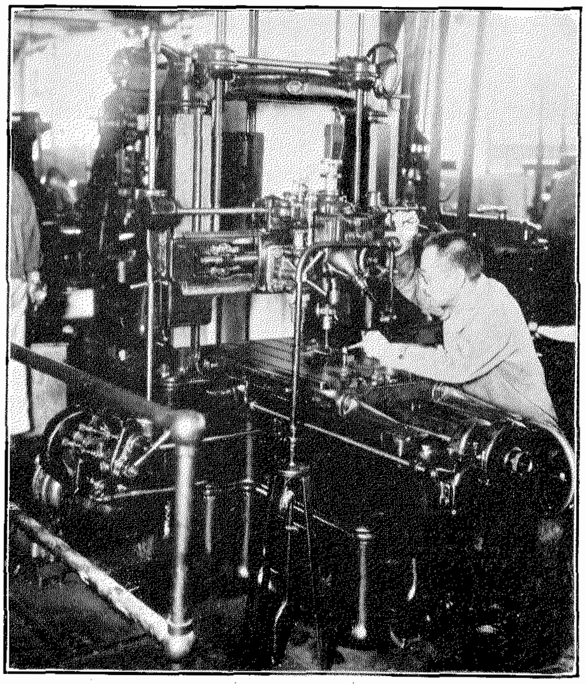


*Figure 6—Koso Kitagawa Operating Direct Motor Driven Precision Jig Boring Machine in the Tool Making Department. Mr. Kitagawa Has Completed Thirty Years of Service with the Nippon Electric Company.*

central organization of the Nippon Electric Company's Associated Companies.

A check inspection of completed apparatus is carried on by the Engineering Department and is accomplished by selecting at random a percentage of the regular shop output and subjecting it to a rigid engineering inspection. This inspection is independent of the regular Manufacturing inspection, and is in the nature of an additional precautionary measure to ensure the maintenance of the high standard of excellence of which the Company is justly proud.

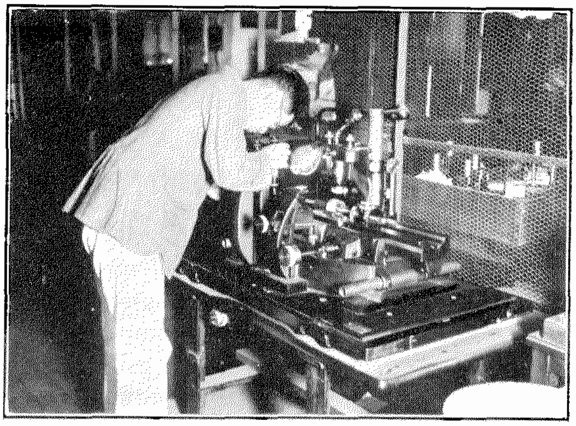
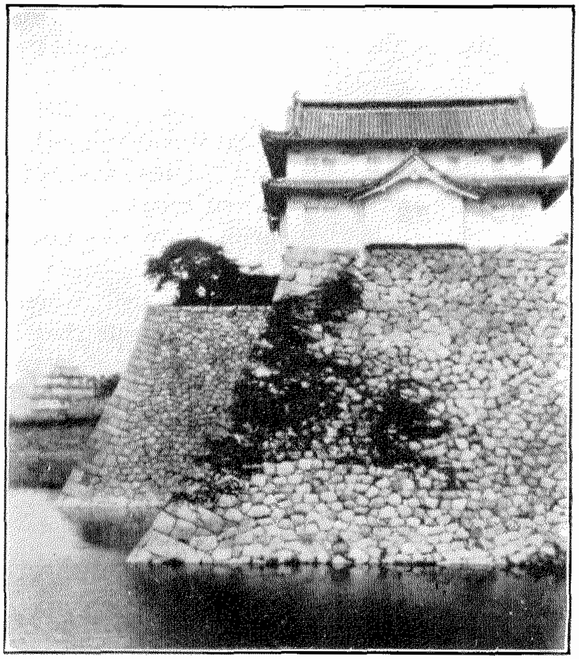


*Figure 7—Yoshinori Nishida Inspecting a Thread Gauge with the Measuring Microscope in the Tool Making Department. This Microscope is Guaranteed to Measure Within .0002 m/m (.00000788") of Absolute Accuracy.*



*The Osaka Castle, Built in 1583. This Picture Was Sent by Wire from Osaka to Tokyo by Means of Nippon Electric Company Picture Transmission Equipment During the First Successful Demonstration in Japan of Long Distance Picture Transmission.*

# Phase Relations in Unbalanced Two-way Telephone Repeaters

By L. T. HINTON, A. R. A. RENDALL and C. S. WHITE

*European Engineering Department, International Standard Electric Corporation*

OWING to the wide use of repeaters in modern high-grade long distance telephone circuits and the importance of attaining a satisfactory repeater gain without singing, the main purpose of this paper is to investigate fundamentally the conditions obtaining in a 22-type repeater in the singing condition, to discuss the differences between singing point values obtained by different methods, and to find a means whereby the practical value of Singing Point can be derived theoretically from knowledge of the lines, networks and repeater units.

An added purpose is to describe a method of measuring phase rotation that was developed to permit a large number of measurements to be taken easily and with sufficient accuracy.

In a general discussion on "The Limitation of Gain of Two-way Telephone Repeaters by Impedance Irregularities" in the Bell System Technical Journal,[1] Crisson points out that if the gain in the singing path is greater than the loss, the power in the reflected current will increase until sustained oscillation occurs.

Another aspect of the subject is dealt with by Erikson and Mack in their paper on the "Transmission Maintenance of Telephone Systems,"[2] where on page 664, in describing the 21-test, mention is made of the effect of the phase of the return current on the value of gain at which the repeater will sing. In the same paper (Figure 16) there is shown an Impedance Unbalance Measuring Set which measures directly the unbalance of two impedances in terms of Singing Point.

Experience in the field has shown that there is often a serious discrepancy between the values of Singing Point as measured by an Impedance Unbalance Measuring Set—or as calculated from the line and network impedance curves—and the gain at which a 22-type repeater will sing when inserted between the impedances.

It has been found also that the shape of the gain-frequency characteristic of a 22-type repeater changes as the gain is increased to approach the value at which the repeater will sing. The effect of this change on the overall attenuation-frequency characteristic of a complete circuit is illustrated in the above mentioned Erikson and Mack paper (Figure 11), from which it can be deduced that at some frequencies the effective gain increases, while at others it decreases, thus giving a characteristic with a distinct periodic wave.

### Theory of Singing Repeater

In order that any "feed-back" circuit such as a 22-type repeater may generate oscillations, at least as much energy must be fed back to the input as originally started the signal. There is an energy condition and a phase condition between the initial and return signals, that must be simultaneously satisfied. These conditions have been stated elsewhere[3] in dealing with the design of oscillators, but are re-stated below for convenience of reference:

(1) *Energy Condition.*

In the singing path, the total amplification must be equal to or greater than the total loss.

(2) *Phase Condition.*

Considering any one point in the singing path, the total phase rotation round the path with respect to this point, must be $2\pi N$ radians (where N is a positive integer).

### Circuit Employed in Measuring Phase Rotation

The principle of the circuit is indicated in

[1]*Bell System Technical Journal*, Vol. IV, No. 1, January, 1925.

[2]*Journal of the Institution of Electrical Engineers*, Vol. 62, No. 332, August, 1924.

[3]J. W. Horton, "Vacuum Tube Oscillators," *Bell System Technical Journal*, Vol. III, No. 3.

Figure 1, where three amplifiers, A, B, and C, are shown. These amplifiers are arranged to have a very high input impedance, and are designed to be efficient at all frequencies at which it is desired to measure the phase difference. It is convenient to make the characteristics of amplifiers A and B as nearly identical as possible in order to simplify the final calculations, but this is not essential. Amplifier C is provided, if necessary, but may be omitted if the outputs from A and B are sufficient. T is a transformer with a primary winding with two identical halves, one half being connected to the output of each amplifier, A and B, while the secondary is connected via the amplifier C, if required, to a thermocouple and milliammeter.

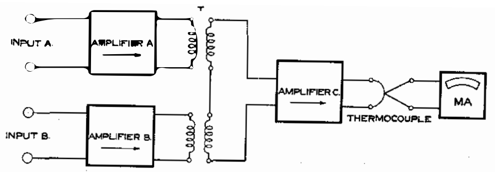



*Figure 1—Circuit for Measuring Phase Difference.*

The two potentials whose phase difference is required are applied to the inputs of A and B, respectively, first separately and then together. In this way three readings of current are obtained in the thermocouple circuit: (1) The current produced by the application of one unknown potential to A; (2) That produced by the application of the other unknown potential to B; (3) The current produced by the application of both unknown potentials to A and B simultaneously. From these three readings, and from a knowledge of the relative constants of amplifiers A and B, it is possible to compute the ratio of the magnitudes of the potentials applied to A and B and their difference in phase.

## Theory

Let amplifier A produce a voltage amplification of n, and a phase rotation of $\beta$, relatively to amplifier B.

Let the ratio of the two instantaneous potentials to be compared be represented by

$$\frac{E_1}{E_2}=\frac{m \sin(\theta+\alpha)}{\sin\theta}$$

and let $E_1$ and $E_2$ be applied to the inputs of A and B, respectively. Since the amplifier C produces the same change in both input potentials, the ratio of the two output potentials obtained in the thermocouple circuit may be represented by

$$\frac{E_1^1}{E_2^1}=\frac{n\,m \sin(\theta+\alpha+\beta)}{\sin\theta}$$

Let the R. M. S. value of $E_1^1$ be $V_1$

Let the R. M. S. value of $E_2^1$ be $V_2$

and let the R. M. S. value of $E_1^1$ and $E_2^1$, when combined in the output, be $V_{12}$.

Then, for the two potentials applied separately, if E denotes the maximum value of $E_2^1$,

$$V_1=\frac{n\,m\,E}{\sqrt{2}} \quad \ldots\ldots (1)$$

and

$$V_2=\frac{E}{\sqrt{2}} \quad \ldots\ldots (2)$$

On applying the two potentials together, the corresponding R. M. S. value in the output measuring circuit is:

$$V_{12}=\sqrt{\frac{E^2}{2\pi}\int_o^{2\pi}\left\{\sin\theta+n\,m\sin(\theta+\alpha+\beta)\right\}^2 d\theta}$$

which, on integration over the range from $\theta=o$ to $\theta=2\pi$ gives

$$V_{12}=\frac{E}{\sqrt{2}}\sqrt{1+n^2m^2+2\,n\,m\cos(\alpha+\beta)} \quad \ldots\ldots (3)$$

Dividing equation (3) by equation (1),

$$\frac{V_{12}}{V_1}=\frac{1}{n\,m}\sqrt{1+n^2m^2+2\,n\,m\cos(\alpha+\beta)}$$

whence

$$(\alpha+\beta)=\cos^{-1}\left[\frac{n\,m}{2}\left\{\left(\frac{V_{12}}{V_1}\right)^2-1-\frac{1}{n^2m^2}\right\}\right] \quad \ldots\ldots (4)$$

## Method of Measurement

In practice, amplifiers A and B are first calibrated to determine their relative constants n and $\beta$. Inputs, equal in magnitude and phase, are applied to A and B, first separately and then together, and the corresponding readings

$V_1$, $V_2$ and $V_{12}$ noted in the thermocouple measuring circuit.

$$\text{Then, } n = \frac{V_1}{V_2} \quad \ldots\ldots (5)$$

$$\text{and } \theta = \cos^{-1}\left[\frac{n}{2}\left\{\left(\frac{V_{12}}{V_1}\right)^2 - 1 - \frac{1}{n^2}\right\}\right] \quad \ldots\ldots (6)$$

If the two amplifiers are made identical, $\theta = 0°$ and $n = 1$.

When the unknown potentials have been applied, and three corresponding readings have been obtained, the ratio of the input potentials may be computed by using equations (1), (2) and (5), and the phase difference is then given by equations (4), (5) and (6).

If the two potentials are nearly 180° out of phase, the combined current in the thermocouple circuit will be very small; in this case it is convenient to reverse one of the inputs to the amplifiers, allowance therefor being made in the final calculation.

If potentials gradually changing in phase-difference are applied to the inputs of A and B, an indication of this change in phase may be observed readily by noting the variation of output-current when the two potentials are applied simultaneously; and a fairly accurate knowledge of the "in-phase" and "out-of-phase" points may be obtained by noting when the output current is a maximum and a minimum respectively.

### *Method of Measuring Phase Rotation Round the Singing Path of a 22-A-1 Repeater*

Measurements were carried out on a 22-A-1 repeater provided with filters which had a nominal cut-off of 2,600 cycles per second.

The circuit employed is shown in Figure 2, all batteries being omitted from the drawing. Various impedances were connected to the West line and network terminals of the repeater to give known unbalances. The East line and network terminals were either respectively open and short-circuited, or, respectively, short and open-circuited.

The singing path was broken between the East bridge points of the hybrid coil and the East potentiometer, and these points were taken via switches $K_1$, $K_2$ and $K_3$ to the inputs of amplifiers A and B, the input to the singing path being associated with amplifier A and the output of the singing path with amplifier B.

An oscillator was bridged across the input, while a 300 ohm resistance, an input transformer, and a vacuum tube and socket were bridged across the output to terminate the bridge points of the East hybrid coil.

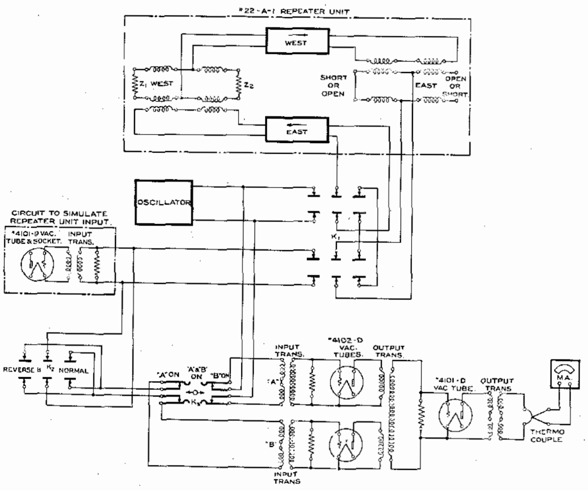



*Figure 2—Circuit for Measuring Phase Rotation Round the Singing Path of a 2-wire Repeater.*

The functions of the keys are as follows:

$K_1$ Switches the repeater through in the normal way to enable 21-tests to be made, or breaks the singing path and connects it to the phase measuring amplifiers.

$K_2$ Reverses the input to amplifier B to enable larger readings to be obtained on the milliammeter when the two potentials to be compared are nearly 180° out of phase.

$K_3$ Connects either input or output or both input and output of the singing path to their respective amplifiers.

The output of the phase measuring amplifiers was connected to the thermocouple and milliammeter.

In order to measure the phase rotation at any particular frequency the oscillator was set and switched on and the repeater was connected, by means of key $K_1$, to the measuring apparatus. Key $K_3$ was then operated to its three positions in turn, and the three corresponding currents in the thermocouple were noted. These currents were proportional to $V_1$, $V_2$ and $V_{12}$. Then from equation (4) above, the phase rotation, $\theta$, was calculated.

In the measurements described below, the phase rotation at frequencies from 200 to 2,500 cycles per second was measured at intervals of 100 cycles.

For convenience, the phase rotation curves are plotted from 0° to 180°. Actually, the rotation is continuous, passing from 0° through 180° to 360° and above. A point on the curves denoted by 0° may therefore mean that the rotation is zero, or some multiple of 360°. From the point of view of utility of the curves, zero indicates an "in-phase" point, while 180° indicates an "out-of-phase" point.

## *Phase Rotations in a Repeater*

The phase rotation experienced when a line with an irregular impedance characteristic is connected to a repeater and is balanced by a network having a smooth impedance characteristic may be shown to be made up of three components:

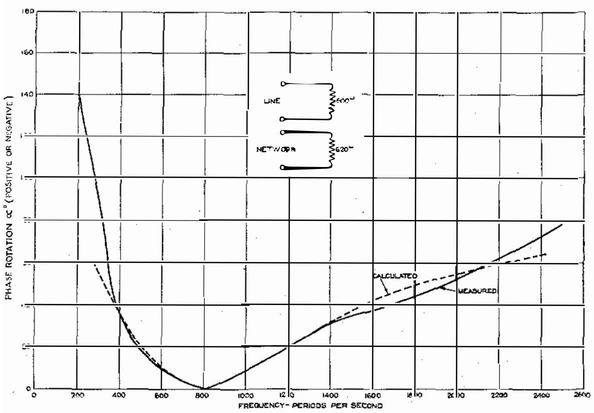



*Figure 3—Phase Rotation Round the Singing Path of a 22-A-1 Repeater Without Filters. Resistance Unbalance.*

(a) The rotation in the amplifiers, input transformers, and other circuit elements.
(b) The rotation due to the filters.
(c) The rotation across the hybrid coil due to the unbalance between the line and the network.

Figure 3 shows the rotation in the amplifier without any filters in circuit, the unbalance being a pure resistance. The curve has an "in-phase" point at about 800 cycles, while over the rest of the speech range no "out-of-phase" point is obtained.

Figure 4 indicates the results when the above measurement was repeated with the normal filters in circuit. This curve shows two "in-phase" points and one "out-of-phase" point. Hence, if a pure resistance line and network were used with sufficient unbalance to satisfy the power condition for singing, the unit would sing at 450 cycles, or at 2,500 cycles, or at both simultaneously. Again, if a large unbalance were located at any other frequency, singing could not possibly take place. This condition is referred to in more detail later.

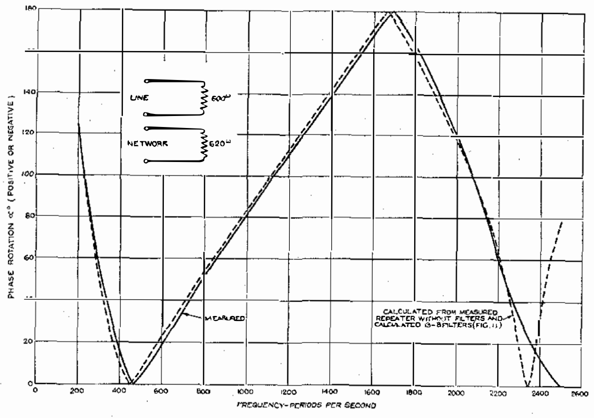



*Figure 4—Phase Rotation Round the Singing Path of a 22-A-1 Repeater with Filters in Circuit. Resistance Unbalance.*

Figure 5 indicates the phase rotation between the third winding and the bridge points of a hybrid coil when two impedances are connected to the line and network terminals having various moduli-ratios, $\frac{Z_2}{Z_1}$, and various angular differences $(\theta_2 - \theta_1)$.

When the above three types of rotation are present and when an artificial lump loaded line is used, the total rotation is as shown in Figure 6. In this case the resistance-component of the line impedance is as shown in Figure 7, where the network for balancing was a pure resistance of 1,600 ohms.

From Figure 6 several remarkable results can be derived. First, it will be seen that the "in-phase" points occur at somewhat closer intervals than the peaks of the resistance ripples in Figure 7, this being due to the added rotation of the amplifiers and filters of Figure 4. Next, it will

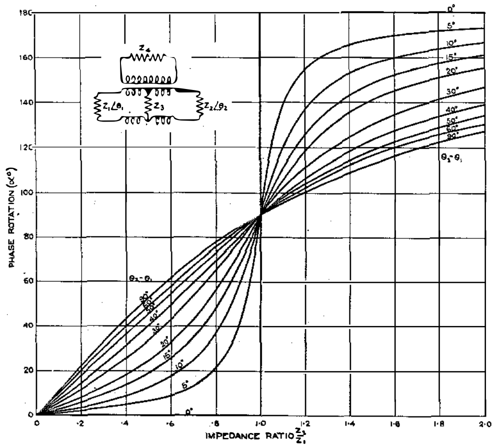


*Figure 5—Calculated Phase Rotation Across a Hybrid Coil Due to Various Unbalances.*

be noticed that above that frequency where the resistance value of the line ceases to cross that of the network, an "in-phase" point is not obtained, and singing cannot take place.

## *Effect of Phase Rotation with an Irregularity —i.e., an Unbalance Between Line and Network—at One Frequency Only*

From the measurements on the repeater with filters in circuit, Figure 4, it appears that an "out-of-phase" point occurs at approximately 1,700 cycles, while "in-phase" points are obtained at 450 and 2,500 cycles; it is therefore to be expected that singing will not take place if a single irregularity exists at 1,700 cycles, or indeed at any frequency other than 450 and 2,500 cycles. The truth of this was verified by connecting to the line terminals a resistance of 600 ohms and to the network terminals a circuit consisting of 600 ohms in series with a circuit resonant at approximately 1,700 cycles.

The impedance (Z) of the circuit connected to the network terminals was measured (Table I). From these measurements, and a knowledge of the impedance connected to the line terminals, namely 600 ohms, the transmission loss and phase rotation across the hybrid coil due to this unbalance was calculated from the well-known expression

$$\text{Transmission Loss (Current Ratio)} = \frac{1}{2}\frac{\left(1-\frac{Z_2}{Z_1}\right)}{\left(1+\frac{Z_2}{Z_1}\right)} \quad \ldots\ldots\ldots\ldots (7)$$

$$= r\underline{/\alpha}$$

Where $Z_1$ = line impedance.
and $Z_2$ = network impedance.

The full line curve in Figure 8 shows the phase rotation, while the broken line curve denotes the transmission loss as a current ratio.

The phase rotation round the singing path is shown in Figure 9, and in discussing these results two polings may be considered. In the case of the poling shown in Figure 9, the measured singing point was 16 Decibels at a frequency of 2,150 cycles, whereas it might have been expected that a singing point of zero would be obtained due to the bad unbalance at 1,700 cycles; but at 1,700 cycles the Phase Condition for singing was not satisfied, and therefore the high value of singing point is explained. More-

TABLE I.

| Frequency cycles per second | R ohms X ohms | Z | Frequency cycles per second | R ohms X ohms | Z |
|---|---|---|---|---|---|
| 200 | 600+ 11.3 | 600 /1.0 | 1,500 | 652+ 368 | 749 /29.4 |
| 400 | 600+ 25.1 | 601 /2.4 | 1,600 | 850+ 782 | 1,152 /42.6 |
| 600 | 600+ 45.1 | 602 /4.2 | 1,700 | 2,060−1,230 | 2,400 \30.9 |
| 800 | 600+ 55.2 | 603 /5.3 | 1,800 | 746− 656 | 995 \41.5 |
| 1,000 | 600+ 81.6 | 605 /7.6 | 2,000 | 616− 264 | 670 \23.2 |
| 1,200 | 600+128.0 | 614 /12.0 | 2,200 | 607− 166 | 630 \15.3 |
| 1,400 | 600+237.0 | 645 /21.6 | 2,400 | 605− 135 | 620 \12.6 |

over, as seen in Figure 8, the loss across the hybrid coil at 2,150 cycles is 0.088 as a current ratio, which corresponds to a singing point of 15 Decibels, which is in fairly good agreement with the observed value.

It is thus apparent that, in order that singing may take place, both the energy and the phase conditions must be satisfied simultaneously, and the value of the singing point depends on the unbalance at the hybrid coil at the particular frequency at which both these conditions are satisfied, and is independent of the unbalance at any other frequency.

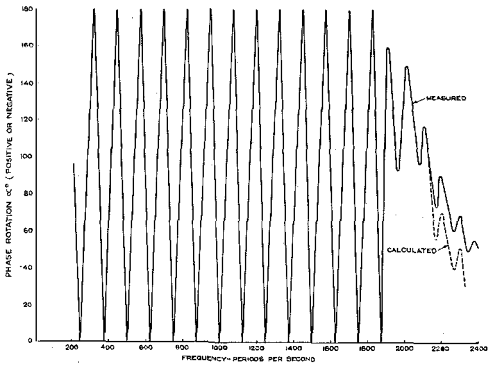



*Figure 6—Phase Rotation Round the Singing Path of a 22-A-1 Repeater with Filters. Unbalance due to Artificial Lump Loaded Cable (H-177-S) and Resistance.*

With the reverse poling, the curve in Figure 9 would be turned over and both conditions for singing would be satisfied at 1,700 cycles, resulting in a very low singing point.

## *Effect of Repeater Rotation on Repeater Gain*

The effect of phase rotation round the singing path on the repeater gain has been referred to in the introduction to this paper. Figure 10 shows the gain-frequency characteristic of an older 22-type repeater, the nominal gain of which was 4.7 Decibels below the average singing point of the two pure resistance lines against their respective resistance networks. Here is seen very clearly the effect of the phase of the unbalance current passing round the singing path on the actual true gain; at frequencies where the return current is in phase with the original current the gain is increased, while at frequencies where the return current is out of phase with the original current the gain is reduced.

If, however, the nominal gain of the repeater is reduced, the return current will be reduced, and the effect on the true gain will not be so marked, i.e., the amplitude of the periodic variation of the gain characteristic will be decreased. It must be understood that it is the effective gain which the repeater gives to the circuit which is affected; the gain of each vacuum tube, of course, remains constant.

## *Effect of Rotation when Line Impedance Does Not Cross Network Impedance*

It was noted above, in the case of an irregular lump loaded artificial line, that the phase of the return current passed through 0° and 180° at frequent intervals, so long as the impedance curve of the line crossed the impedance curve of the network (Figure 6). Above about 1,900 cycles, however, the character of the phase rotation changed, since, instead of passing through 0° and 180°, the phase of the return current oscillated about a mean value which gradually decreased until, at a frequency of 2,400 cycles, the mean value was about 50°.

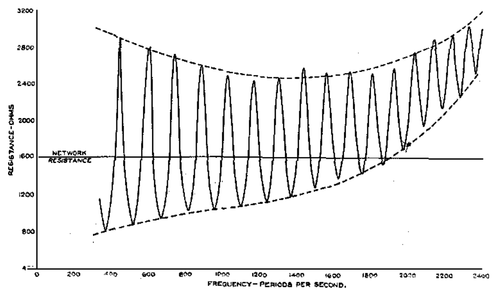



*Figure 7—Resistance Component of the Impedance of an H-177-S Artificial Loaded Cable, Open Circuited at the Distant End.*

The reason for this sudden change in the character of the phase rotation at 1,900 cycles is to be found in the fact mentioned above, that the resistance component of the line impedance oscillates about the network impedance of 1,600 ohms up to this frequency, i.e., at one frequency the ratio of the network impedance to the line impedance is greater than unity, while at another frequency this ratio is less than unity. Above about 1,900 cycles, however, this ratio is always less than unity. The effect of this variation in ratio is seen if it is remembered that the transmission loss across the hybrid coil is given by equation (7).

Denote the ratio $\frac{Z_2}{Z_1}$ by $(R+jX)$, where R is the resistance component and X the reactance component. Now consider R at points where $X=0$. The phase rotation across the hybrid coil is 0° when R is less than unity, and 180° when R is greater than unity. Above 1,900 cycles, however, R is never greater than unity, hence the phase rotation will never be as much as 180°. This, of course, is true only in cases where the repeater itself produces no rotation. In the actual case shown in Figure 6, the rotation due to the hybrid coil is added to that produced by the repeater unit itself.

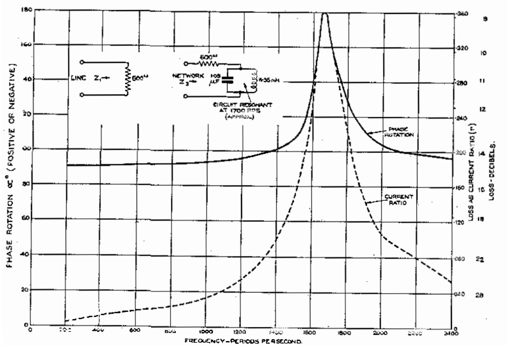



*Figure 8—Calculated Phase Rotation and Loss Across a Hybrid Coil. Large Unbalance at 1,700 Cycles as Shown.*

## *Similarity of a Number of Repeaters*

Measurements on a number of repeater units with similar filters showed that with a constant resistance unbalance the units all sang at one of two frequencies, depending on the poling, and that these two frequencies were approximately the same for every unit.

## *False Field Singing Points and the Calculation of True Singing Point*

An important result of this investigation is that it proves that a repeater will not necessarily sing at the frequency corresponding to the maximum unbalance between the line and the network, but that the frequency of singing and the actual magnitude of the Singing Point are determined solely by the conditions at the frequency at which both the Energy and Phase conditions are satisfied. It follows, therefore, that the use of a singing 2-wire repeater is unsuitable for measuring the true Singing Point of a line against its associated network, and experience in the field has shown that the error involved may be considerable. It is desirable, therefore, to consider in some detail, methods by which true Singing Point may be calculated from a knowledge of all the relevant constants of the system. In the case of a repeater without any filters, Figure 3, it is only necessary to consider the phase rotation introduced by the input transformer and associated apparatus and the hybrid coil. This rotation may be simply calculated by well-known methods. In Figure 3 the broken line curve shows the result of such a calculation in the case of the type of repeater under discussion. The agreement between theory and experiment is very close.

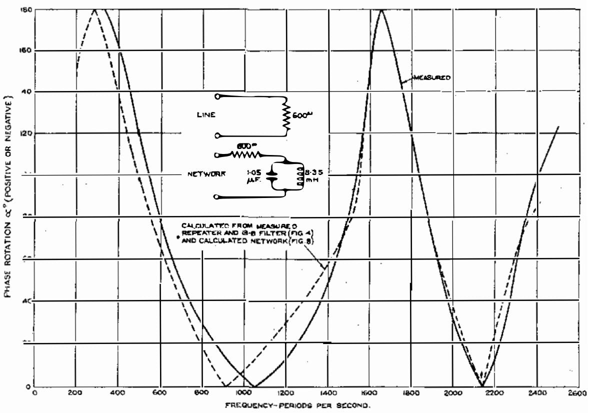



*Figure 9—Phase Rotation Round the Singing Path of a 22-A-1 Repeater with Filters. Large Unbalance at 1,700 Cycles as Shown.*

In computing the phase rotation across the hybrid coil for various conditions of unbalance between the line and network, it is convenient to use the curves shown in Figure 5.

Turning now to the case of a normal repeater with filters having a nominal cut-off of 2,600 cycles (Figure 4), in addition to the rotation produced by the hybrid coil, input transformers and other apparatus, the rotation produced by the two filters has to be considered. Knowledge of the constants of the filters in question enables

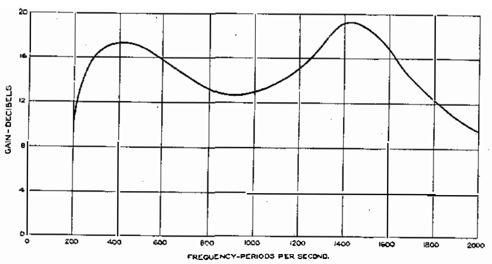



*Figure 10—Gain-frequency Characteristic of a 2-wire Repeater When Near Singing Condition.*

the rotation produced to be calculated, and Figure 11 shows this rotation for both one and two filters in the singing path.

Sufficient information is now available to determine the true Singing Point under any given conditions. Consider, as an example, the condition shown in Figure 9. In this case the line impedance is a pure resistance of 600 ohms, while the network impedance is given in Table I.

Calculate in the first place, as indicated above, the phase rotation due to the repeater and its associated transformers and filters, considering the case of a pure resistance unbalance at the hybrid coil terminals, Figure 4. Determine then the rotation across the hybrid coil due to the particular unbalance (Figure 8, full line curve). Combining these two results a curve is obtained for the total rotation, Figure 9. "In-phase" points occur at approximately 1,000 cycles and 2,150 cycles. Hence, provided the energy condition is satisfied at these points, the repeater will sing at one or both of these frequencies. From the broken line curve of Figure 8, the loss across the hybrid coil as a current ratio is 0.034 at 1,000, and 0.088 at 2,150 cycles. The repeater will sing at the frequency corresponding to 0.088

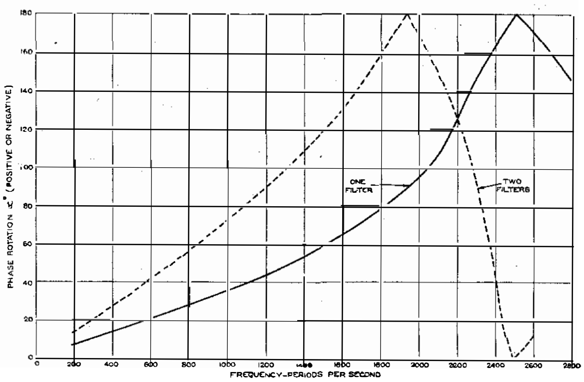



*Figure 11—Calculated Phase Rotation Due to Filters Used*

current-ratio, which is the greater, i.e., at 2,150 cycles, and the Singing Point corresponding to this current ratio is 15 Decibels. In an experiment, the value obtained actually was 16 Decibels.

# The Unit of Transmission and the Transmission Reference System

By G. H. GRAY

*Engineering Department, International Telephone and Telegraph Corporation*

VERY early in the life of the telephone industry it became evident that the handling of telephone transmission problems required the establishment of a unit of transmission in terms of which different circuits could be compared, the effects of changes in the telephone plant could be stated, the usefulness of a given circuit for transmitting conversations could be expressed, etc.

Quite naturally some of the telephone engineers selected as their unit the effect which a unit length of the then standard telephone cable (No. 19 gauge cable having a resistance of 88 ohms and a capacity of 0.054 microfarads per mile) had upon telephone conversation. This gave rise to the unit called the "mile of standard cable"—a unit which has been very widely used.

In other localities a cable having slightly different constants was used, while in still others the practice developed of expressing transmission in terms of the ratio between two currents. Furthermore, a single frequency unit referred to as the "800 cycle" mile was found useful for certain purposes, so that by 1922 the following units were in use:

English mile of standard cable.
American mile of standard cable.
800 cycle mile.

B unit (also called the Napier, Attenuation Unit or Hyp).

None of these units appeared to be universally satisfactory, particularly in view of the development of circuits having greatly improved quality and the advent of radio. This led the American Telephone and Telegraph Company to suggest the use of a purely arbitrary unit, based upon the decimal logarithm of the ratio of two amounts of power, which they called the Transmission Unit or TU. A discussion of this unit as well as the advantages and disadvantages of some of the other units mentioned is given by Mr. R. V. L. Hartley of the Bell Telephone Laboratories in a paper entitled, "The Transmission Unit," which was published in the July, 1924, issue of *Electrical Communication.*

In 1924 the International Advisory Committee on Long Distance Telephony in Europe was organized for the purpose of studying the international telephone situation in Europe and making recommendations for improvements to the various telephone administrations represented on the Committee.

Soon after its organization the International Advisory Committee took up the question of standardizing a unit of transmission. At the invitation of the Committee, the American Telephone and Telegraph Company (the sponsor of the TU) was represented at some of the meetings. Some of the countries favored the TU (based on decimal logarithms) and others the Bl unit (based on naperian logarithms). Since it was found impossible for the different countries to agree upon either of these two units the International Advisory Committee recommended that all other units be abandoned and that each country adopt one or the other of these two units. For the time being, it was agreed that all losses, gains, equivalents, etc., would be expressed in both units in the official texts of the International Advisory Committee.

It was considered important by the European Committee that the magnitudes of the fundamental units in the two systems be as nearly equal as practicable. Accordingly they defined the naperian unit so that:

$$\text{No. of units} = \tfrac{1}{2}\log_e \frac{P_1}{P_2}$$

where $P_1$ and $P_2$ are two amounts of power; and the decimal unit so that:

$$\text{No. of units} = \log_{10} \frac{P_1}{P_2}$$

It was agreed that the naperian unit should be called the "Neper" from the name Napier, the inventor of naperian logarithms, and that the decimal unit should be called the "Bel" in honor of Alexander Graham Bell. Nevertheless, in order to avoid the confusion which would inevitably result from the use of the word "Bell," it was decided to omit the final l.

It will be noted from the above that the magnitude of the Bel is ten times that of the TU as defined in Mr. Hartley's paper, to which reference has already been made. It was understood at the time the Bel was adopted as the fundamental unit that a unit having one-tenth of this magnitude, or a "decibel," would be used as the working unit. This unit is obviously of exactly the same magnitude as the TU. The arguments advanced in Mr. Hartley's paper in favor of the TU apply therefore with equal force to the decibel.

The American Telephone and Telegraph Company has decided to adhere to the decimal unit but, in the interest of standardization of terminology, has advised the International Advisory Committee that it will use the name "decibel" for its unit in place of the former designation TU. This amounts merely to a change in name, or, rather, to giving the unit a name since the abbreviation TU was adopted initially for use only until a satisfactory name could be selected for the unit. It is expected that, in the Bell System, the designation TU will gradually fall into disuse.

After carefully considering all aspects of the problem, it has seemed to the International Telephone and Telegraph Corporation that the arguments for the decimal unit outweigh those for the naperian unit. Accordingly the decimal unit has been adopted by the International as its working unit of transmission and the name decibel will be used by it for this unit. The abbreviation for decibel is expected to be db. Ten decibels will therefore be written 10 db.

As mentioned above the Bel has such a magnitude that

$$\text{No. of Bels} = \log_{10} \frac{P_1}{P_2}$$

$$\text{or No. of decibels} = 10 \log_{10} \frac{P_1}{P_2}$$

from which the following table is readily obtained:

| No. of db | Approximate Power Ratio $\left(\frac{P_1}{P_2}\right)$ | |
|---|---|---|
| | Gains | Losses |
| 1 | 1.25 | 0.8 |
| 2 | 1.6 | 0.63 |
| 3 | 2.0 | 0.5 |
| 4 | 2.5 | 0.4 |
| 5 | 3.2 | 0.32 |
| 6 | 4.0 | 0.25 |
| 7 | 5.0 | 0.2 |
| 8 | 6.3 | 0.16 |
| 9 | 8.0 | 0.13 |
| 10 | 10.0 | 0.1 |
| 20 | 100.0 | 0.01 |
| 30 | 1000.0 | 0.001 |

It will be noted that the power ratio doubles (or halves) approximately every three db. In other words, if at some point, A, in a circuit the power is twice as great as at some other point B, the gain (or loss) between the two points is 3 db. Conversely, if the loss in a given part of a circuit is 6 db, we know that the power has been decreased one-fourth in that part of the circuit. Likewise a gain of 6 db indicates that the power has been increased four times.

Since

$$\text{No. of Nepers} = \log_e \frac{P_1}{P_2} = \frac{2.3026}{2} \log_{10} \frac{P_1}{P_2}$$

and

$$\text{No. of db} = 10 \log_{10} \frac{P_1}{P_2}$$

it follows that

$$\text{No. of Nepers} = \frac{2.3026}{2\text{x}10} \text{ No. of db} = 0.1151 \text{ No. of db and No. of db} = \frac{10\text{x}2}{2.3026} \text{ No. of Nepers} = 8.686 \text{ No. of Nepers.}$$

The following table will be found convenient for converting readily from one unit to the other:

| Multiply | by | To Obtain |
|---|---|---|
| db | 0.1151 | Nepers |
| Nepers | 8.686 | db |

The standardization of this new distortionless unit of transmission made desirable the standardization of a better reference system than that previously used; namely, two standard common battery sets connected through repeating coils and a variable artificial line having the unit constants of the mile of standard cable.

A discussion of a preliminary model of a new transmission reference system was given by Mr. L. J. Sivian of the Bell Telephone Laboratories in a paper entitled, "A Telephone Transmission Reference System," which was published in the October, 1924, issue of *Electrical Communication.* Additional development work on this system has since been carried out with the result that a reference system, practically distortionless in the voice frequency range, has now been adopted. A general view of the system is shown in Figure 1.

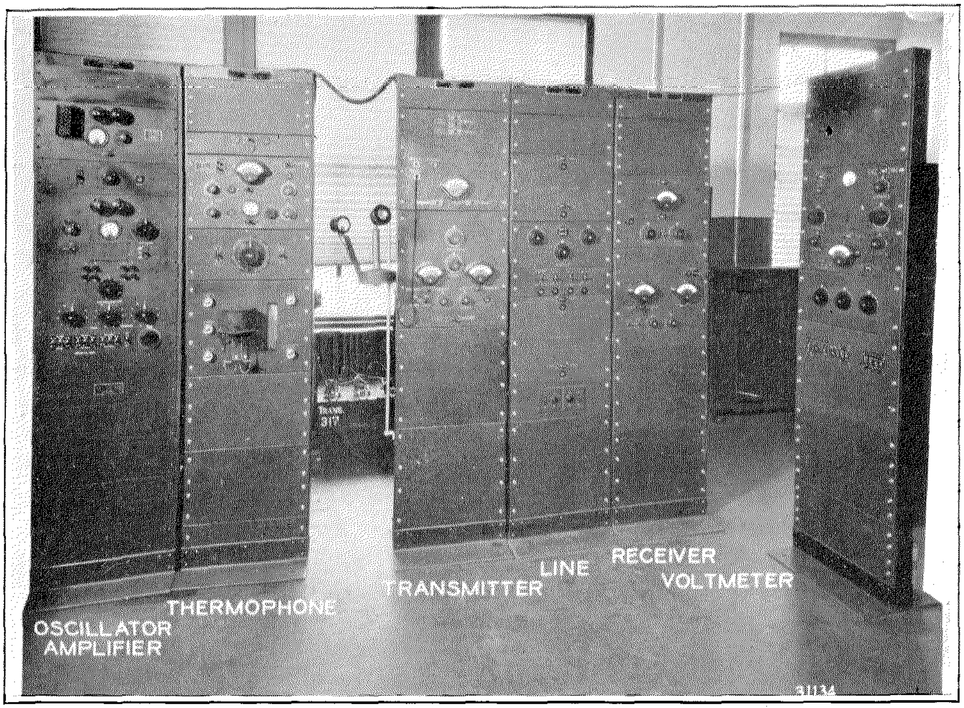



*Figure 1—Master Telephone Transmission Reference System.*

This Master Telephone Transmission Reference System consists essentially of three parts: a Reference Transmitter, a Reference Line and a Reference Receiver, as shown in Figure 1. The acoustic and electric performance of the system can be specified and measured in terms of definite physical quantities, and hence is reproducible. For this purpose suitable calibrating and measuring equipment, also shown in Figure 1, is associated with the system.

The Reference Transmitter consists of a condenser transmitter with four stages of amplification. It is equipped with an open wire guard which serves to keep the speaker's lips at a fixed distance from the diaphragm.

The Reference Line consists of a distortionless resistance line having a range of 101 db or a power variation of more than 10,000,000,000 to 1. The attenuation may be varied in steps of 0.2 db. By means of switches and jacks provided on the Line Bay it is possible to use the Reference Transmitter, Reference Line and Reference Receiver together, as a system, or to use each individually. This permits a ready comparison of any individual element of a commercial telephone circuit with the corresponding element of the Master System.

The Reference Receiver consists of an electrodynamic receiver and associated three stage amplifier. The receiver is of the permanent magnet type with the moving coil supported by an aluminium alloy diaphragm which is firmly clamped but not stretched.

# Methods of Locating Crosstalk Faults on Loaded Cables

By K. E. LATIMER

*European Engineering Department, International Standard Electric Corporation*

IN THE course of maintaining loaded toll cables, it occasionally becomes necessary to locate a high crosstalk fault. Two methods for locating a resistance unbalance—the form of crosstalk fault generally encountered in practice—were described by Mr. B. Lister in 1923 in paper No. 98, Institution of British Post Office Electrical Engineers, entitled, "Maintenance Precision Testing of Main Trunk Cables." One of these is a ballistic method for use on long cables. The other is an alternating current single frequency method, for very short lengths. Both of these depend for their accuracy upon the constancy of the resistance unbalance—a condition not always fulfilled.

There are, however, two other methods by which a crosstalk fault may be located. These involve the use of variable frequency alternating current, and are less dependent than the others upon the constancy of the fault. The first of these, which has been known for many years, involves the use of a special impedance bridge and a variable frequency oscillator. The second, which has been successfully used by International Standard Electric engineers for about two years, makes use of a crosstalk set and a variable frequency oscillator.

The second method presents some advantages over the first in respect to sensitivity, convenience, and the possibility of obtaining a location from both ends of the circuit without shifting the apparatus. Both methods are described below.

### *Impedance Bridge Method*

This method has been described in a paper on "Telephone Circuit Unbalances," by L. P. Ferris and R. G. McCurdy, in the Journal of the American Institute of Electrical Engineers, Volume XLIII, No. 12, December, 1924. For convenience, an account of the method is reproduced to show how the test may be carried out with the No. 74001-B Impedance Bridge, and for reference purposes.

The diagram of an instrument for locating resistance unbalances and other faults causing phantom to side crosstalk is shown in Figure 1. This consists of a simple bridge circuit, variable resistance and inductance being inserted in one

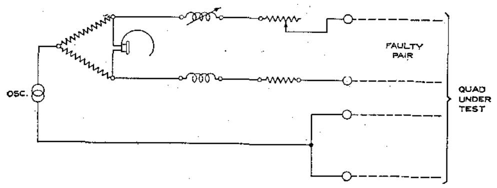



*Figure 1—Diagram of Bridge for Locating Resistance Unbalances.*

wire of the side circuit under test for the purpose of producing in the receiver a current equal and opposite to the crosstalk current returning from the fault. Fixed inductance and resistance are inserted in the other wire of the side circuit in order to avoid the necessity of switching the variable resistance from one side of the circuit to the other, and to bring the reading of the inductometer to a convenient position on the scale. The quad should be terminated at the distant end with a crosstalk terminating set.

The procedure in making a test is similar to that in making an ordinary impedance frequency test. Readings of the resistance and inductance adjustments necessary to produce silence in the receiver are made at uniform frequency intervals, say 20 or 40 cycles, from 400 to 2,000 cycles. When these readings are plotted as functions of the frequency, the shapes of the curves obtained depend upon the type and location of the unbalance. An unbalance is indicated by periodic "humps" or peaks in the curves.

It will be seen that the tone from the oscillator is effectively applied to the phantom circuit, and travels out to the fault, at which point it is transferred to the side circuit by phantom to side crosstalk. It returns on the side circuit to the impedance bridge and enters the receiver.

The current passing through the receiver is neutralised by a second current which is produced by adjusting the resistance and inductance. Thus there will be variations in the settings of resistance and inductance necessary to balance the bridge at varying frequencies, corresponding to the time of transmission of tone to the fault on the phantom circuit plus the time of return transmission on the side circuit.

From the above consideration it may be deduced (see Appendix) that the distance to the unbalance from the testing point is given by the formula

$$x = \frac{V_1 V_2}{(V_1 + V_2) f}$$

where x is the distance from the testing end to the fault causing crosstalk, $V_1$ and $V_2$ are the velocities of the side and phantom circuits respectively, and f is the frequency interval between "humps" on the curve. This formula may be compared with the well-known formula for the location of ordinary impedance irregularities, namely,

$$x = \frac{V}{2 f}$$

where V is the velocity of the circuit under test.

To avoid separate determinations of $V_1$ and $V_2$ it is usually convenient to make a second test on a good quad with a resistance unbalance inserted at a known distance from the testing end.

The No. 74001-B and other similar Impedance Bridges of the International Standard Electric Corporation may be modified for making the above test in the manner indicated in Figure 2. It will be seen that the fixed inductance (of 30 ohms resistance) is placed on the same side of the bridge as its compensating resistance (also 30 ohms). The resistance of the inductometer is balanced out by the 100-ohm resistance. The bridge is therefore initially out of balance by about 60 ohms, and the variable resistance must be set approximately to this figure when there is zero unbalance in the line.

## *Crosstalk Set Method*

If near end crosstalk is measured at various frequencies on two circuits between which there is some single fault causing high crosstalk, the crosstalk frequency curve will be nearly smooth.

The irregularities normally present in near end crosstalk frequency curves are due to the inter-action of many random irregularities. If, however, there is a large single crosstalk fault present, this one crosstalk predominates over all the others; and as the crosstalk due to one fault does not vary in an irregular manner with frequency, the resultant curve is practically smooth.

If there is a second fault causing high crosstalk at any point in the circuits, the crosstalk currents due to the two faults will give rise to mutual interference, i.e., the crosstalk frequency curve will exhibit a series of "humps." A brief examination of the problem will readily indicate that the frequency interval between the "humps" corresponds to the difference between the times of transmission round the two crosstalk paths. Thus, in Figure 3, the series of "humps" resulting from a crosstalk fault at A close to the

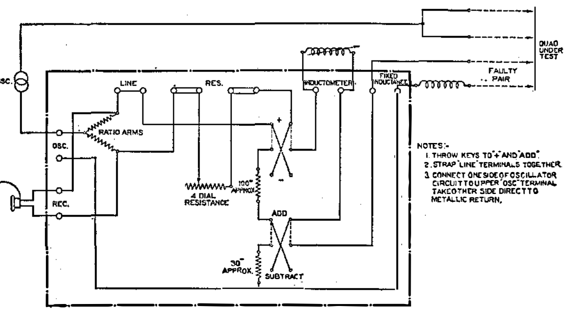



*Figure 2—Method of Adapting No. 74001-B Impedance Bridge for Locating Resistance Unbalances.*

measuring set and a second fault at B would correspond to the time of transmission round the path ABA; the series of "humps" resulting from a crosstalk fault at B and a second fault at C, close to the terminating set (there being no fault at A), would correspond to the difference in lags of the paths ABA and ACA, i.e., to the lag of the path BCB.

This at once suggests a convenient method of locating a high crosstalk fault, using the following procedure. First, additional crosstalk is introduced at the terminals of the measuring set, in any convenient manner, and to a sufficient extent to cause large "humps" on the crosstalk frequency curve. A crosstalk frequency run is then taken. The interval between the "humps" so determined gives the distance of the fault from the testing end, using the same formula as for the impedance bridge method, namely,

$$x = \frac{V_1 V_2}{(V_1 + V_2)\ f}$$

In this case, $V_1$ and $V_2$ are the velocities of the disturbing and the disturbed circuits, respectively.

It is possible to make a check test of the location of the fault by removing the added crosstalk at the measuring end, and inserting crosstalk at the terminating set. If a second crosstalk frequency run be taken, the interval between the "humps" now obtained, using the above formula, gives the location from the distant end of the circuit up to the fault. If the work has been accurately carried out, these two locations should indicate the same point. The velocities may be determined by taking a third test on two good circuits with crosstalk inserted at both ends.

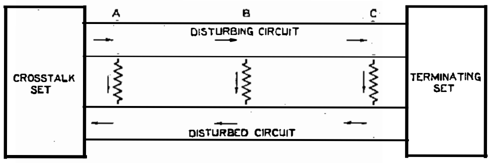



*Figure 3—Diagram Showing Paths of Crosstalk Currents.*

It is thus seen that it is possible to make a check location without shifting instruments about. A further advantage with this method is that no additional apparatus is required besides means of producing crosstalk and a variable frequency oscillator. The former are generally available in any place where tests are being carried out, while even if an oscillator is not available on the spot, it is usually possible to send tone over the cable from a station where such an oscillator is available.

In carrying out the test, care should be taken to use the right value of added crosstalk; if too much or too little has been added, the test will be insensitive. The right amount is indicated when sharply defined minima occur in the resulting crosstalk frequency curve. The maxima are generally less sharply defined.

The method described can be used for locating any type of near end crosstalk, that is, phantom to side, side to side, phantom to phantom, phantom to pair, or pair to pair. It cannot, however, be used for far end crosstalk, unless the velocities of the two circuits under test differ from one another, in which case the formula

$$x = \frac{V_1 V_2}{(V_1 - V_2)\ f}$$

applies. This limitation is, however, not very serious, since high far end crosstalk is usually accompanied by high near end crosstalk, and may be located as such.

A typical crosstalk frequency curve, taken for crosstalk location purposes, is shown in Figure 4. The velocities of side and phantom circuits were 14,600 and 20,400 kms. per second approximately. The distance between "humps" is seen to be 398 cycles per second.

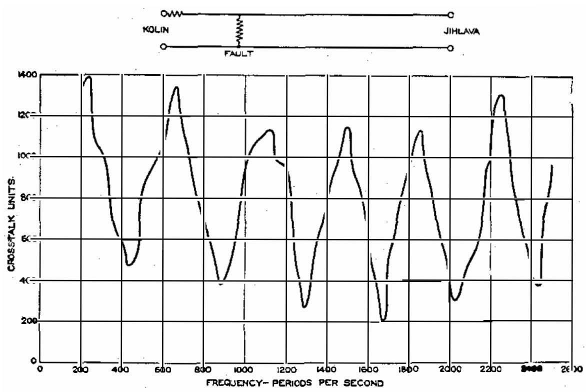



*Figure 4—Specimen of Crosstalk Location Curve.*

From these figures the crosstalk fault locates at a distance of 21.4 kms. from the testing end. In this particular case the fault was found to be within 0.1 km. of the position deduced from the test. As a general rule, however, such accuracy is not obtained, but the location is usually not more than one loading section distant from the fault.

The accuracy of the impedance-bridge method is of the same order.

## *Appendix*

Both the methods described involve the determination of the small increment of frequency $(F_1 - F_2)$ necessary to increase the number of wave-lengths in a portion of the circuit under test by unity. Let

$V$ = Velocity of transmission, assumed to be constant over the frequency range and the same for the disturbing as for the disturbed circuit.

$\lambda_1$ = Wave-length corresponding to $F_1$.

$\lambda_2$ = Wave-length corresponding to $F_2$.

$x$ = Distance from sending end to fault, in the case of the impedance-bridge method; and the distance between the position of the fault and the point at which crosstalk is introduced, in the case of the crosstalk set method.

Then, in a length of cable x

$\frac{x}{\lambda_1}$ = Number of wave-lengths in the disturbing circuit, and also in the disturbed circuit when the frequency is $F_1$.

$\frac{x}{\lambda_2}$ = Number of wave-lengths in the disturbing circuit, and also in the disturbed circuit when the frequency is $F_2$.

If $F_1$ represents a frequency for which the phase relation between the outgoing and returning currents is such that a peak occurs on the crosstalk-frequency curve, it is obvious that the next peak will occur at such a frequency that the phase relations are again the same as for frequency $F_1$—in other words, at the frequency for which there is one additional complete wave-length in the distance 2x. Let this frequency be $F_2$: then,

$$\frac{2x}{\lambda_2}-\frac{2x}{\lambda_1}=1$$

But

$$\lambda_1=\frac{V}{F_1}$$

$$\lambda_2=\frac{V}{F_2}$$

$$\therefore \quad 2x\frac{F_2-F_1}{V}=1$$

or

$$x=\frac{V}{2\,f}$$

where

$$f=F_2-F_1$$

If the velocities of the two circuits are different, the same formula may be used, provided that the velocity V is that which gives the same total time-lag as that corresponding to the actual velocities $V_1$ and $V_2$.

The time-lag on the disturbing circuit will be $\frac{x}{V_1}$, and on the disturbed circuit $\frac{x}{V_2}$. Hence, V is determined by the following equation:

$$\frac{2x}{V}=\frac{x}{V_1}+\frac{x}{V_2}$$

thus,

$$V=\frac{2\,V_1\,V_2}{V_1+V_2}$$

And substituting in the above equation,

$$x=\frac{V_1\,V_2}{(V_1+V_2)\,f}$$

# The "Solid Back" Carbon Button Telephone Transmitter

By L. C. POCOCK

*Engineering Department, Standard Telephones and Cables, Ltd.*

As EVERY telephone engineer is aware, fully dimensioned drawings are not enough for the successful building of communication apparatus. In addition to drawings, there must be a description of materials and processes used; and before success is achieved there must be a fund of experience, precise understanding of the exact requirements of the apparatus, knowledge of the permissible variations in the material and the reactions of these variations on the behaviour of the completed article. Probably experience and knowledge are nowhere more essential than in transmitter manufacture, partly because of the extraordinary delicacy and sensitivity of the instrument, and partly because of the complex conditions to be satisfied.

The extremely small movements of a transmitter diaphragm under normal speech conditions and the large amplification factor are not generally appreciated. In the case of the well-known "solid back" transmitter, the diaphragm movement may be of the order of $10^{-5}$ cms. (.0001 cm. or .00004 inches). This extremely small amplitude is comparable with the changes of dimensions that occur in the instrument through expansion due to temperature variations of one or two degrees centigrade. Dimensional changes of the same magnitude may be produced also by elastic deflection under loads of a few grammes. The minute movements of the diaphragm, however, result in an electrical output of the order of 10 milliwatts, which may be about one thousand times as great as the speech power directed into the transmitter. That such an amplifier exhibits a certain amount of instability, and that it cannot be built properly without skill and experience is, therefore, not surprising.

The most obvious requirement in a transmitter is efficiency. Mechanical faults, badly fitting parts, errors in adjustment, and variation in quality of material, all reduce efficiency. Such faults may be very difficult to detect and may be guarded against best by rigid inspection of parts and processes at all stages of manufacture by men who appreciate the fact that they are concerned with making an instrument operating with movements smaller than ordinary gauges will measure.

Ranking with efficiency in importance for effective speech communication is quality, or freedom from excessive distortion. The faults that have been mentioned as adversely affecting efficiency, generally also affect quality, so that a mechanically poor transmitter may often be defective both in efficiency and in quality.

Whilst efficiency depends to a considerable extent on the accuracy with which the structure is built, it depends also upon the characteristics of the granular carbon. An efficiency range of at least 10 decibels ($b=1.15$) can be covered by using different grades of granular carbon; and one of the chief problems to be dealt with is the selection and uniform preparation of carbon that will most suitably meet all the requirements of the completed instrument. The most suitable, however, is generally not the most efficient for there are many other requirements to be met, such as resistance, freedom from "burning," microphonic characteristics, tendency to pack, and durability or freedom from aging effects. These depend mainly upon the physical properties of the carbon, though the effects are complicated and may be masked by the mechanical structure of the transmitter.

The resistance should be uniform and stable; it should not rise during any quiescent period to a value such as to prevent proper functioning of the signalling relays at the central office, or to reduce the receiving efficiency of the subscriber's set. "Burning," which causes sputtering or frying noises, while inherent in carbon, must be kept below the trouble point. Since burning tends to increase with age, it is a characteristic that must be studied, especially in connection with "aging" effects, or variations during the life of the transmitter.

A transmitter is said to be over-microphonic when its efficiency characteristic rises too rapidly as the load (impressed sound) increases from very weak values. Correspondingly, the efficiency of such an instrument falls rapidly as the load increases beyond normal intensity. Since speech intensity varies greatly among consonants and vowels, the more variable the efficiency of the transmitter, the poorer the quality.

"Packing" is caused, as the name implies, by packing of the carbon granules to the point where the resistance variation necessary to the proper functioning of the instrument no longer occurs.

It will be appreciated readily that with so many diverse properties depending upon the quality of carbon employed, the utmost care is essential in its manufacture. Western Electric carbon, which is used by the International Standard Electric Corporation, is made in several grades for different purposes, the grades differing not only in the size of the granules, but also in their microphonic and resistance characteristics.

The raw material from which the carbon is produced is a uniform, high quality anthracite which is picked over lump by lump by experts; the subsequent crushings, roastings, washings, and sievings are varied to secure maximum sensitivity with the particular combination of resistance and freedom from burning necessary in any particular kind of transmitter. Samples from each lot of carbon are subjected to physical tests and finally, before the lot is accepted, fifteen transmitters are assembled with specially selected parts, and filled with sample carbon. The transmitters are searchingly tested for characteristics such as efficiency, burning and resistance; and any failure to show the expected properties is followed by the rejection of the whole of that particular lot of carbon.

The policy of Standard Telephones and Cables, Ltd., is to supply only highly efficient and closely uniform instruments and it is, therefore, scarcely possible to exaggerate the importance of adherence to rigid inspection requirements for the granular carbon used in transmitter manufacture. For example, even with the manufacturing processes controlled as carefully as possible, the variations occurring in the finished material are so wide as to call for frequent rejections of lots of carbon, or for the selection of different lots for different purposes, although made by the same process. Tabulated below are the results of tests on twelve different lots, all manufactured by the same process, but selected to cover a wide range of different properties:

| Sample | Allowance | | Resistance in ohms, while talking |
|---|---|---|---|
| | db. | b. | |
| A | −0.25 | −0.029 | 52 |
| B | −0.25 | −0.029 | 51 |
| C | −0.50 | −0.058 | 50 |
| D | −0.75 | −0.086 | 58 |
| E | −0.90 | −0.103 | 57 |
| F | −1.1 | −0.126 | 49 |
| G | −1.1 | −0.126 | 44 |
| H | −1.1 | −0.126 | 37 |
| I | −1.4 | −0.161 | 49 |
| J | −1.6 | −0.184 | 33 |
| K | −1.7 | −0.198 | 40 |
| L | −2.1 | −0.241 | 45 |

These tests were made with about fifty milliamperes flowing through the transmitter.

The indiscriminate use of these varieties of carbon for ordinary common battery transmitters would lead to endless difficulties: some of the lower resistance carbons would produce transmitters of low efficiency, but, worse still, the high efficiency, high resistance carbons would develop burning after comparatively short use.

Carbon electrodes for common battery transmitters, while not quite as important as the granular carbon, are manufactured with the same care as the latter, including the making of similar tests on sample transmitters.

The assembly of the microphonic button, and its assembly and adjustment in the transmitter, offer many opportunities for serious errors. It has been found advisable to adopt a number of devices to make the various assembly operations fool-proof; in fact, nearly all tightening up and clamping operations are carried out under conditions controlling the degree of tightness used.

The testing of the finished transmitter is carried out by trained assistants whose function it is to compare every transmitter individually by means of a speech test with a standard transmitter in a representative telephone circuit. The instruments to be tested, and the standard, are mounted side by side and spoken into alternately, while a second observer at the other end of the circuit determines the difference in efficiency and quality. The successful application of this very practical test depends upon the strict maintenance of the efficiency of the standard instruments at a constant level, and consequently a group of master standards carefully built and frequently compared with each other under laboratory conditions must be maintained. The work involved in maintaining standards for use in the inspection departments is considerable, but is well justified by the advantage of being in a position to know with certainty whether the manufactured apparatus is satisfactory or not, so that in the latter case investigation can be started promptly to trace the cause of the trouble. Furthermore, effective investigation is hampered, or rendered practically impossible, if thoroughly trustworthy standards are not available.

Transmitters passing the first shop inspection are sampled twice by separate inspection departments for much more complete and thorough tests, and finally samples may be taken for life tests.

Notwithstanding all precautions, certain variations in the efficiency of the manufactured product occur, as illustrated in Figure 1, which show the average efficiency of samples taken from successive deliveries. Such fluctuations are

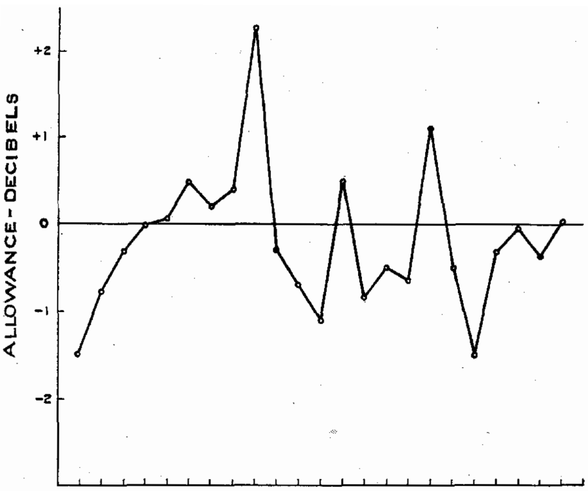



*Figure 1—Averages of Tests on 20 Representative Transmitters Taken From Deliveries Each Month.*

caused chiefly by variations within the permitted limits of some of the parts, but may be due also to a certain extent to variations in the carbon quality. Using a given grade of carbon and selected parts specially fitted, it is quite possible to make transmitters equal to each other within 1 db. (b = 0.115) or less, but such close uniformity has proved to be impossible under mass production conditions.

While considerable development work has been done on this type of instrument, it is a fact that comparatively few modifications have been introduced in the solid back carbon button transmitter in countries where it has been standardized. One reason is that, while not ideal, the instrument is the best that has thus far been proposed for commercial use. Furthermore, the adoption of a radically new design, a modification of the present type, or the use of carbon from new sources of supply, in the opinion of those qualified to judge, involves a real danger of encountering serious trouble through low efficiency, large percentage of instruments liable to pack, or what is most serious, development of burning after one or two years of life. Even with artificial life tests, it is extremely difficult to obtain warning of the faults that may arise in the field. A transmitter should have a reasonably long life, and failure after one or two years is a heavy loss. Furthermore, a fair trial necessitates placing a considerable number of instruments in service and some years may elapse before the results of a departure from ordinary practice can be evaluated.

The transmitter, converting as it does the sound power input into electrical power which is transmitted over the line to the receiver, is one of the most important pieces of apparatus in the telephone system. It must be efficient, high in quality, and relatively constant in its characteristics, even when subjected to the rough usage frequently encountered under service conditions. When manufactured in quantity, these requirements can be met only by close attention to detail both in design and in manufacture, by careful inspection and testing, especially of the carbon itself, and, finally, by comparison of the commercial product with reliable transmitter standards.

# The Creed High Speed Morse Printing Telegraph System

By F. G. CREED

*Chairman, Creed Company, Limited*

AT THE end of the nineteenth century, seventy years or more after the invention of the electric telegraph, but little progress had been made in the development of Printing Telegraphs. The position in Europe at about that time was that the Hughes, the Stock Ticker and the Baudot Systems were in use on some of the more important circuits in several countries, but the Morse Telegraph was by far the most extensively used System. In Great Britain, the Baudot and Hughes were employed principally for Continental circuits; but the Stock Ticker, for the distribution of market and other news, could be found in all the large cities of the Kingdom. The busiest commercial circuits, and all the more important news circuits of the Post Office, were operated by means of the Wheatstone System, and in addition, a great many Morse duplex and Morse quadruplex systems were employed in handling traffic between larger towns.

The provincial newspapers were nearly all served through the British Post Office by a special organisation based on the Wheatstone System. News gathered in London by the Press Agencies was dealt with in a special section of the Central Telegraph Office, where it was first punched up on the Wheatstone tape by means of a special arrangement of Wheatstone Perforators which enabled a single operator to perforate simultaneously any number of tapes from one to sixteen. The tapes thus prepared were then run through groups of transmitters by means of which the news was distributed simultaneously to provincial towns, where it was written up by hand and delivered by messengers to the newspapers entitled to receive it. In some cases as many as one hundred newspapers in fifty or more towns would receive a news item thus distributed from the common centre.

For the reception of this news at the provincial stations, a staff of nine men (one key clerk and eight writers) was usually provided, the duty of the key clerk being to supervise the line and terminal apparatus, to distribute the Wheatstone tape to the writers, and to ask for and obtain repetitions. Usually several stations would be connected to one line, called a "YQ" circuit, and the normal speed of working was 200 words or more per minute.

In addition to the Post Office News Services a number of the provincial newspapers had private lines to their London Offices in Fleet Street, and the busier of these lines were generally worked by Wheatstone—some of them at very high speeds. A Glasgow newspaper for many years maintained a normal speed of 400 words per minute, although the traffic load seldom exceeded 6,000 words per hour, or an average rate of 100 words per minute. Such high speeds led to an excessive number of RQ's (repeats), and probably did more than anything else to prevent wider use of the Wheatstone System, and to encourage the development of the less speedy but more efficiently operated Printing Telegraph Systems since introduced.

## *The Early Keyboard Perforator*

In 1897 the writer came to England with the object of developing a Keyboard Perforator for use in connection with the Wheatstone System. He had had some experience in telegraphy in the Western Union, and the Central and South American Telegraph Companies, and hoped, by the introduction of a Keyboard Perforator, to save much of the labour involved in the preparation of the Wheatstone tape. After years of hard work and financial stringency, he, and later, Mr. Gell, produced a satisfactory machine.

The first Creed Perforator was not unnaturally of a somewhat crude, if efficient, design. It was operated by compressed air. A keyboard was provided, coöperating with a group of punches, an air-operated hammer and distance pieces adapted to be inserted between the hammer and the punches by a selecting mechanism under the control of the keys, and an air-operated feed mechanism, Figure 1. This instrument could perforate and feed from one to four tapes at a time, and was on the whole a satisfactory machine, its chief drawbacks being the noise produced, and the necessity of providing air-compressing plant.

### *The Early Receiving Reperforator*

Attention was next directed to the receiving end of the Wheatstone circuit, with the object of providing an automatic means of printing

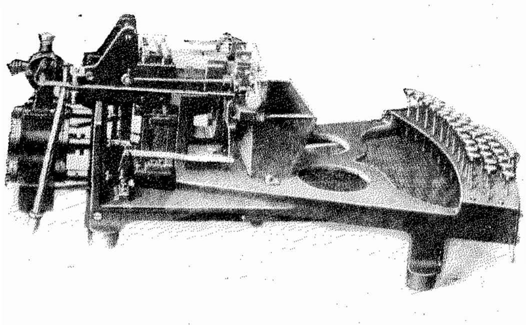


*Figure 1—Early Keyboard Perforator.*

the messages in Roman characters as fast as they were received over the line. This was not an easy task. On consideration of the problem of printing from the Morse code, it is evident that the principal difficulty lies in the fact that the Morse letters are of unequal length, and that the shortest and most frequent letter "e" is, in point of time, very short indeed. For instance, when operating at a speed of only 100 words per minute, the letter "e," together with its following space signal, only occupies one-twentieth of a second in transmission. No mechanism existed at that time, nor does it exist at present, which enables a type to be selected from a group, printed on a tape or page, and everything returned to normal in such a short space of time.

The problem of direct printing from Morse signals *at high speed* has not yet been solved. Confronted with this difficulty, the problem was attacked in another way. If the dots and dashes as represented by perforations in the Wheatstone tape, could be reproduced in the same form at the receiving end of the line, the reperforated tape thus received could perhaps be used to actuate a typewriter or similar mechanism operating at a speed lower than that of the line. Such a solution would involve the invention of two machines instead of one, and would cost a great deal of time and expense, but it seemed to be the only way out of the difficulty, and so the development was undertaken along these lines.

After a year or more, a Receiving Perforator (Figure 2) was finally developed which was sufficiently fast and reliable for most commercial purposes. In this instrument compressed air was again employed. A Standard Post Office Line Relay was used to control a Power Relay in a local circuit. The Power Relay in turn moved the tiny piston valve of a small compressed air engine. The reciprocations of this little engine, under the control of the Line Relay, actuated a pair of punches which perforated the corresponding holes in a blank tape drawn through the machine by means of a feed wheel mounted on a frictionally-driven spindle. A wedge inserted at the moment of punching, between the teeth of a saw-tooth wheel on the feed spindle, brought the tape into the correct position and held it there during the operation

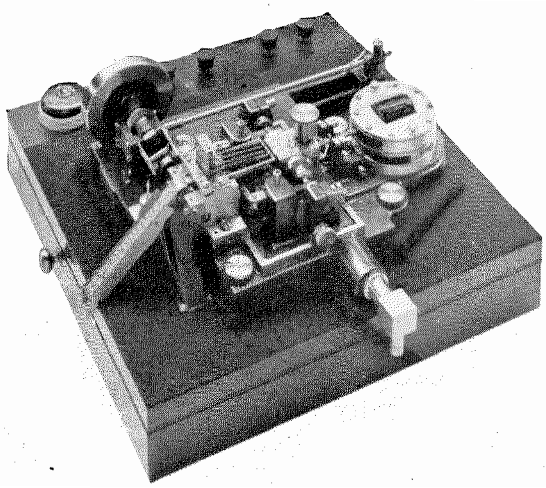


*Figure 2—Air Type-Reperforator.*

of punching, so that the holes made by the punches always came directly opposite to the corresponding feed holes on the tape. This simple method of correction for speed variation between the transmitter and receiver proved very satisfactory, and was capable of dealing with speed differences as between transmitter and receiver of not less than 15% up or down. Operating speeds up to 150 words per minute were quickly obtained, and the commercial exploitation of the apparatus was begun. It was soon evident, however, that although the machine was able to do as much work as several operators, it would have very little vogue because there were comparatively few cases where such reperforating, apart from any printing operation, was necessary; but at last an application was found for the Reperforator in Manchester, where a certain class of news was received daily for retransmission to Northern towns.

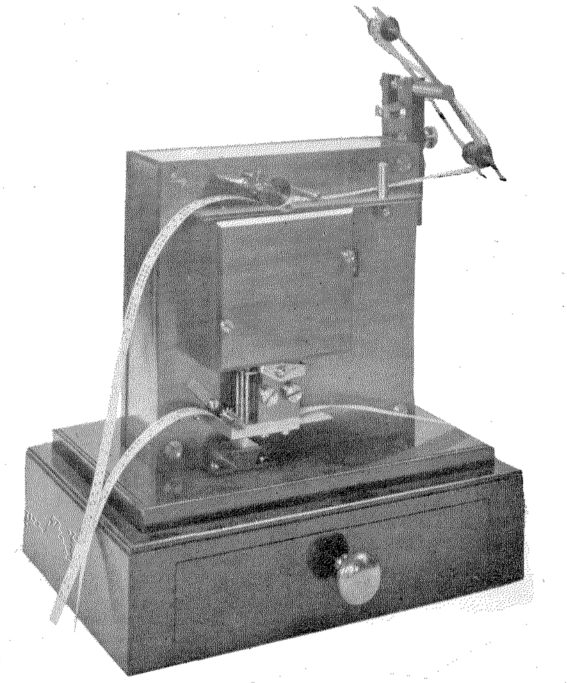


*Figure 3—The Cable Translator.*

The usual procedure was to provide a staff of nine operators, one to supervise the receiver, and the other eight to write the messages from the Wheatstone tape, at the same time making copies for local newspapers. Another group of eight operators then perforated the messages for retransmission over the YQ lines to Glasgow, Edinburgh and other cities. The introduction of the Receiving Reperforator made it unnecessary to employ these eight operators for reperforating purposes, and thus secured important savings in time and operating costs.

Another field for the apparatus was found at Fredericia in Denmark, where messages passing over the Great Northern Telegraph Company's lines between England, Russia and Scandinavian countries were perforated for retransmission. No other applications could be found for the Reperforator alone, except at the cable station of the Anglo-American Telegraph Company on Valencia Island. At this Station messages were received by Wheatstone from London and Liverpool, and then reperforated in cable code for transmission over the submarine cables. Before the Receiving Reperforator could be introduced at this station, it was necessary to devise some means of causing the Wheatstone Morse signals to perforate Cable Code, or of causing the perforated Wheatstone tape from the Receiving Reperforator to control another machine in which a Cable Code tape would be perforated.

The latter alternative was adopted, and a satisfactory machine was designed for the purpose. This was known as a Cable Translator, Figure 3. By the use of the Receiving Perforator and the Cable Translator, it was found possible, under the control of one Transmitter in London or Liverpool, to produce enough Cable Code tape at Valencia to keep three Trans-Atlantic cables fully occupied. Some years later, the Eastern Telegraph Company employed the

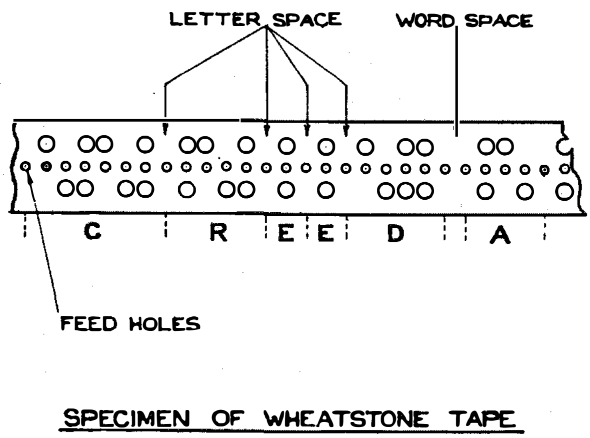



*Figure 4—Specimen of Wheatstone Tape.*

Receiving Reperforator for automatic retransmission at certain intermediate stations between England and South Africa, Australia, South America and the Far East, but at the time the Valencia Station was equipped in 1900/1904 there seemed to be no further applications for the apparatus, and the writer was driven, by the necessities of the case, to invent a Printer in order to complete his Morse Printing Telegraph System, and thereby to open the doors of the whole telegraph world to his inventions.

## The Early Morse Printer

The invention of a machine to print from the Wheatstone tape was by no means an easy task. Obviously it was necessary to provide a sufficient number of selective elements to deal with the longest or shortest character at one operation. The longest character, the figure 0, contains eleven spaces along the tape. The shortest character contains two spaces, and in addition, there is the space itself, so that it was essential to be able to deal with characters containing any number of spaces from one to eleven. These lengths of tape must not only be "read" but also "fed." It would be easy to read any particular character provided that, like the figure "0" or the apostrophe, it filled out the whole eleven spaces; but when several short characters, as, for instance, the letters of the word "the," all came within the space occupied by the selective group, how were the selectors in that group to know where each letter began and ended, and how could they deal with only one letter at a time, and pay no attention, until the right moment arrived, to the letters following? The solution of the problem of "reading" was to be found in the "feed." If means could be found to feed forward only one letter at a time, and no more, it might be hoped by the same mechanism to find a means of "reading" that letter, and of shutting out the unwanted residue. The solution, when found, was so simple that it is surprising someone had not stumbled upon it

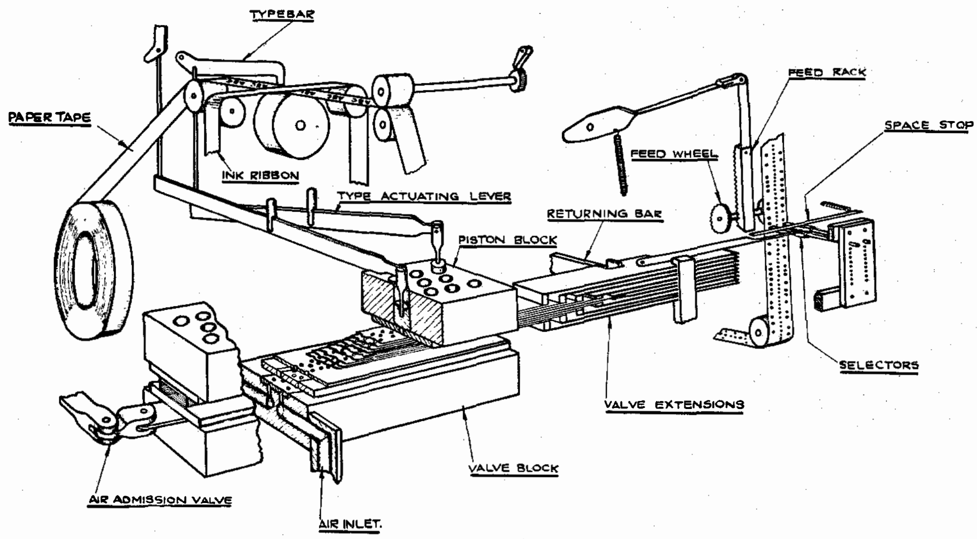



*Figure 5—Principle of Printer Selecting Mechanism.*

before. The secret lay in the fact that while the holes representing dots and dashes in the Wheatstone tape may be perforated on either or both sides of the central row of feed holes, there is always at least one such perforation opposite each feed hole throughout the length of any particular letter; and the double blank, which is a feed hole perforation with blank tape on both sides of it, only occurs when a space is indicated, as in Figure 4.

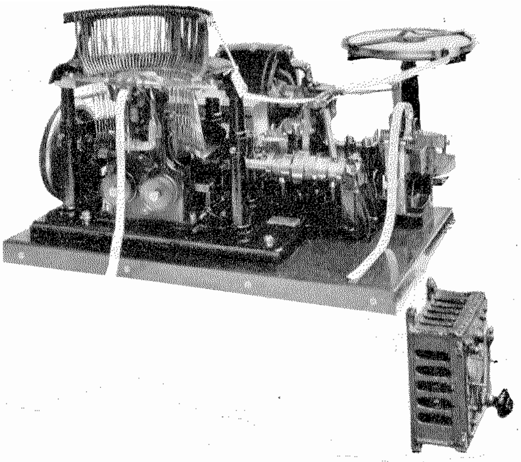


*Figure 6—Creed Air Type-Printer.*

Having observed this, it was only necessary for the Inventor to provide selective mechanism of a kind in which any selector, entering a hole in a tape, pushed a stop out of the track of a feed bar. The selectors being arranged in pairs, either one or both of each pair would go through the tape for every part of a letter, and would push the space stop out of position, and at the end of the letter the double blank of the space would prevent both the selectors from acting, so that the corresponding space stop would remain in position, and limit the exploring movement of the spacebar, (Figure 5).

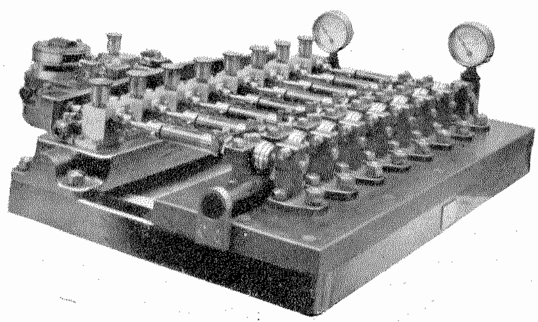


*Figure 7—Creed Wireless Key (250 KW).*

When this means of determining the length of a letter on the tape had been discovered, it was comparatively easy to develop a feed mechanism that would feed forward the letter being dealt with, and that would bring the next letter up into position to be read at the next operation, and also to provide a shutter mechanism that would render inoperative selectors which might be dealing with perforations beyond the space occupied by the letter being translated. It was afterwards found that the use of a shutter was unnecessary, as the effect of the unwanted combinations could be eliminated by cutting away the corresponding parts of the type selecting combs which were set up by the selectors.

Although a solution in principle had now been found, the task remained of developing a satisfactory Printer. One of the first problems was to decide what kind of printing mechanism should be used; whether to cause the type-operated mechanism to work the keys of a standard typewriter, or to make a special printing mechanism for the purpose. It was at first intended to use a standard typewriter, but finally a special printing mechanism was developed, in which the primary selectors admitted compressed air to little cylinders containing pistons, each of which, when operated, caused the type to strike the paper through a typewriter ribbon. This was found to be an advantageous arrangement, because the little pistons could move any convenient distance, and thus follow the type-bar home, whereas the

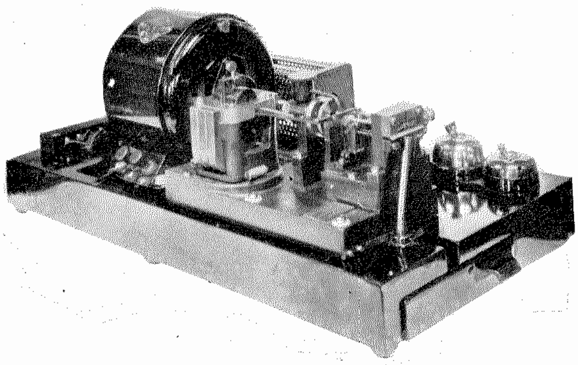


*Figure 8—Morse Reperforator.*

common striking bar employed by other inventors for operating the keys of a typewriter called for great accuracy in the alignment of the key levers and associated trip-bars.

In the earlier models of this Printer, the compressed air was supplied by the compressor used for the Reperforator, the pressure being regulated by a specially designed reducing valve. Later, however, a small compressor unit was introduced on the Printer itself, actuated by an eccentric on the main shaft (Figure 6). This eccentric was so set that the puff of air was delivered at the correct moment to operate the small piston after its selection. This resulted in considerable simplification of the Printer mechanism, and a reduction in the size of the compressing plant.

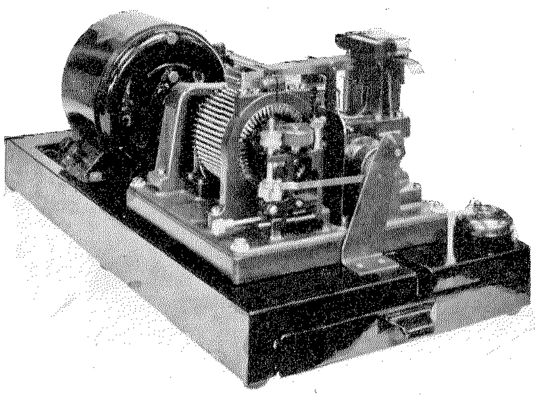


*Figure 9—Morse Printer.*

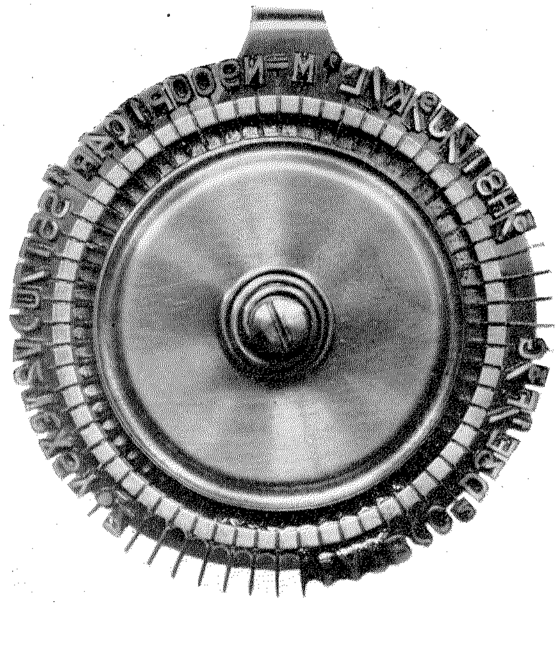


*Figure 10—Printer Typehead.*

The Reperforator and Printer remained more or less in this form from 1914 until 1919, when it was again possible to devote attention to development. In the meantime, it was found that the Reperforator could be adapted to the control of Radio Stations using Arc transmission, which were very popular at that time. The punches were replaced by large contacts which were arranged to short-circuit a portion of the transmitting inductance. The instrument was controlled by a Wheatstone Transmitter or hand key. Many of the large Radio Stationsl such as Leafield (Oxford), Cairo and Eiffe. Tower, were equipped with these (Figure 7),

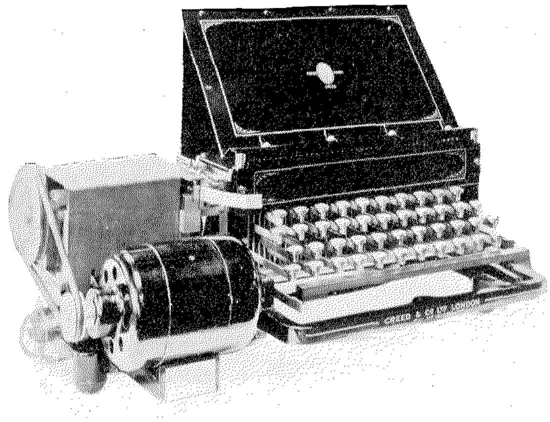


*Figure 11—Morse Keyboard Perforator.*

## *The Modern Reperforator*

Effort was now directed toward the production of a Reperforator and Printer which would not be pneumatically operated. The necessity for an air compressing plant had always been recognised as a disadvantage; and the improvement effected by the removal of this necessity, in the case of the Printer, served to emphasise the advantages to be gained by its entire elimination.

As the result of two years' investigation and experiment towards this end, the present Reperforator and Printer were evolved, and the first models were put into service in 1921 by the Pacific Cable Board and Commercial Cable Company. Since that date, minor improvements have been introduced, but the general design remains substantially the same.

In the case of the Reperforator (Figure 8) the operation of the punching mechanism is carried out by a cam, frictionally driven, and under the control of a power relay. This control is effected through a simple escapement, which permits the cam to make half a revolution for every movement of the relay tongue. During the half revolution, the corresponding punch is forced through the paper. The method of correction adopted is similar to that used in the older type of machine, except that it is cam-operated. The power for driving the clutch and feeding the tape is derived from a shunt-wound motor, the speed of which is adjusted by means of a variable resistance in series with the field. Apart from the motor and the power relay, the action of the machine is entirely mechanical.

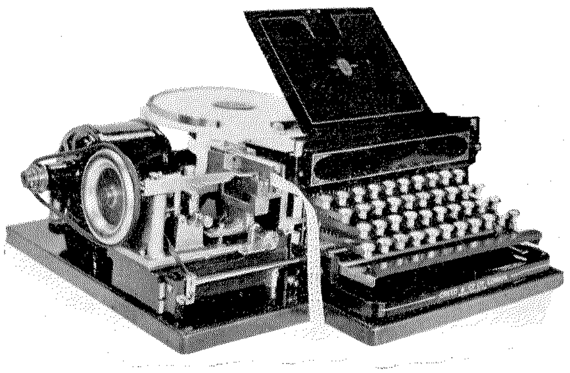


*Figure 12—Morse Keyboard Perforator with Horizontal Tape Wheel.*

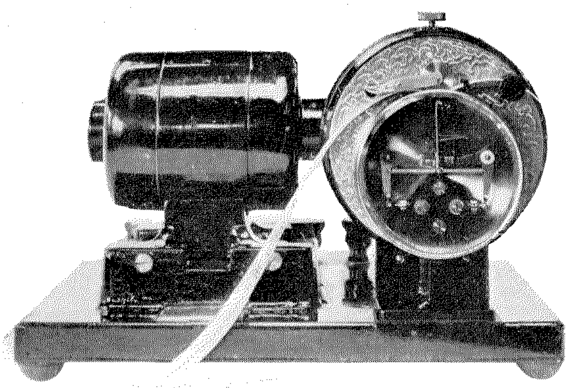


*Figure 13—Morse Tape Transmitter.*

### *The Modern Morse Printer*

The Printer (Figure 9) also is a motor-driven cam-operated machine, and differs from the pneumatic printer principally in the method of setting up the selection, and the design of the typehead.

The Selectors themselves are very similar to those of the older machine, but in this case a combination disc is provided for each one of the twenty, instead of one for every pair. In this way the unwanted letters which may follow and occupy selectable positions, can be eliminated, by suitably cutting the combination on the discs.

The combinations are notched round the periphery of the discs. Arranged around them concentrically are a number of latches which can be raised and lowered on to the edges of the discs. According to the combination set up, a clear track is left across the twenty discs into which one latch is permitted to drop. It is so arranged that the end of this latch comes into the path of, and arrests, a rotating, frictionally driven stop, attached to which is the typehead. In this manner the type corresponding to the particular selection set up is brought to rest in front of a hammer, which at the correct moment, presses it forward on to the paper.

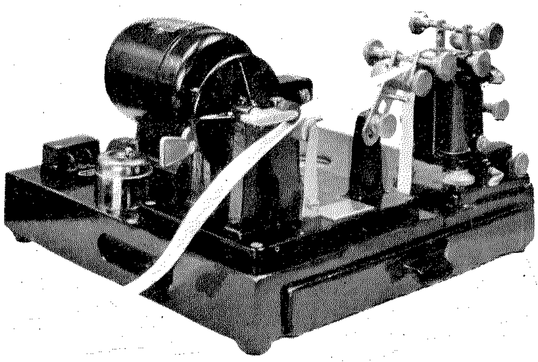


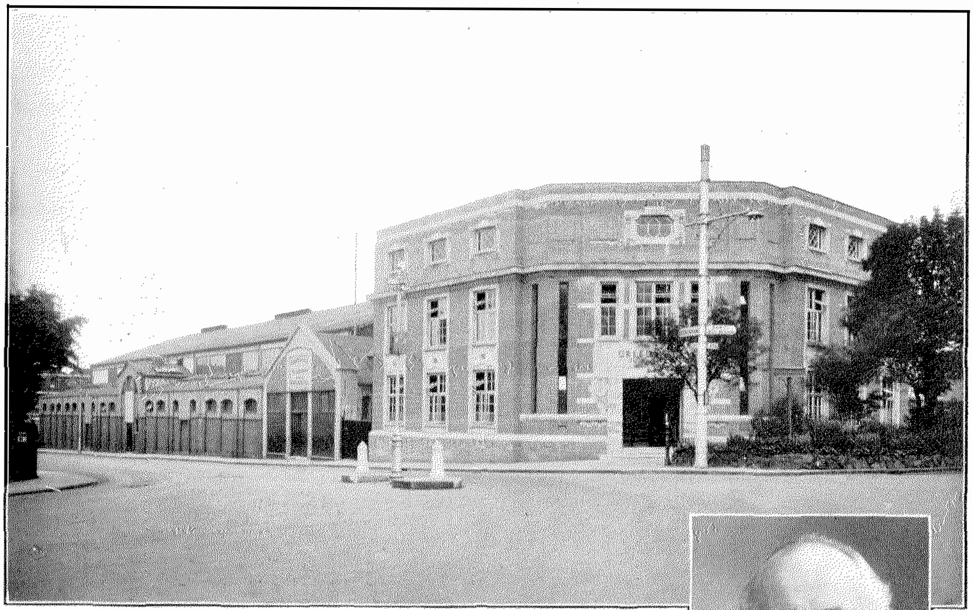
*Figure 14—The Creed Undulator.*

It was necessary to evolve a typehead of very light yet strong construction, which could be rotated at a high speed, yet stopped and restarted instantly. The weight of this typehead is 23 grammes (Figure 10). Each type is a separate bar, made of steel, hardened, and tempered. These are mounted on an annular pivot, and can be operated independently of each other.

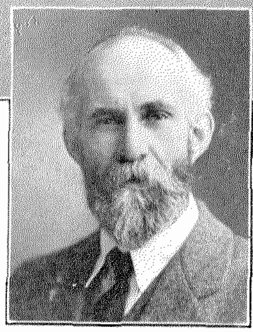
The method of achieving the differential feed of the perforated tape is identical with that used on the pneumatic printer.

## *The Modern Keyboard Perforator*

The High Speed Morse Printing Telegraph System was completed by the provision of a simplified form of Morse Transmitter, Undulator, and improved model Keyboard Perforator, in 1922. The improved model Keyboard Perforator (Figures 11 and 12), avoids the use of compressed air, being cam-operated and motor-driven. The combination bars are arranged so that they can be positively held by the selector bars carrying the operating keys. The punches are supported in a frame, with their heads opposite to the ends of the combination bars. This frame also carries the paper tape, and at the correct time is moved by the cam, forcing the paper against the punches, and the punches against the ends of the combination bars. Those combination bars which are held by the depressed selector bar cause the corresponding punches to be forced through the paper tape. A differential feed mechanism is provided similar to that on the Printer.



*Creed Works and Offices.*



*Portrait of the Author.*

## *The Automatic Tape Transmitter*

The development of the secondary cell, and its introduction into telegraph service led to the use of universal batteries with their mid-points earthed. This rendered unnecessary one of the two pairs of contacts included in the design of the Wheatstone Transmitter, and it was obvious that a considerable simplification of the mechanism could be effected by the elimination of these unnecessary contacts. It was to this purpose that the Creed Morse Transmitter was developed.

Further simplification was made possible by the simultaneous development of a polarised relay, one of the special features of which was its very firm contact pressure. By using this relay in conjunction with the transmitter, it became possible to eliminate the jockey retention of the armature. The mechanism of the Transmitter was reduced to two bell-cranks carrying contacts oscillating under the action of an eccentric, and controlled through the usual "peckers" by the tape (Figure 13).

### *The Undulator*

This apparatus (Figure 14) is used where it is required to record incoming telegraph signals in graph form. It embodies the principle of the Kelvin siphon-recorder, and consists essentially of a special type of quick acting galvanometer, and a light siphon tube with one end trailing on a paper tape, and the other end dipping in an inkwell. The paper tape is fed forward by a motor-driven mechanism. A variable gear permits the speed to be adjusted to suit the incoming signals.

The Undulator completes the group of apparatus units used in the High Speed Morse Printing Telegraph system now in widespread use throughout the world.

ERRATA: *Electrical Communication*, Vol. VII, No. 4, April, 1929.

Pages 283 and 289—Schematics of Figures 3 and 5 should be interchanged.

Page 285—In bracket at bottom of column 2, quantity $\frac{1}{2\pi C}$ at right should be separated from rest of the equation by a minus sign, viz., "$-\frac{1}{2\pi C}$."

Page 286—Bracket, column 1, second line, should read:

$$\left[\frac{K}{2\pi C\,[4-3K-\sqrt{(4-3K)^2-K^2}]}-\frac{1}{2\pi C}\right]$$

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