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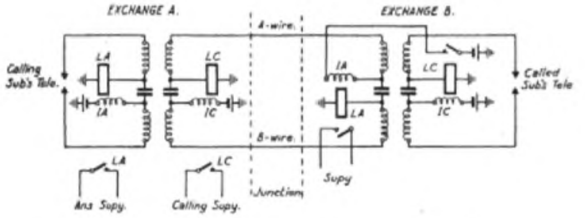
I. INTERMEDIATE TELEPHONY: QUESTIONS AND ANSWERS

By W. S. PROCTER, A.M.I.E.E.

Q. 1. Describe, with the aid of a diagram, how "through signalling" is effected over junction circuits between central battery exchanges. State the reason for providing this facility. (30 marks.)

A. 1. The diagram shows the principle of through signalling over junction circuits between C.B. exchanges. It is assumed that the operator at the originating exchange, A, controls the



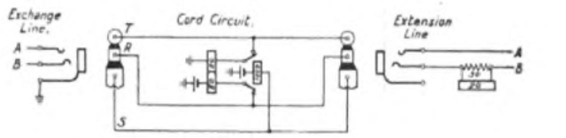
connexion and receives all supervisory signals during the progress of the call. The calling subscriber controls relay LA by means of the gravity switch; this relay controls the supervisory lamp associated with the answering cord. Relay LC, controlling the calling supervisory lamp, is operated by battery received over the A-wire of the junction (*a*) when the B-operator is speaking on the junction and (*b*) when the called subscriber has his receiver off the rest. Relay LA at the objective exchange, B, is controlled by the battery applied to the B-wire at the calling exchange; this battery is also used to operate the junction calling signal in the initial stage of the call.

The reason for providing this facility is to enable the operator controlling the call to exercise complete supervision. The following supervisory signals are received on the calling supervisory lamp of the cord circuit at the controlling exchange :—

(i) The lamp glows when the calling plug is inserted into an outgoing junction jack.
(ii) The lamp darkens when the B-operator at the distant exchange has inserted a plug into the junction answering jack and also placed the cord circuit key into the speaking position.
(iii) The lamp again glows when the B-operator has inserted the calling plug into the called subscriber's jack and also restored the cord circuit key.
(iv) The lamp darkens when the called subscriber replies.
(v) The lamp glows, so giving a clearing signal to the A-operator, when the called subscriber replaces the receiver.

Q. 2. A certain private branch exchange of the central battery type is supplied with current by means of a power lead. Calculate the current flowing in this lead when three pairs of cords are in use for exchange connexions, and six pairs for extension connexions, the voltage at the branch exchange under these conditions being 12. Assume a constant loop resistance of 80 ohms inclusive in each extension circuit. (30).

A. 2. The skeleton connexions of the exchange line, cord circuit, and extension circuit of a $\frac{5 + 20}{25}$ type switchboard are shown in the diagram; this size of branch exchange is the most likely one to be used under the conditions postulated.



On each exchange connexion the transmitter current for the extension instruments is fed over the exchange line from the battery at the public exchange. The battery cut-off relay in each cord circuit is operated over the S-wire of the exchange line jack, and this is the only portion of the circuit taking current from the power lead; the amount of this current for the three connexions is $12 \times \frac{3}{1000} = .036$ ampere.

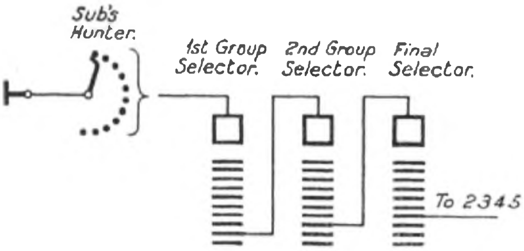
Extension connexions. The resistance of each extension line is $80 + \frac{30 \times 20}{30 + 20} = 92$ ohms. The resistance across the power supply to each of the six pairs of cords is therefore $80 + 80 + \frac{92}{2} = 206$ ohms. Hence, the resistance across the power lead is $\frac{206}{6}$ ohms. The current fed to the six pairs of extension connexions is $\frac{12 \times 6}{206} = 0.350$ ampere.

The total current flowing in the power lead is therefore $0.350 + 0.036 = 0.386$ ampere $= 386$ mA.

Q. 3. Draw a simple diagram indicating the route of a call through an automatic exchange in a case where the calling subscriber dials 2345. At what stage of the call, and in what circumstances, would each of the following tones be applied:— (a) dialling tone; (b) ringing tone; (c) busy tone; and (d) number unobtainable tone? (30).

A. 3. The sketch indicates the route of a call through a non-director automatic exchange, when the calling subscriber dials 2345.

(*a*) *Dialling tone* is connected to the calling line when the subscriber's hunter has seized a free 1st group selector in readiness for the reception of the thousands digit; absence of the tone indicates that the hunter is still rotating in search of a free 1st selector.



(*b*) *Ringing tone* is connected to the calling line from the final selector on completion of dialling and the seizure of the called line.

(*c*) *Busy tone* is connected to the calling line—

(i) from the 11th contact of level 2 of the 1st group selector, should all the outlets in the level be engaged.

(ii) From the 11th contact of level 3 of the 2nd group selector, should all the outlets in this level be engaged.

(iii) From the final selector, should the called subscriber's line be engaged.

(*d*) *Number Unobtainable tone* is connected to the calling line—

(i) should the wipers of the 1st group selector be stepped to level 1, due to the receipt of a false initial impulse.

(ii) Should the wipers of the 1st or 2nd group selector be stepped to a spare level, for any reason.

(iii) Should the number dialled be spare.

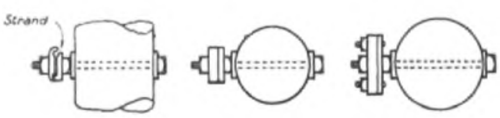
(iv) Should the called subscriber's line be faulty or otherwise temporarily out of service.

Q. 4. State the circumstances in which lead-covered aerial cable is used on telephone routes. Give a short description, with explanatory sketches, of the method adopted in erecting aerial cable on a line of poles. (30).

A. 4. Aerial cable of the lead-covered type is used for clearing obstructions in an overhead or local underground route, for leading-in external circuits to a small exchange, for providing subscribers' circuits on an overhead trunk route where the maximum arm capacity of the poles is required for trunk circuits, and for providing trunk circuits using star quad cable having conductors of 10 lb. gauge.

The sheath of the cable consists of a lead-antimony alloy, a proportion of 0.8—1 per cent. of antimony being added to obtain a sheath more capable of withstanding the stresses to which aerial cables are subject than the lead sheath used for underground cables.

Where a pole route is erected specially to carry an aerial cable, the spans are limited to an average length of 40 yards to reduce the dip and the stress of the cable. The more common case, however, is the construction of an aerial cable route supported on existing poles.



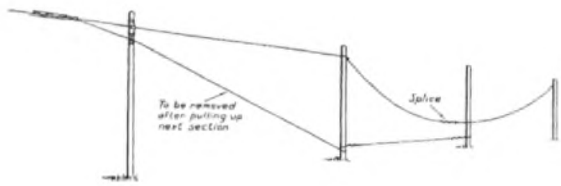
BRACKET No. 12 (1 Bolt) BRACKET No. 13 (3 Bolt)

Supporting brackets are fitted to the poles and are placed on the same side of the pole throughout the length of the line to facilitate the erection of a second cable if required later. Any additional stays required are erected.

The suspension strand is next erected, the size depending upon the weight of the cable to be carried; one 7/14, 7/12, or 7/10 steel strand is used, and is supplied in half-mile lengths wound upon a drum. The strand is run out either by hand or from a light motor lorry, depending upon circumstances, and is lifted into position on the brackets by means of a sash line.

Lengths of suspension wire are spliced by means of thimbles and 3-bolt clamps as shown in the sketch. As each half-mile

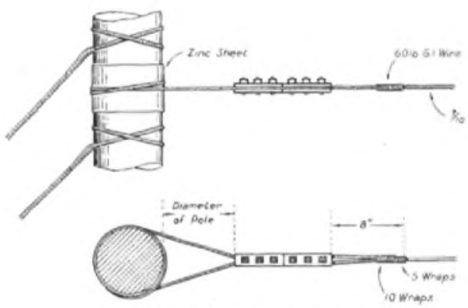
length is run out, and lifted into position, it is regulated by means of blocks and tackle attached to temporary poles which are suitably stayed if the ground is at all soft. The tension is



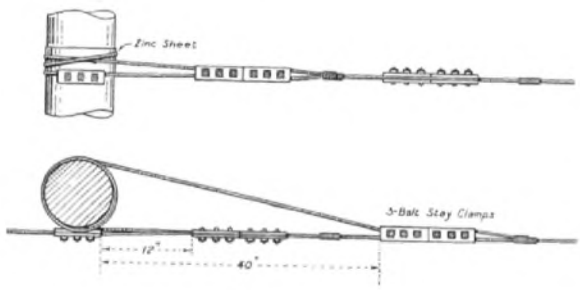
checked by means of an oscillation test, no measuring instruments being employed.

On spans of greater length than 65 yards, an auxiliary strand is run at a height of from 4 to 7 ft. above the main strand, and the two suspension strands are clamped together at the centre of the span.

At the beginning and end of the route, and also at any acute angles in the line, a true termination is made as shown in the sketch. At road and railway crossings and at every



TRUE TERMINATION.



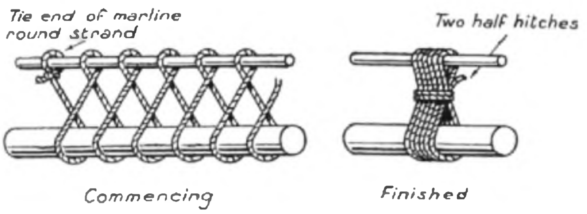
FALSE TERMINATION.

pole provided with line stays, a false termination is made as shown.

The cable rings are next fitted at 20-inch intervals along the suspension strand by a workman riding in a bosun's chair supported on the strand by two grooved wheels. The draw rope, to be used for pulling the cable into the rings, is placed in position during this operation. At railway crossings, the distance between the rings is reduced to 10 inches. The rings are self-gripping on the strand and resist considerable force tending to move them during pulling-in operations.

The aerial cable is supplied in lengths of 500 yards and the cable drum is placed at a suitable distance behind the first pole and is mounted on jacks. The end of the cable is passed through a grease box and is then dressed and fitted with a cable grip. The draw-rope is fixed to the grip by means of thimbles in order to prevent fouling the cable rings during the operation of drawing-in. Suitably placed blocks supported on temporary back stays are used to guide the cable into position for entering the first ring. The cable may be drawn in either by a high speed winch or by a motor lorry. In either event, a pulling-in rate of 3 to 4 miles per hour is practicable.

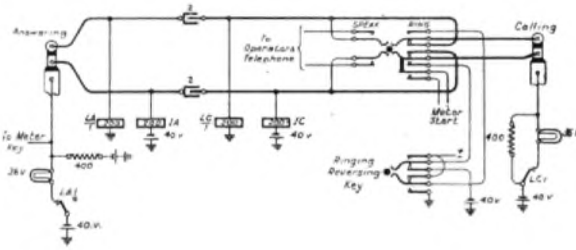
The grease box is kept filled with petroleum jelly, and a short length of rubber piping is passed round the cable where it emerges from the box, in order to restrict the jelly to a thin film. The jelly is used mainly as a lubricant since, without its use, considerable chattering of the rings would take place during drawing-in.



After the cable has been drawn in, it is supported on either side of the suspension brackets at each pole by means of a marline tie, as shown in the sketch.

Q. 5. Draw a diagram showing the connexions of a central battery A-position cord circuit of the impedance coil and condenser type. What would be the effects on speech transmission, and on signalling, if both condensers were short-circuited? (35).

A. 5. The required diagram is given in the sketch.



If both condensers were short-circuited, the cord circuit would become the equivalent of the bridged impedance type used in some P.B.X. cord circuits. If the loop resistances on the answering and calling sides were equal, transmission would be slightly better as the loss of about 0.5 decibel caused by the two condensers would be removed; in addition, the lower frequencies would be more readily transmitted, since the condensers act as high-pass filters, and articulation would be improved. If the loop resistances were unequal, the transmission from the lower resistance loop would be better than that in the reverse direction, since the point of division of the current is on the line side of the impedance coils so resulting in a heavy current flowing in the loop of lower resistance and a correspondingly weak current being fed to the transmitter in the higher resistance loop. This arrangement is quite satisfactory for P.B.X's, because the loop resistances of the extension lines are approximately equal, but it is not suitable for public exchanges because the loop resistances of subscribers' lines vary within much wider limits.

The effect on signalling would be that both supervisory lamps would be darkened when the answering plug was inserted in a calling subscriber's jack and the lamps would not glow until both subscribers had replaced their receivers. In addition, due to the presence of a potential on the tip of the calling cord, from the battery fed round the calling subscriber's loop, a false engaged test would result.

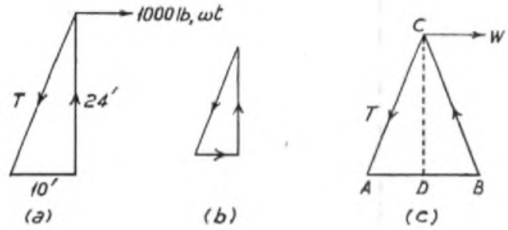
Q. 6. A stay at a terminal pole has a "spread" of 10 ft. At its upper end, 24 ft. from the ground, there is a horizontal pull, due to the line wires, equal to 1,000 lb. wt. Calculate the tension in the stay. Explain how the tension would be modified if the pole had a slight backward tilt, away from the line, the pull of the wires still being in a horizontal direction. (35).

A. 6. The tension, T, in the stay is:—

$$T = \frac{\sqrt{24^2 + 10^2}}{10} \times 1{,}000$$

$$= 2.6 \times 1000 = 2{,}600 \text{ lb. wt.}$$

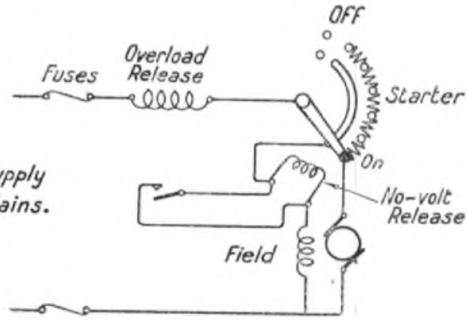
In sketch (*c*), $CA^2 = AB^2 + BC^2 - 2AB \cdot BD$. If AB and BC remain constant, CA^2 (and hence CA) becomes shorter as BD is increased. Hence, from the force triangle, T is reduced as the pole is tilted backwards. The stress in the pole, in



this condition, can be resolved into horizontal and vertical components; the horizontal component, though small, is in the opposite direction to the pull of the line wires and hence the effective stress in the line wires, to be counteracted by the tension in the stay, is less than when the pole is vertical.

Q. 7. Draw the connexions of the starting apparatus used with a shunt-wound direct current motor. State the reasons for providing (a) an overload release, and (b) a "no-volt" release. (35).

A. 7. The connexions of a starter for a shunt-wound motor are shown in the diagram.

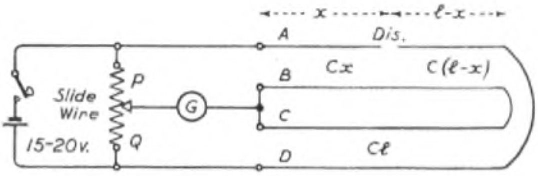


An overload release is fitted to disconnect the motor from the supply in the event of an overload being placed on the motor. In such circumstances the speed of the armature falls, so reducing the back e.m.f.; the current taken by the motor rises and may reach dangerous proportions. The overload release carrying the full line current, however, is set to operate at about 1.5 times the working current; when operated, the spring contacts short-circuit the no-volt release and the starter arm is returned to the "off" position by a spring.

The no-volt release is fitted to ensure that the motor shall be disconnected from the supply should the current fail. The no-volt release is connected in the field circuit and when, for any reason, the field current fails, the starter arm is released.

Q. 8. Two pairs of wires form a quad in a long length of cable. One of the four wires is disconnected at some point along the route. Show how the position of the fault may be estimated, using for the test a sensitive ballistic galvanometer, a slide-wire resistance, and a battery and key. (35).

A. 8. The apparatus is joined up to the faulty quad as shown in the diagram; at the distant end of the length under



test, the A and D wires, and the B and C wires are looped as shown.

Let C = capacity of the line, per mile.
l = length of the line, in miles.
x = distance to fault, in miles.

Then C_x = capacity on one side of the fault and $Cl + C$
and $Cl + C(l - x) = C(2l - x)$ = capacity on the other side of the fault.

If V_1 is the voltage charging C_x,
V_2 is the voltage charging $C(2l - x)$,
Q_1 is the quantity charging C_x,
and Q_2 is the quantity charging $C(2l - x)$,

then when no galvanometer kick is obtained on depressing or raising the battery key,

$$Q_1 = Q_2$$

i.e., $V_1Cx = V_2C(2l - x)$.

$$\therefore \frac{V_2}{V_1} = \frac{Cx}{C(2l - x)}$$

But $$\frac{V_2}{V_1} = \frac{Q}{P}$$

$$\therefore \frac{Q}{P} = \frac{Cx}{C(2l - x)}$$

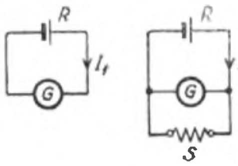
whence $$\frac{x}{2l} = \frac{Q}{P + Q}$$

and $$x = \frac{Q}{P + Q} \times 2l.$$

To obtain reliable results, the test should be made from both ends of the cable.

Q. 9. A primary cell is connected to a voltmeter of G ohms resistance, and the reading V_1 is noted. A shunt of S ohms resistance is then applied, and the reading falls to V_2. Establish a formula for the internal resistance (R) of the cell, in terms of G, S, V_1 and V_2. (40).

A. 9. Let E = e.m.f. of cell,
I_1 = total current in first test,
I_2 = total current in second test.



Test 1. *Test 2.*

Then $E = I_1 R + V_1$ ....(1)
and $E = I_2 R + V_2$ ....(2)

Equating (1) and (2)—

$$I_2 R + V_2 = I_1 R + V_1$$

$$\therefore \quad R = \frac{V_1 - V_2}{I_2 - I_1} \quad \text{..........(3)}$$

$$\text{But } I_1 = \frac{V_1}{G} \quad \text{..........(4)}$$

$$\text{and } I_2 = \frac{V_2}{G} + \frac{V_2}{S} \quad \text{..........(5)}$$

Substituting (4) and (5) in (3)—

$$R = \frac{V_1 - V_2}{\left(\frac{V_2}{G} + \frac{V_2}{S}\right) - \frac{V_1}{G}}$$

$$= \frac{GS(V_1 - V_2)}{V_2S + V_2G - V_1S}$$

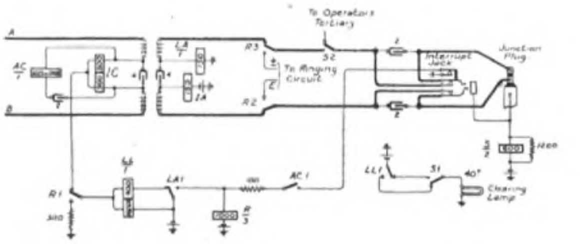
$$= \frac{GS(V_1 - V_2)}{V_2G - S(V_1 - V_2)}$$

Q. 10. Enumerate the facilities provided at a central battery exchange on order wire junction circuits incoming from a trunk exchange. Sketch that portion of the circuit arrangements which enables the trunk operator to control the application of ringing current to the wanted subscriber's line. (40).

A. 10. The facilities provided are as follows:—

(i) The B-operator can "interrupt" the call should the called subscriber's line be engaged and, if the subscriber accepts the trunk call, can flash the cord circuit supervisory lamp on the position at which the subscriber is connected.
(ii) The ringing current is controlled by the Trunk operator and is tripped when the called subscriber answers.
(iii) Through signalling is provided to enable the called subscriber to control the supervisory lamp of the Trunk cord circuit.
(iv) Control of the B-position supervisory lamp by the Trunk operator.
(v) The Trunk operator can re-ring the called subscriber.

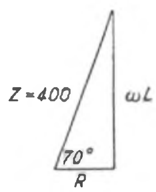
The sketch shows the connexions of an order wire junction



circuit incoming from a trunk exchange. Relay AC, operated by ringing current from the Trunk exchange, operates relay R which, in turn, applies ringing current to the called subscriber's line.

Q. 11. A certain telephone receiver has an impedance of 400 ohms with an angle of lag of 70°, when an alternating current with a frequency of 800 cycles per second is passing. Calculate its effective resistance and inductance at this frequency. (Tan 70° = 2.75). (40).

A. 11. $Z^2 = R^2 + (\omega L)^2$
where Z = impedance, in ohms,
R = resistance, in ohms,
L = inductance, in henries,
and $\omega = 2\pi f$, where f is the frequency in periods per second.



Substituting the figure given in the question :—

$$400^2 = R^2 + (\omega L)^2$$

$$= R^2 + \left(\frac{11}{4} R\right)^2$$

since $\frac{\omega L}{R} = \tan 70^\circ = 2.75 = \frac{11}{4}$

$$400^2 = R^2\left(1 + \frac{121}{16}\right)$$

$$= R^2 \times \frac{137}{16}$$

$$\therefore\ 400 = R \times \frac{\sqrt{137}}{4}$$

$$\therefore\ R = \frac{1600}{\sqrt{137}} = \frac{1600}{11.7} = \underline{136.7\Omega.}$$

$$\omega L = \frac{11}{4} \times 136.7$$

$$\therefore\ L = \frac{11 \times 136.7}{4 \times 5000}$$

$$= \frac{1503.7}{20{,}000} = 0.075 \text{ H} = \underline{75 \text{ mH}}.$$

Q. 12. Compare the transmission characteristics of (a) open wire, (b) unloaded cable, and (c) loaded telephone cable circuits. (40).

A. 12. If, in a perfectly homogeneous line, the primary constants R, L, G and C are so related that R/L and G/C are equal, then it can be shown that propagation is distortionless, all frequencies being transmitted with the same attenuation and at the same velocity. The primary constants are as follows :—

R = resistance per mile, in ohms.
L = inductance per mile, in henries.
C = capacity per mile, in farads,
and G = leakance per mile, in mhos.

(*a*) *Open wire.* The resistance of open wire is necessarily low since considerations of mechanical strength necessitate conductors of comparatively heavy gauge. Because the conductors are spaced widely apart, the capacity is lower and the natural inductance of the line is higher than that of underground cable pairs. The leakance, too, is higher. The results of these factors on transmission are that the attenuation is low, due to the low resistance and the higher natural inductance of the line, and the cut-off point is considerably higher—about 30,000 p.p.s.—than that of underground cable.

(*b*) *Unloaded cable.* Here the resistance is higher than for open wires, due to the use of conductors of small gauge; the close proximity of the wires results in a capacity per mile some seven times greater than that of open wire, and also reduces the natural inductance of the line to approximately one quarter that of open wire. Due to the high insulation resistance, the leakance is low. This results in a high attenuation per unit length of line and causes the cut-off frequency to be low.

(*c*) *Loaded cable.* In this case, inductance is added to the line in either lumped or continuous form with the object of making the ratios R/L and G/C more nearly equal, so improving the transmission. The attenuation constant is reduced and the cut-off frequency of the line raised to a value between 2,500 and 10,000 p.p.s., depending upon the type of loading.

II. TELEPHONY, FINAL; SECTION 1, AUTOMATIC TELEPHONY. QUESTIONS AND ANSWERS.

W. S. Procter, A.M.I.E.E.

Q. 1. The magnetic circuit of a certain relay is equivalent to that provided by a round iron rod of 0.8 sq. cm. cross-section, and 15 cms. in length, bent into a circle, with its ends 0.05 cm. apart. Calculate the ampere-turns required to produce a total flux of 5,000 lines in the iron, its permeability under these conditions being 3,000. (30 marks).

A. 1.

$$\Phi = \frac{\frac{4\pi}{10} NI}{\frac{l_1}{a_1\mu_1} + \frac{l_2}{a_2\mu_2}}$$

where Φ = total flux,
N = number of turns,
I = current in amperes,
l_1 = length of iron, in cms.,
l_2 = length of air gap, in cms.,
a_1 = cross-sectional area of iron, in sq. cms.,
a_2 = cross-sectional area of air gap, in sq. cms.,
μ_1 = permeability of iron,
μ_2 = permeability of air = 1

Substituting the figures given in the question :—

$$5{,}000 = \frac{1.257\ NI}{\frac{15}{0.8 \times 3{,}000} + \frac{.05}{0.8 \times 1}}$$

$$= \frac{NI}{0.8\left(\frac{15}{0.8 \times 3{,}000} + \frac{.05}{0.8}\right)}$$

$$= \frac{NI}{\frac{15}{3{,}000} + .05} = \frac{NI}{.005 + .05}$$

$$NI = 5{,}000 \times .055 = \underline{275 \text{ ampere turns}}.$$

Q. 2. Explain what is meant by (a) traffic unit and (b) grade of service. A group of selectors observed for 10 busy hours carried an average of 20 traffic units, and the total number of calls lost was 12. The calls had an average duration of two minutes. What grade of service was given? (30).

A. 2. (*a*) *Traffic Unit.* The unit of traffic flow; a unit employed in estimating the amount of switching equipment required in automatic exchanges to carry the traffic. In any given volume of traffic, the traffic flow for a specified period is said to be unity when the average number of simultaneous calls during the period is unity; the specified period is the busy hour unless otherwise stated. The traffic flow, in traffic units, for a period can therefore be shown to be the number of calls originated during the period multiplied by the average holding time of a call, holding time being expressed in terms of the period. A traffic unit is, therefore, equivalent to the traffic flow in one circuit continuously occupied.

(*b*) *Grade of Service.* A measure of the service given in an exchange from the point of view of sufficiency of plant. In practice it is expressed as the proportion of calls which are allowed to fail during the busy hour, owing to the limitation, for economic reasons, of the amount of switching plant.

Average number of calls originated during one busy hour

$$= \frac{20 \times 60}{2} = 600.$$

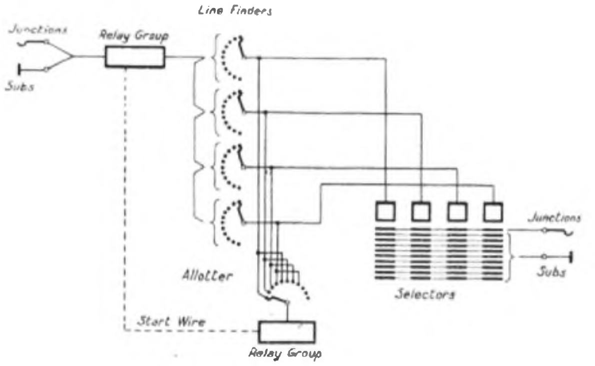
Average number of lost calls during one busy hour = 12/10 = 1.2.

$$\text{Grade of service} = \frac{1.2}{600} = \frac{1.0}{500}$$

= 1 lost call in 500.

Q. 3. Describe any type of switching plant suitable for a rural automatic exchange. Give a diagram showing typical trunking arrangements. (30).

A. 3. The diagram shows the trunking arrangements of a rural automatic exchange using Units, Auto, No. 5. Each



unit has a capacity for 25 subscribers' lines and four units is the maximum capacity of the standard building adopted for this type of exchange. Each unit contains four connecting links, each link consisting of a 25-point uniselector used as a line finder and a 100-outlet two-motion selector used as a final selector. An allotter—a uniselector—is provided in each unit to ensure that the links are brought into service in cyclic order, so equalizing the load on each link. Tones, ringing, and other subsidiary facilities are provided by a common apparatus unit which embodies, inter alia, a uniselector used as a time delay switch for providing forced release to any link held by a faulty line; a vibrator for supplying ringing current and tone; a buzzer and relay group for supplying continuous and interrupted tone; and apparatus for fault observation from the distant manual exchange. Dialling tone is not provided and the busy and ringing tones are of non-standard sequence.

Access to other exchanges is obtained over junctions to a manual switchboard; the junctions are connected to the 0 level of the selectors and P.B.X. hunting facilities are provided on this level only. Two or more junction groups can be accommodated if required. Incoming calls are received over junctions from the nearby manual exchanges and the lines are terminated upon ordinary subscriber's calling apparatus. A number on the exchange is allotted to the fault observation equipment and operators at the distant manual exchanges are able to differentiate between certain types of fault by means of different tone sequences connected by the apparatus.

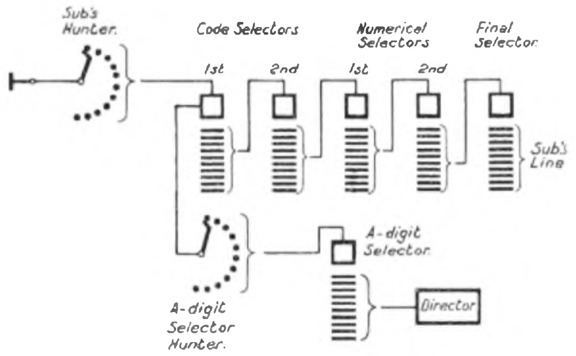
If a public electricity supply is available, the power plant consists of a tungar rectifier (for A.C.) or a charging generator (for D.C.). Otherwise, a petrol-engine charging set is used. Two sets of 50-volt batteries are installed and automatic termination of the charge is provided. Recently, an automatically controlled single battery charging plant has been introduced for use at exchanges of this type where the electricity supply is A.C.; the equipment makes use of a static rectifier, contact voltmeter set to the upper and lower voltage ranges (52—46 volts), and mercury tube relays for controlling the charge and discharge circuits. Counter e.m.f. cells are also used in the control of voltage range.

Q. 4. Give a simple grouping diagram showing the various types of switch used at a director exchange in establishing calls between subscribers on automatic exchanges, and state the principal functions of each type. (30).

A. 4. The diagram shows the arrangement of the various types of switch used at a director exchange in establishing calls between subscribers on automatic exchanges.

The functions of the *subscriber's hunter* are (i) to search for and seize a free 1st code selector when the subscriber removes the receiver, and (ii) to return its wipers to the home position when the receiver is replaced.

The *A-digit* hunter searches for and seizes a free A-digit selector, and extends the pulsing-in wires to this switch.



The *A-digit selector* returns dialling tone to the calling line and, on receipt of the first train of dialled impulses, steps its wipers to the level dialled and searches for a free director. Should all the outlets be engaged, the selector steps its wipers to the 11th position and connects busy tone to the caller.

The *director* accepts the remaining digits dialled by the caller, and translates the code portion into the impulse sequence required to reach a junction to the objective exchange. Having pulsed out this sequence, the numerical portion is pulsed out. The director then releases itself and the A-digit selector. The director also applies release conditions after the expiry of 29—59 seconds after its seizure, in the event of its sequence of operations remaining uncompleted due to any delay in dialling on the part of the calling subscriber. Certain of the directors in each group are arranged to send out a pre-determined translation when seized from the 0 level of an A-digit selector.

The *1st code selector* switches the calling line to the associated A-digit hunter. The wipers are stepped by the first impulse train pulsed out from the director and, on seizure of a free outlet, the pulsing-out loop is extended forward. On completion of pulsing out, the calling line is switched through to the seized outlet and thence to the chain of connexions. The selector also provides a transmission bridge, and "called subscriber held" alarm. When the called subscriber answers, the 1st code selector causes the operation of the calling subscriber's meter and, when the calling subscriber replaces the receiver, releases itself and the other selectors in the circuit.

The *2nd code selector* wipers are stepped by the second train of impulses forming part of the translation pulsed out by the director. The wipers then search for and seize the first free outlet. Busy tone is returned to the caller from the 11th rotary position should all the outlets be engaged.

The *1st and 2nd numerical selectors* function similarly to 2nd and subsequent code selectors, except that they respond to the thousands and hundreds digits respectively.

The *final selector* responds to the tens and units digits sent out from the director, so positioning its wipers on the bank contacts of the called subscriber's line. The selector tests the line and if it is free, connects ringing current and returns ringing tone to the caller. When the called subscriber answers, the ringing is tripped and a supervisory condition returned to the 1st code selector which then effects metering. The final selector provides a transmission bridge. Should the called line be engaged, the selector returns busy tone and flash to the incoming trunk.

Q. 5. Enumerate the principal services provided for by means of the auto-manual switchboard in a non-director area. Describe the arrangements made, in each case, for intercommunication between the manual board and the automatic plant (a) at the main exchange, and (b) at a satellite exchange provided with discriminating selectors. (35).

A. 5. The principal services provided by the auto-manual switchboard in a non-director area are :—

(i) Incoming 0-level lines for calls from subscribers to exchanges outside the multi-exchange area.
(ii) Incoming 0-level lines from selectors terminating dialling-in junction and trunk circuits.
(iii) Incoming lines to Enquiry (level 91).
(iv) Incoming lines to Rural Party Line position (level 93).
(v) Incoming and bothway circuits to and from other manual exchanges.
(vi) Keysender B-positions for order-wire circuits from other manual exchanges.
(vii) Outgoing lines to the automatic plant for calls to local subscribers.
(viii) Outgoing lines to trunk offering final selectors.

In (i), the 0-level circuits from the main exchange 1st selectors pass through relay-sets to provide operator hold conditions. The circuits terminate upon ancillary calling equipment at the auto-manual switchboard. The trunking of the 0-level of subscribers' and coin box lines is segregated to permit the separation of these two classes of traffic at the switchboard, the calling lamps of call office 0-level lines being provided with a red opal.

In (ii), the 0-level traffic is segregated and terminated upon ancillary calling equipment distinctively marked.

For (iii) the lines are terminated upon the Monitor's Desk, whilst for (iv) calling equipment is provided on the position set aside for rural party lines, this provision being necessary because such lines, although allotted a number commencing with the digits 93, are operated on a manual basis.

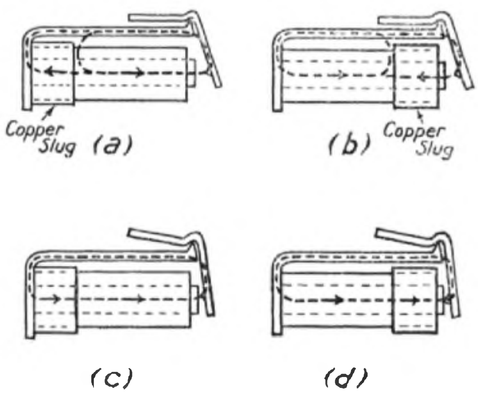
The junction and trunk circuits referred to in (v) are operated on a junction signalling basis and are jack-ended.

The circuits outgoing to local subscribers (vii) are terminated at the main exchange upon penultimate group selectors to reduce the amount of dialling to be done by the operators. At a satellite exchange, the junctions are terminated upon penultimate group selectors having their banks graded with those of the discriminating selectors; where the satellite exchange is too small to warrant this provision, the outgoing lines from the auto-manual switchboard are terminated upon 1st selectors at the main exchange and communication made over the usual channels.

The trunk offering circuits (viii) are terminated upon trunk offering distributors whence access to the trunk offering final selectors is obtained.

Q. 6. Explain fully, with the aid of sketches, how the operating and releasing lags of a relay are affected by fitting a copper slug (a) at the heel end, and (b) at the armature end of the core. How is the rate at which the current rises on closing the circuit of a relay coil modified by the presence of a slug? (35).

A. 6. Sketch (*a*) is a diagrammatic representation of a relay fitted with a copper slug at the heel end. The slug is an annular ring of solid copper and is equivalent to a short-circuited winding having one turn of extremely low resistance.



When the circuit of the coil is first closed, the lines of force of the rising magnetic field induce a current in the slug; this, in turn, gives rise to a magnetic field which, by Lenz's Law, opposes the field due to the coil current. The inductance of the winding is thereby reduced and this leads to a faster growth of current in the coil in the initial stages. The flux due to the coil leaks across the gap between the core and the yoke, and completes the magnetic circuit through the armature air gap.

The effect on the operating lag of the relay is only slight because the more rapid growth of the current in the coil compensates for the added reluctance of the magnetic circuit in the initial stages.

When the coil is disconnected, the main flux immediately collapses, so inducing a current in the slug and giving rise to a magnetic field in the same direction as the main flux, as shown in sketch (*c*). The armature flux is thus prolonged for some little time after the disconnexion of the coil and a long releasing lag is obtained.

With the copper slug at the armature end of the core, as in sketch (*b*), the electrical and magnetic effects are similar to those already described. When the coil is first connected, however, the growth of the flux across the armature air gap is delayed by the presence of the opposing flux due to the induced current in the slug. This delays the operation of the relay until the reaction between the two fields has died down sufficiently to permit sufficient of the coil flux to traverse the air gap and operate the relay. Thus, despite the more rapid growth of the current in the coil, the relay has a long operating lag.

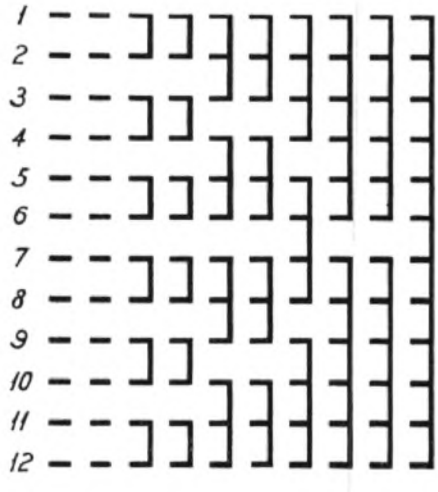
On disconnecting the coil, the effects are the same as with a heel-end slug. The condition is shown in sketch (*d*).

Q. 7. Explain the terms (a) full availability and (b) grading. The busy hour traffic from level 2 of a group of selectors having ten outlets per level, and fitted on 12 shelves, requires 52 trunks. Show, by means of a schematic diagram, a suitable grading for such a case. (35).

A. 7. (*a*) *Full Availability* is the condition under which a selector has access to the whole of the trunks on a given route.

(*b*) *Grading* is (i) the method of connecting level multiples together so that a group of selectors is given access to individual trunks on the early choices, but on the later choices shares access to trunks with other groups; (ii) an arrangement of trunks connected to the banks of selectors by the method of grading.

The diagram shows a suitable grading, providing smooth progression, for the group of selectors specified.



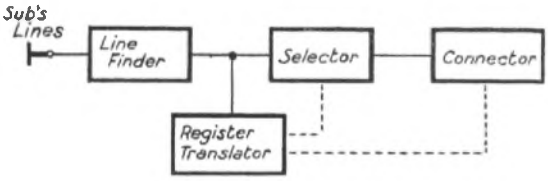
TOTAL OUTLETS = 52

Q. 8. Answer either (a) or (b):—

(a) Explain, with the aid of a diagram, precisely what is meant by "reverted impulse control."

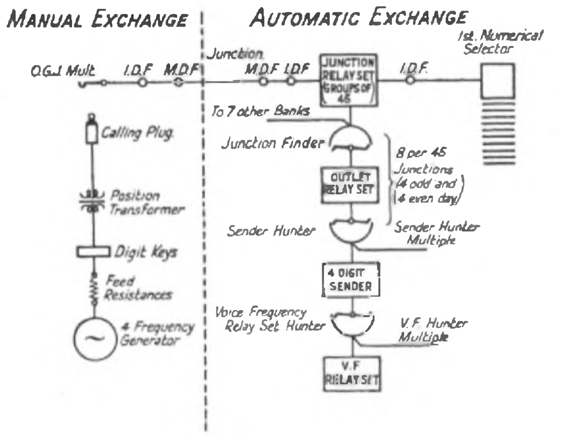
(b) Give an account of some recent development in automatic telephony which you consider to be of outstanding importance. (35).

A. 8. (*a*) In a system of machine switching using a group drive for the selecting mechanisms, it is necessary that the apparatus controlling the setting up of a connexion should be able to determine the precise amount of movement desired. Group drive systems usually employ a non-decimal basis of selection and the function of translating the decimal signals received from the dial is performed by a register-translator associated with each connexion only for the purpose of setting up the call. The selecting mechanisms required for the call are first associated with the driving gear and, then, as the moving parts reach each group of contacts, an impulse is sent back to the controlling register-translator which thereupon records the completion of the movement. When the required amount of movement has taken place, as indicated by the summation of the reverted impulses, the register-translator causes the selector to be dissociated from the driving gear.



By this means, the register-translator, although not moving the selectors directly, is able to control the movement in accordance with the objective number as recorded on the registers. The sketch shows the arrangement of the apparatus, the reverted impulses being received over the dotted lines.

(*b*) *Voice Frequency Keysending.* This method of operating junction and trunk circuits from a manual to an automatic



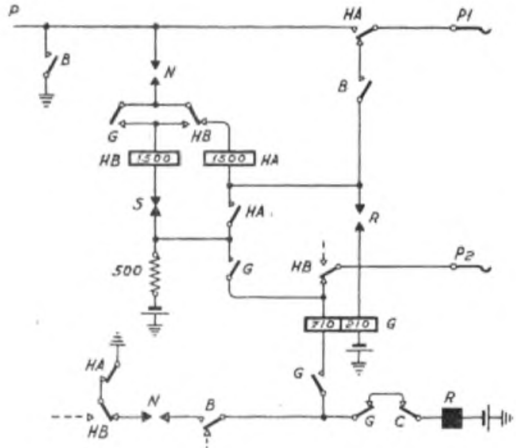
exchange is designed to place complete control of the setting up of the call in the hands of the A-operator. The diagram here reproduced represents the through circuit in schematic form.

At the manual exchange, the A-positions are provided with a digit key strip and a "start and cancel" key in place of order-wire keys. A 4-frequency generator supplies frequencies of 500, 600, 750, and 900 p.p.s. to the A-positions. In making a connexion, the A-operator takes up an outgoing junction, waits for the receipt of a pip-pip tone from the distant end, and then depresses the start key and the requisite digit keys. The resulting combinations of the four frequencies are transmitted over the junction and received by the voice frequency relay-set; the frequency combinations here operate certain relays, and the storage of the digits is transferred to the sender.

At the automatic exchange, the seizure of a junction causes a junction finder to search for and seize the calling junction; the sender hunter also seizes the first free sender. When a sender is seized, the voice frequency relay-set hunter searches for and seizes a free voice frequency relay-set. At this stage a pip-pip tone is sent back over the junction to the A-operator as an indication that the apparatus is ready to receive the voice frequency impulses. These cause the operation of specially tuned relays which, in turn, cause the corresponding digit storage relays in the sender to be operated. The sender then pulses out the Strowger pulses required to step the 2-motion selectors. When pulsing-out is completed, the junction is connected through to the 1st selector and the junction finder, outlet relay-set, etc., are released.

Q. 9. Sketch the circuit arrangements by means of which the private bank contacts of a two-motion group selector of the 200-outlet type are tested until a free outlet is found. Explain how two trunks are tested on each rotary step. (40).

A. 9. The circuit arrangements are shown in the diagram. When the wipers come to rest on the bank contacts of the first two outlets, relay B is in the operated condition, the off-normal springs are changed over, and the rotary interrupter springs are making.



If the first outlet is engaged, the earth on the P1 wiper is extended through contacts of HA and B relays to one side of relay HA; the other side of this relay is also connected to earth through contacts of relays HB and B, and the off-normal springs. Relay G operates *via* the rotary interrupter springs to the earth on the P-wire.

The P2 wiper is now extended to one side of relay HB and if the second outlet is also busy, the earth on the other side of relay HB prevents the operation of this relay. The operation of relay G disconnects the rotary magnet and, when the rotary interrupter springs break, relay G releases. The rotary magnet circuit is thereby closed and the wipers are stepped to the bank contacts of the next two outlets.

Should the P1 wiper encounter a free outlet, relay HA operates in series with relay G which, being a marginal relay, will not operate in series with 1,500 ohms. The incoming trunk is switched to the free outlet and the rotary magnet disconnected.

If the P2 wiper encounters a free outlet—and testing can only take place in the event of the P1 outlet being engaged—the operation of relay G connects the earth from a contact of relay B to one side of relay HB. Since there is now no earth *via* the P2 wiper, relay HB operates from the 500-ohm battery. Relay HA is disconnected; the incoming trunk is switched to the P2 outlet; relay G is disconnected; and the circuit of the rotary magnet is broken.

(To be continued.)

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