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Supplement

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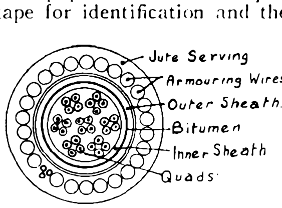
The answers to the examination papers which are given in this Supplement are not claimed to be thoroughly exhaustive and complete. They are, however, accurate so far as they go and are such as might be given within the time allowed by any student capable of securing high marks in the examinations.

IV.—TELEPHONY, INTERMEDIATE; QUESTIONS AND ANSWERS

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

Q. 1. Sketch and describe a cross-section of a submarine cable. Describe a typical repair of a fault in a submarine cable laid in shallow water. (30 marks).

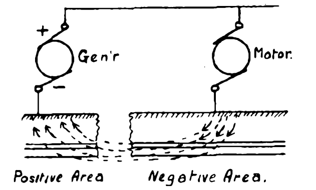
A. 1. The submarine cable shown in the sketch contains 28 solid copper conductors .08 inch in diameter; the cable is continuously loaded, each conductor being wrapped with one layer of iron wire .008 inch in diameter which increases the inductance of the pair circuits to approximately 12.5 mH per naut. Each conductor is insulated with four helical wrappings of paper, the outer paper being coloured for identification purposes, and the insulated conductors are arranged in seven quads, formed by stranding four insulated conductors on a paper centre. Each quad is lapped with a coloured paper tape for identification and the seven quads, with paper wormings filling the interstices, are stranded to form a compact cable. This is lapped with a paper tape and sheathed with two continuous, seamless sheaths of lead-antimony-cadmium alloy, the two sheaths being separated by a coating of bitumen compound. The cable is served with jute to form a bedding for 25 No. 4 S.W.G. and 3 No. 12 S.W.G. stranded armouring wires. A jute serving overall completes the cable.



The position of the fault having been ascertained, the repair ship proceeds to the position indicated. Grapnels are towed in a direction at right angles to the route of the cable and, when the cable is caught, it is hauled inboard. The cable is cut and the end on the good side is sealed and buoyed. The cable on the faulty side is hauled inboard and cut at intervals until the faulty section has been cut away. The end of the cable is then jointed to a spare length of similar cable carried aboard the repair ship and the spare cable paid out over the side. The buoyed end is recovered and jointed to the spare length, and the cable is then lowered into the water.

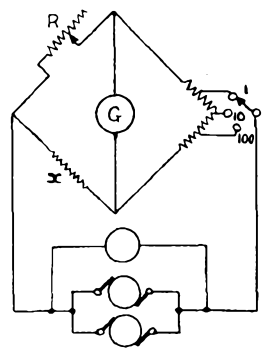
Q. 2. What do you understand by the "positive" and "negative" areas in connexion with electrolysis of cable sheaths? Illustrate your answer by a sketch and explain how electrolytic damage occurs. (30).

A. 2. A positive area is one in which there is a flow of current from the pipes and cable sheaths in the area to the surrounding earth. A negative area is one in which the direction of current flow is from the surrounding earth to the pipes and cable sheaths in the area. (See sketch). It is in positive areas that electrolytic damage occurs to cable sheaths; the current leaving the sheath sets up electrolytic action which causes the lead composing the cable sheath to be decomposed and deposited in the surrounding earth.



Q. 3. Describe a bridge-megger and explain how it is used. (30).

A. 3. The bridge-megger consists of two gear or motor driven generators and a moving double-coil galvanometer together with switches to change from megger to bridge conditions and to provide for ratio arms in the bridge condition. When used as a megger, the resistance to be measured is connected to the line and earth terminals; the generator handle is turned until the clutch is felt to slip and the resistance is read directly from the scale, the range of the instrument being from 1,000 Ω to 20 MΩ.



With the change-over switch at "bridge," the ratio switch is brought into circuit and the two 125-volt generators are connected in parallel. Four terminals at the back of the instrument are used, two being connected to the resistance under test and two to an adjustable resistance. The connexions in these conditions are shown in the sketch. The pressure coil is used as the control coil and holds the needle at "infinity" when no current is flowing in the current coil, which is used as a galvanometer. The unknown resistance is measured by keeping the generators running and adjusting the adjustable resistance and, if necessary, the ratio switch until balance is obtained. The unknown resistance is then the value of the resistance contained in the adjustable box divided by the ratio (1, 10, or 100).

Q. 4. How is wire for overhead construction work tested at the maker's works? (30).

A. 4. Wire for overhead construction work is subjected to wrapping, twisting, tensile and electrical tests, and each coil of wire is examined for any defects such as scale, splits, inequalities, etc. In the *wrapping test,* the wire is bent into a U shape and the bend gripped in a vice. One limb of the U is wrapped round the other limb in a close helix of seven turns. Six of these turns are unwrapped and again wrapped in a close helix in the same direction as before. For the *twisting test,* a short length of the wire is gripped by two vices and an ink line marked on the wire. One vice is then rotated at a speed not greater than one rev. per second, the torsion being shown by the helix made by the ink mark. The minimum number of twists specified, which varies with the gauge of the wire, must be distinctly visible. The *tensile test* is made by means of a lever testing machine. The test sample is placed in the machine which is set at 0.9 of the minimum breaking weight and the sample lifts this. The remainder of the load is added steadily until the test piece breaks. The test samples should withstand these three tests without breaking. For the *electrical* test, the length of the test piece should be not less than 1/30 of a mile. Its resistance is measured by means of a decimal plug bridge, a reflecting galvanometer being used to obtain a balance. The resistance measured is then corrected to 60°F, an accurate thermometer being used to ascertain the temperature of the wire under test.

Q. 5. Describe a coin-collecting box suitable for direct connexions from a call office to an automatic exchange. (35).

A. 5. A multi-coin collecting box suitable for call offices in an automatic exchange area consists essentially of coin slots, coin gauges, and deposit and refund press buttons. The coin slots and gauges are provided to accept penny, sixpenny and shilling coins of correct dimensions and weight, rejected coins being returned through a refund chute. For a local call, the insertion of two pennies causes the depression of a balance arm which, in turn, operates a springset to release the dial for use by the caller. A springset controlled by a coin slot crank arm also operates to render the call office transmitter ineffective. When the called subscriber replies, depression of the A or deposit button deposits the coins in the cash box and releases the transmitter for use by the caller. In the event of no reply or called subscriber engaged conditions, depression of the B or refund button causes the coins to be returned down the refund chute and also operates a springset which disconnects the line, the springset returning to normal under the control of an escapement governor.

For trunk calls, the sixpenny and shilling coin slots are used. Insertion of a coin operates the coin slot crank arm springset, rendering the call office transmitter ineffective and bringing into circuit a small transmitter housed in a gong provided for the detection of silver coins. A sixpence strikes this gong once whilst a shilling strikes both the upper and the lower edges of the gong. Pennies strike a wire gong of distinctive tone. By means of the two gongs and the coin box transmitter, operators are able to check the insertion of the fee demanded.

Q. 6. What is cable balancing and how is it carried out in practice? What modern developments in cable design have affected the problem? (35).

A. 6. The purpose of cable balancing is to reduce to a minimum the interference between each pair and the phantom of a quad, and between the circuits provided in different quads. Cable balancing also provides for the equality of the length distribution of the primary constants of a cable quad.

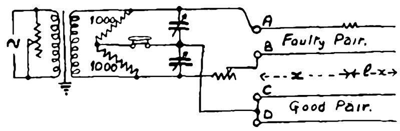
Cable balancing is carried out by measuring the capacity and resistance unbalances of cable lengths and so selecting the joints between adjacent lengths that these unbalances are reduced. Similarly, the mutual electrostatic capacity of pairs to be used for 2-wire repeater working is measured and pairs of high capacity jointed to those of low capacity to secure an even length distribution of mutual capacity. The cross-talk between the side and phantom circuits of loaded cable quads is also measured and reduced by crossed joints between the quads of adjacent lengths of cable.

The use of star quad formation, which results in a more compact cable, and cellulose string wrappings around each conductor to hold it centrally within the paper insulation, has the effect of reducing the capacity unbalances of the quads in cable lengths. This permits more cable lengths to be straight-jointed before capacity balancing becomes necessary.

Q. 7. Describe a typical case of precision testing used in localising an underground fault. (35).

A. 7. The connexions of an A.C. bridge for the location of a resistance unbalance (high resistance fault) in a conductor of a short unloaded length of cable are shown in the sketch. The adjustable resistance across the input of the balanced and screened transformer is for the purpose of adjusting the testing current to a minimum consistent with sensitivity. At the distant end, the four wires of the quad under test are bunched together, and the bridge is balanced by adjusting the resistance R. The magnitude of this resistance, R_c, in the condition of balance is the resistance of the fault.

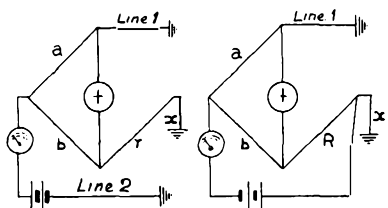
The four wires are then insulated from one another and from earth at the distant end, and the bridge again balanced to silence. In this test, it is necessary to balance the capacity of the line and two adjustable air condensers of 600 or 1,200 $\mu\mu$F are provided for this purpose. If R_0 is the value of the resistance in the adjustable arm required to balance in this test, then $x = l\,(1 - \sqrt{R_0/R_c})$ where x = the distance to the fault from the testing end and l = the length of cable under test.



For success in this test, it is necessary (i) to connect all screens to the cable sheath and to earth, (ii) to obtain a silent balance, and (iii) to make the test from both ends of the cable length.

Q. 8. What are the problems involved in testing the resistance of an earth connexion? Describe a method of making a test. (35).

A. 8. In testing the resistance of an earth connexion, it is necessary to obtain a second independent earth for the test. With normal bridge methods, the tests are usually unreliable owing to the presence of earth currents, *i.e.*, currents set up by electrical disturbances over the surface of the earth and also currents due to the polarization of the earth plates.



(a) (b)

Pomeroy's test for the resistance of an earth connexion is shown in sketches (*a*) and (*b*). In the first test, two lines earthed at the distant end are connected as shown. It is necessary that the value of the current flowing at the earth connexion under test should be approximately the same in both cases and the battery power required for the second test should be adjusted accordingly, the detector in series with the battery serving to check the value of the current flowing in the two tests. The battery connexions are reversed in the second test so that the direction of the current from the earth connexion under test may be the same in both cases.

First test. $a(r + x) = b\mathrm{L}$

Second test. $a\mathrm{R} = b(\mathrm{L} + x)$

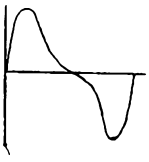
$$\text{whence} \quad x = \frac{a(\mathrm{R} - r)}{a + b}$$

If the proportional arms a and b are equal,

$$x = \frac{\mathrm{R} - r}{2}$$

Q. 9. Describe an oscillograph. Draw a curve similar to that which would be produced by an oscillograph if operated by the resultant of two alternating currents, the first of which is a fundamental sine current and the second a harmonic of twice the fundamental frequency. How is a curve of this type related to the theory of speech transmission? (40).

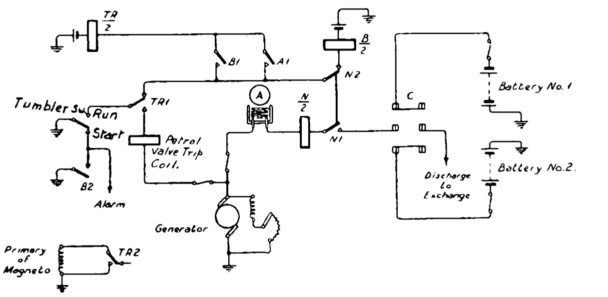
A. 9. An oscillograph consists of one, or more, sensitive mirror galvanometers and an optical system for focussing a ray of light from the light source as a light spot on the mirror, and for focussing the reflected light beam on to the surface of sensitized paper carried on a drum capable of rotation. As an auxiliary means of observation, a frosted screen may receive the reflected light beams, continuity of motion being obtained by viewing the screen through a system of rotating mirrors.



The oscillogram required is shown in the sketch. Any complex wave form can be resolved into a fundamental wave and a number of harmonic waves of increasing frequency. For the faithful reproduction of a complex speech wave, it is necessary that the fundamental and harmonics comprising the wave shall be transmitted without distortion either in phase or amplitude. As this is impracticable, it is necessary to determine how many of the higher harmonics are essential to intelligibility and then so design telephone transmission networks that the essential frequencies are propagated with a minimum of distortion.

Q. 10. Describe the power plant used at a rural automatic exchange where a public power supply is not available. Draw the power circuit and explain the method of charging the cells. (40).

A. 10. The power plant consists of two 50-volt secondary batteries of suitable capacity, a petrol engine and dynamo, and a power panel. The power circuit is shown in the sketch. For charging the cells, the pointer of the ampere-hour meter is set to the reading corresponding to the charge. The tumbler switch is placed in the starting position and the petrol valve opened. The engine is started and, after putting the ammeter switch to "charge," the charge switch and the no load release relay are closed by hand. The tumbler switch is then



placed in the running position and the throttle and the field rheostat, if necessary, adjusted so that the charging current is at the required value. On the completion of the charge, the local contact of the ampere-hour meter closes, operating the trip coil of the circuit breaker. This disconnects the trip coil of the petrol valve, so shutting off the petrol supply, and short circuits the primary winding of the magneto. The petrol engine stops and the no load release relay restores to normal, disconnecting the charged battery from the dynamo.

Q. 11. Give a common-sense meaning to the complete expressions and also to each of the terms used in the following giving illustrations of their practical importance in telephony :—

(*a*) $X = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$

(*b*) $\tan\phi = \frac{\omega L}{R}$

(*c*) $f = \frac{1}{2\pi\sqrt{LC}}$ (40).

A. 11. (*a*). Assuming that X stands for "the unknown quantity," usually written *x*, then X is the impedance of a network possessing resistance, inductance and capacity. R is the resistance between the terminals of the network, in ohms; L is the inductance of the network, in henries; C is the capacity of the network, in farads; and ω is the periodicity of the applied voltage, in radians per second. The quantity $\omega L - \frac{1}{\omega C}$ is usually termed the reactance.

Impedance varies with the frequency and, hence, the degree of attenuation of the components of a complex wave varies, giving rise to distortion.

(*b*). The tangent of the angle of phase difference (ϕ) between the applied voltage and the current is the inductive reactance divided by the resistance, both in ohms.

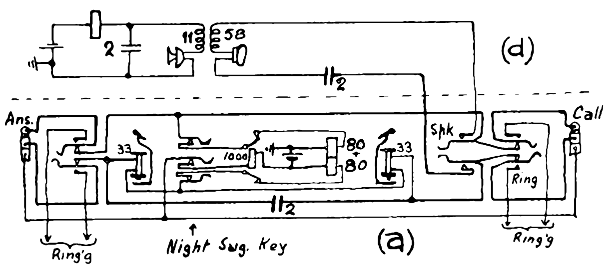
As the components of a complex wave are propagated along a line, they become out of place so introducing phase distortion.

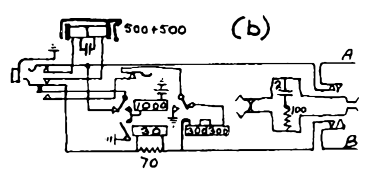
(*c*). The natural frequency of the network, *i.e.*, the frequency at which the inductive and capacitive reactances neutralize one another, is the reciprocal of the square root of the inductance multiplied by the capacity. To express this frequency in periods per second, the quantity 2π is introduced as a divisor.

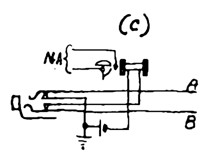
When it is required to separate a given frequency from a band of frequencies, a filter can be designed so that its impedance to the critical frequency is low, but the impedance offered to other frequencies is high.

Q. 12. Draw (a) a cord circuit, (b) an exchange line circuit, (c) an extension circuit, (d) an operator's circuit, of a floor pattern P.B.Ex. switchboard fitted with dialling facilities. (40).

A. 12. See sketches (*a*), (*b*), (*c*) and (*d*) respectively.







V.—TELEGRAPHY, FINAL; QUESTIONS AND ANSWERS

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

Q. 1. A long span of overhead wires carried on 85-ft. extra stout poles has to be erected across a river. Describe the erection of the poles, using a derrick and luff tackle, the staying of the poles and the erection of the wires. (35 *marks*).

A. 1. The derrick consists of a short stiff pole, buried to a depth of at least 3 ft., to which an arm is fixed at the top. Above this arm a sling-chain is placed round the pole, and to this is attached the treble block end of the main tackle. The pulling end of a 3 in. rope is passed through a snatchblock hooked on a sling-chain at the base of the derrick. To prevent this chain from slipping up the derrick when a stress is placed upon the rope, 6 in. spikes are driven into the derrick. A couple of crowbars are driven into the ground and connected so that the rear bar forms a stay upon the forward one. To this a smaller set of luff tackle, with 2 in. rope, is attached by means of another sling-chain. The double end of the luff tackle is secured to the running end of the main set. The derrick is stayed in at least three directions to crowbars driven into the ground. Every hook is moused so as to make it impossible for the chain to jerk out.

The pole is wheeled to the post hole upon the pole cart, and a length of stout timber is placed against the back of the hole for the butt to slide down, and thus avoid it sticking into the ground at the back of the hole. Four sash lines are attached to the upper part of the pole, and are used to resist any tendency towards swinging. Finally, the double block of the main tackle is attached to a sling-chain fixed just above the centre of gravity of the pole.

The pole is then reared by pulling the running end of the luff tackle. When the blocks of this tackle come together, the running end of the main tackle is stoppered by means of a length of rope attached to the snatchblock sling-chain. The luff tackle is then extended and connected to the main rope close to the snatchblock. In this way the pole is gradually erected.

During the progress of erection a man is stationed at the hole with a punner or rammer with which the butt of the pole is eased down the plank at the back of the hole. As there is a heavy downward stress upon the derrick, it should rest upon a substantial block of wood when the ground is at all soft.

After erection of the pole, the hole is filled in and the earth well consolidated by means of a punner. The stays are next erected and, by virtue of the situation of the poles, two side stays on opposite sides of the pole and longitudinal stays will be required. The four stays are made off on the pole and their respective stay bows attached to stay rods and blocks buried in the ground.

The wires are erected by the endless sashline method, a double length of sashline being used to draw the wires over one at a time from one side of the river to the other.

Q. 2. Describe in detail the erection of an aerial cable along a road route, dealing particularly with the erection of the suspending wire, the fitting of the cable suspenders and the erection of the cable. (35).

A. 2. Each pole on the route is fitted with a supporting bracket, any additional stays required being fitted at the same time. The suspending wire is then run out and tensioned, the clamps of the supporting brackets being tightened to grip the wire firmly. The tension is usually checked by means of an oscillation test. True terminations are made at the beginning and end of the route, and at all sharp angles; false terminations are made at road and railway crossings and at all poles provided with line stays.

The cable suspenders are fitted to the wire at intervals of 20 inches by a man riding in a bosun's chair along the span of wire. The draw rope, to be used for pulling the cable into place, is passed through the rings as they are fitted.

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 to prevent fouling the cable rings. The cable is guided into position for entering the first ring by means of blocks, suitably supported. Drawing-in may be performed either by a high-speed winch or by a motor lorry, a speed of 3—4 m.p.h. being quite practicable. After it has been drawn in, the cable is supported on either side of the suspension brackets at each pole by means of marline ties.

Q. 3. Discuss briefly, from the point of view of transmission efficiency and cross-talk, the effects of the various electrical characteristics of a cable to be used for phantom working. Give a description of multiple twin and star quad paper core underground cables, comparing the relative merits of the two types. (30).

A. 3. The transmission efficiency decreases with increase of resistance, whilst the presence of leakance reduces the amplitude of the current without causing distortion. The presence of capacity reduces the transmission efficiency and produces distortion; the presence of inductance balances this distortion to some degree.

The resistance, leakance, inductance and capacity must be separately balanced to prevent cross-talk between circuits. The first three are sufficiently balanced by careful manufacture of the cable, but the capacity unbalances of quads need to be reduced by cross jointing during the laying of the cable.

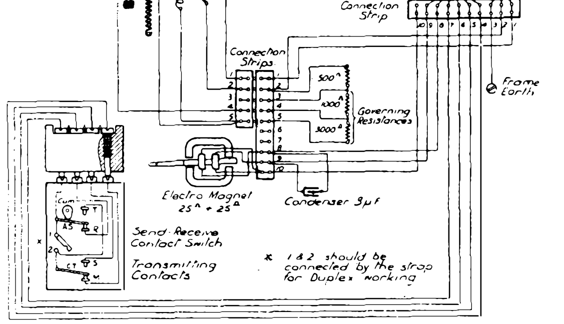
In a multiple twin cable, each quad is made up of two twisted pairs twisted together; in the star quad cable, the four wires of a quad are twisted together about a common axis. Due to the closer arrangement of the wires in a star quad cable, more pairs can be accommodated in a given diameter; for the same reason, the capacity is also higher, being .066 μF per mile compared with .0625 μF per mile for multiple twin cable. Multiple twin cables, however, can be used for phantom working whereas, owing to the high phantom-to-side capacity unbalance, the phantoms of star quad cables are unsuitable for telephone channels, although they can be used for teleprinter working or as signalling channels using 17 p.p.s. ringing current.

Q. 4. Describe in detail various methods of terminating underground cables led into offices, stating the conditions under which each is employed. Which method is likely to give the best insulation? (30).

A. 4. For local cables, enamelled silk and wool terminating cable is connected to the street cable and terminated upon fuse mountings which may be of the ordinary glass-tube fuse type or special high insulation fuse mountings using clip-in type cartridge fuses. For junction and trunk cables, the wires are connected to a pothead of vulcanized-indiarubber-insulated wires laid up in quad formation and terminated upon high insulation fuse mountings or upon trunk test tablets which consist of pairs of U-links set in a bakelite strip. The best insulation is likely to be obtained with the high insulation fuse mounting which is not as susceptible to humidity conditions as the trunk test tablets.

Q. 5. Make a skeleton diagram of the internal connexions of a Creed Combined Transmitter and Tape Printer (Teleprinter No. 3A). When a Teleprinter No. 3A is replaced on a duplex circuit, explain the procedure for starting up the new instrument and proving that it is working satisfactorily. (40).

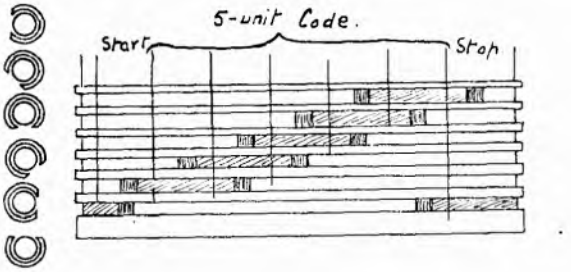
A. 5. The switches are placed in the correct positions for teleprinter working and the movement of the working parts of the teleprinter is tried by hand, by turning the motor spindle slowly by means of the cover of the governor. If quite free, the motor is switched on and the speed checked by the stroboscope. As a test for correctness of working, the letters RY are sent repeatedly and then the test sentence " + The



quick brown fox jumps over the lazy dog + ." Assuming that the duplex circuit is already balanced, the sending test is made first in one direction and then in the other, and finally in both directions simultaneously.

Q. 6. Sketch and explain the function of the transmitting cam-sleeve used in the Creed Combined Transmitter and Tape Printer (Teleprinter No. 3A). Show in section, and in their relative angular positions, the " start and stop " cam, the " code " cams and the " re-setting " cam. Draw a developed view showing the cam surfaces laid out flat. Mark the positions corresponding to the various signals transmitted during one complete revolution of the cam-sleeve. (35).

A. 6. The function of the transmitting cam-sleeve is to control the transmission of the start signal, the five-unit code signals, and the stop signal and then to reset the combination bars in readiness for the next character. In addition, an



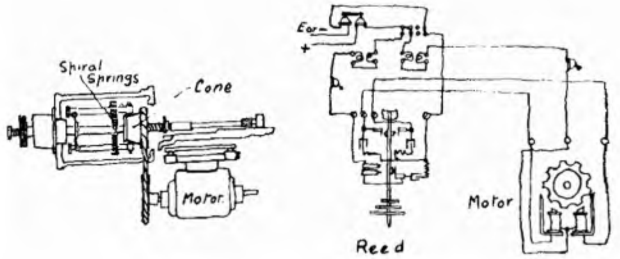
automatic send-receive switch for use in simplex working is controlled by the cam-sleeve.

Q. 7. Explain what is meant by the terms " Synchronous Speed " and " Phase Relationship " as applied to the running of distributors in a Baudot multiplex system. Sketch and describe one *of the following types of distributor drive :—*

(a) A direct motor drive using a Doignon-Mendonça-D'Oliveira governor.

(b) A vibrating reed and phonic wheel drive. (40).

A. 7. The synchronous speed is that at which two distributors in a Baudot multiplex system are running at the same



(*a*) (*b*)

speed. The phase relationship is the angular displacement between the brushes at the correcting and corrected stations required to ensure correct reception of signals.

Q. 8. Discuss briefly the various factors such as type of apparatus, speed of working, and line characteristics which tend to limit the distance over which reliable telegraph working is practicable. Explain how the use of repeaters extends the range. What is a regenerative repeater and what advantages does it give over an ordinary repeater? (40).

A. 8. In general, the distance over which reliable telegraph working is practicable depends upon the sensitivity of the receiving apparatus, the signalling speed, and the product of the capacity (C) and resistance (R) of the line. The more sensitive the receiving apparatus, the greater the distance. The higher the speed of working, the less the distance over which communication is reliable. The higher the CR of the circuit, the less the reliability.

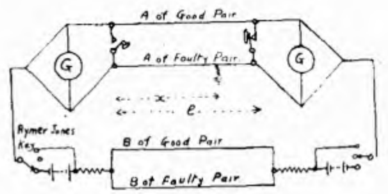
Repeaters are inserted in telegraph circuits to receive the transmitted signals and re-transmit them to the distant end of the circuit. By this means, a long telegraph circuit becomes the equivalent of two or more shorter circuits.

A regenerative repeater is one which receives signals distorted by their passage along the line and re-transmits them without distortion. In an ordinary repeater, the distortion is cumulative and the repeater itself may introduce distortion. In a circuit with regenerative repeaters, the amount of distortion is that of one repeater section of the line only.

Q. 9. Describe the Varley Loop Test for localising an earth fault on a line. Draw a diagram of a precision Varley test suitable for locating a low insulation fault in a cable, when the insulation resistances of the good and bad wires are comparable with the normal insulation. State the formula to be used in this precision test when all the wires are of equal gauge and Varley tests are made from both ends. Describe the precision apparatus employed and the precautions to be taken in carrying out the test. (40).

A. 9. The pair of wires containing the faulty one is looped at the distant end and the resistance (L) of the loop is measured by Wheatstone bridge. The testing battery is then earthed and connected to the centre point of the ratio arms; the bridge is again balanced and the distance to the fault is then $x = (L - R)/2$ where R is the resistance required to balance in the second test and x is the resistance to the fault. The connexions for a precision Varley test are shown in the sketch. The formula to be used is $x = l\left(\frac{R_1}{R + R_1}\right)$ where R and R_1 are the balancing resistances required at each end.

The galvanometer is of the reflecting type and is associated with a lamp and transparent scale. The adjustable arm of the bridge is a 4-dial decade resistance box, whilst the ratio arms each have values of 10, 100, 1,000 and 10,000 ohms. A universal shunt—multiplying powers 1 to 10,000—is used with the galvanometer. A high insulation short circuiting key, a Rymer Jones charge and discharge key and a testing battery of 350 small dry cells complete the equipment.



Instead of an earth, two wires are connected to the centre point of the bridge, as shown in the sketch, to overcome the effect of variations in the potential of the Earth along the route. In making the test, the batteries at both ends of the line are connected by closing the charge keys and opening the short-circuiting keys. The cable is allowed to charge—in some cases, this takes as long as 2 hours—and then tests are taken from both ends. The interval between tests should be as small as possible and a series of tests should be made. When changing over from one end to the other the battery should be switched on at one end before being disconnected at the other. To prevent the effect of leakage currents in the apparatus, the apparatus and batteries are placed upon blocks of paraffin wax and connecting leads are of V.I.R. covered wire with 6 inches of the ends thoroughly waxed and left unhandled subsequently.

Q. 10. Explain the following terms used in connexion with secondary cell batteries :—

Ampere-hour capacity at 9-hour rate.

Ampere-hour efficiency at 9-hour rate.

Watt-hour efficiency at 9-hour rate.

If the capacity of a secondary cell is low, explain how to determine, by means of a " Cadmium Electrode " test, whether the positive or negative plates are defective. (35).

A. 10. The ampere-hour capacity at the 9-hour rate is the quantity of electricity which a cell is capable of delivering when discharged over a specified range of specific gravity in a period of 9 hours.

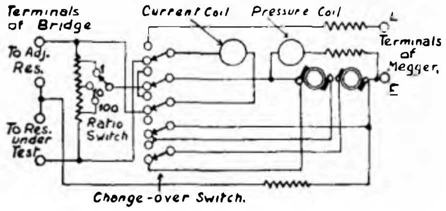
The ampere-hour efficiency at the 9-hour rate is the ratio of the current in amperes multiplied by the time in hours for charge and discharge, the discharge being subject to the conditions specified in the preceding paragraph.

The watt-hour efficiency at the 9-hour rate is the ratio of the energies involved in charge and discharge and is the ratio of the ampere-hours multiplied by the average voltage for charge and discharge under the conditions of the first paragraph.

The cadmium electrode is used to measure the voltage between the positive or negative plates and the cadmium electrode. On open circuit, a cell giving, say, 2.05 volts will show a voltage of about + 2.2 between cadmium and positive, and about − 0.15 volt between cadmium and negative, the cadmium being negative to the negative group. The algebraic sum of these two voltages is the terminal voltage of the cell. At the end of discharge, the cadmium to positive voltage is about + 2.05 volts, whilst the cadmium to negative voltage is about − 0.2 volt, the terminal voltage of the cell being about 1.85 volts. Whether the positive or negative plates are defective in a cell of low capacity is shown by the failure of the voltage figure obtained on test to reach the figures quoted.

Q. 11. Draw a diagram of the internal connexions of a bridge megger and explain how this instrument is used to measure (a) an insulation resistance of 10 megohms, (b) a resistance of 35.23 ohms. (30).

A. 11. (*a*). The insulation resistance under test is connected to the line and earth terminals of the bridge megger. With



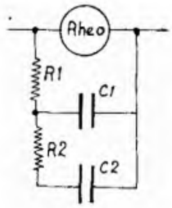
the switch to " megger," the handle is turned until the clutch is felt to slip, when the value of the insulation resistance is measured directly from the scale.

(*b*). With the switch to " bridge,' the resistance under test is connected to the terminals at the rear of the instrument. The ratio switch is turned to " 100 " and whilst the generator handle is turned, the 4-dial decade resistance box is adjusted until the needle of the megger remains on the " infinity " mark. The resistance contained in the box, 3,523 ohms, divided by the ratio in use, 100, gives the value of the resistance under test.

Q. 12. Describe the construction of a telegraph condenser. What are the relative merits of waxed paper and mica dielectrics in condenser construction? Draw a diagram of the compensation circuit for a long underground duplex circuit, giving the reasons for the particular arrangement adopted. (30).

A. 12. The tinfoil paper for making condensers is prepared by finely-divided tin upon one side of a thin body paper. The tin paste coating is subjected to a calendering process which consolidates and burnishes the particles of tin, and firmly fixes the metal to the paper; this process also renders the tin coating practically continuous, so improving its electrical conductance.

The process of making a condenser consists in winding into the form of a flat roll two strips of this paper, each strip being of sufficient length to produce the capacity desired. A strip of plain paper is interleaved between the tinfoil strips to obtain very high insulation and to increase the dielectric strength. For the external connexions, two strips of thin metal foil are laid one between each tinfoil surface and the interleaving paper.



The rolled strips are subjected to desiccation under vacuum and, when thoroughly dry, are soaked in paraffin wax for some hours. The vacuum is then broken, the excess wax drained off, and the plates put under considerable pressure until cold. After being tested for capacity and insulation, the plates are assembled in protecting cases and the metal foil lugs connected to the external terminals.

The specific capacity of mica is more than twice that of paraffined paper (2.8), so that for a condenser of given capacity less than half the surface area would be required with mica as the dielectric. Mica, however, is costly and this consideration prohibits its use for any but standard condensers. Moreover, paraffined paper condensers have the property of sealing ruptures due to discharges occurring across the dielectric, the heat from the spark burning away the tinfoil around the hole, so preventing a recurrence; with mica, a puncture of this nature would necessitate replacement of the mica affected.

In the compensation circuit for a long underground duplex circuit, it is necessary to simulate the charging of the capacity of the line. In the sketch, R1 is the resistance introduced for the purpose of lengthening the time of charge of the condensers, whilst R2 further increases the time taken to charge the condenser C2.

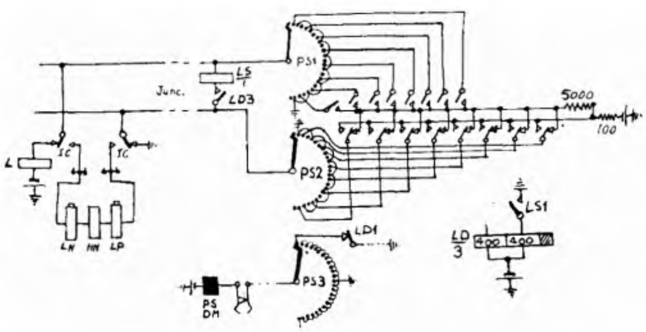
VI.—TELEPHONY, FINAL; SECTION 1, AUTOMATIC TELEPHONY. QUESTIONS AND ANSWERS

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

Q. 1. What is a Coder? Draw the pulsing-out circuit and explain how it is controlled. (30 marks).

A. 1. A coder is an apparatus for storing groups of step-by-step impulses at an automatic exchange and discharging groups of current impulses which are designed in such a way that the time needed to transmit them to a manual exchange when a position is available is a minimum.

The pulsing-out circuit is shown in the sketch. It is con-



trolled by relay LS which, in turn, controls relay LD. So long as battery and earth are connected to the junction at the manual exchange, relay LS remains operated; relay LD is also operated. When the call indicator apparatus is ready to receive the call, the battery and earth are removed and substituted by the three decoding relays. Relay LS now releases and, after an interval, relay LD releases and closes the driving circuit of the pulse send switch.

Q. 2. How is the translation on a director carried out? What advantages are derived from the use of directors? (30).

A. 2. Translation is carried out by jumpering the bank contacts of the BC-selector to the appropriate digit terminals on the translation field, the unused bank contacts being connected to the D.C.O. terminals.

The use of directors permits the trunking scheme for a multi-office area to be divorced from the numbering scheme. This makes it possible to route calls to the objective exchange over the most economical route and also to change the route at will. Further, the use of tandem exchanges permits the use of large groups of junctions for all calls from exchanges not having direct junctions to the objective exchange. In turn, the traffic-carrying efficiency of the junctions is increased.

Q. 3. Describe briefly (a) a 2-step relay, (b) a shunt field relay, and (c) a polarized relay, and give instances of their use. (30).

A. 3. (*a*). A 2-step relay is a relay with two groups of contact springs, one group of which is operated by an initial small magnetic flux—and both groups by a subsequent greater magnetic flux. The first group is said to be *x*-operated.

Relay F, the ringing trip relay, is of the 2-step type, its *x* contact closing a circuit for the second coil of the relay, so causing the full operation of the relay.

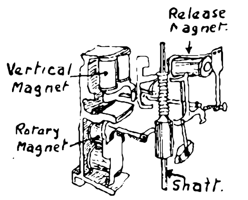
(*b*). A shunt field relay is one with two windings and a closed magnetic circuit. Normally the direction of the current in the windings confines the magnetic flux to the closed magnetic circuit, but when the current is reversed in one winding the flux is caused to take a shunt path which effects the operation of the relay.

The supervisory relays in auto-manual switchboard cord circuits are of the shunt field type to enable them to respond to the battery reversals on the T and R wires, whereby supervision of the call is given.

(*c*). A polarized relay is one the operation of which depends upon the direction as well as upon the magnitude of the current in the controlling circuit. A typical polarized relay used in the decoding relay group is polarized by means of a small permanent magnet included in the magnetic circuit of the relay.

Q. 4. *Draw a sketch of the mechanical system of a 2-motion selector and comment on the adjustments required.* (30).

A. 4. The shaft should be free in its bearings and should have very little lateral movement. The vertical pawl spring should be correctly tensioned to ensure that the pawl strikes the teeth of the vertical ratchet. Both vertical and rotary armatures should strike both magnet cores simultaneously to ensure that the detent movement is smooth. To prevent excessive wear of the teeth of the vertical detent, the vertical pawl should snap cleanly into the vertical notches without causing any fall in the shaft when the vertical armature restores. The rotary armature back stop must be so adjusted that, when the armature is normal, the hub can rotate on release without risk of striking the pawl. The stationary detent should ride clear of the sides of the vertical slot to prevent it from interfering with the movement of the shaft.



Q. 5. *Describe the facilities afforded by a test desk at an automatic exchange.* (35).

A. 5. The test desk at an automatic exchange provides facilities for reaching any one of the subs' lines, by means of test distributors and test final selectors, and of carrying out exhaustive electrical tests thereon. In addition, lines to the test jack frame, where the outgoing junctions are led through for testing purposes, are provided ; together with test and plugging-up circuits for accommodating faulty lines; temporary terminations to accommodate subs' lines under construction ; and, at exchanges with satellite exchanges, alarm extension equipment.

A dial speed tester, and voltmeter form the testing instruments and they are controlled from the test cord circuit. A sounder is also provided to facilitate the identification of wires.

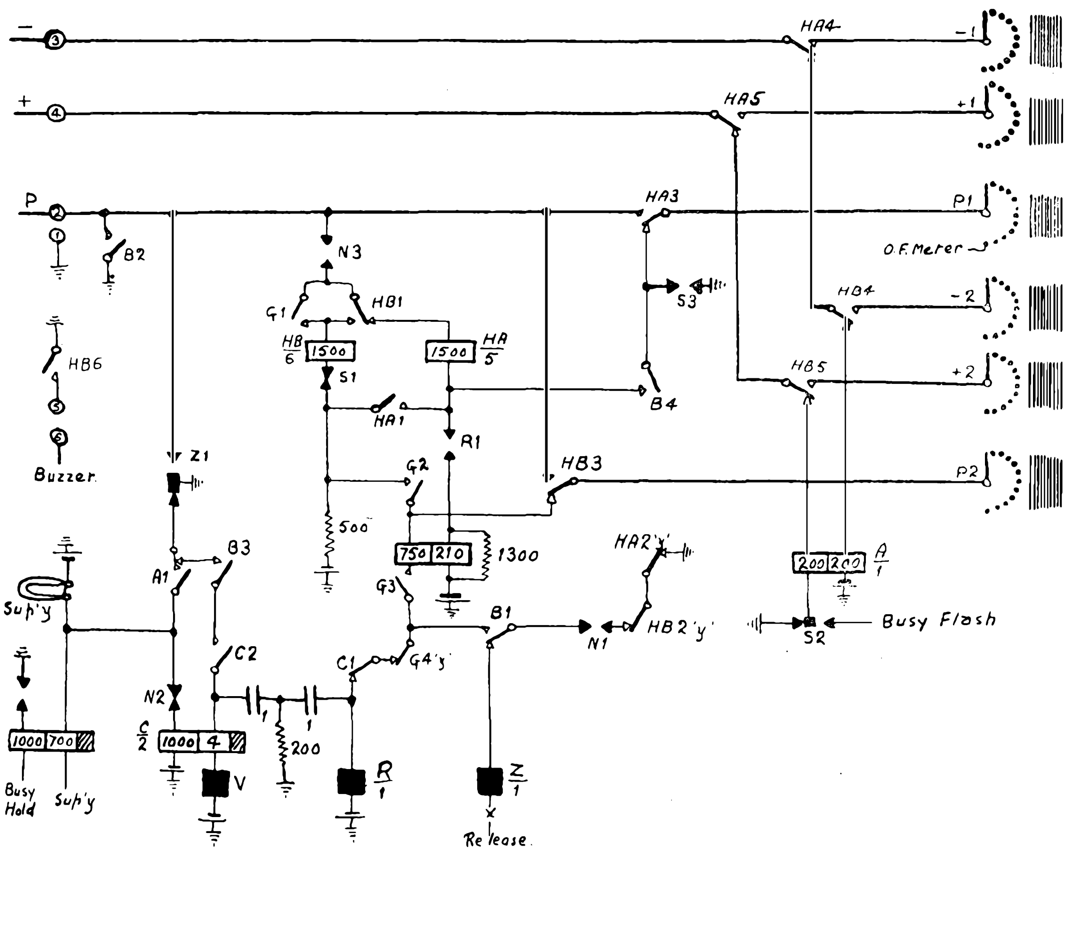
Q. 6. *How is 4-frequency signalling used to facilitate the operation of calls between exchanges?* (35).

A. 6. In 4-frequency keysending, frequencies of 500, 600, 750 and 900 p.p.s. are provided at manual exchanges and, by means of a digit key strip, single frequencies or combinations of the four frequencies can be sent to the junction line. At the receiving automatic exchange, the frequencies pass through four tuned relays ; of these, the particular relays operated are those which respond to the frequencies transmitted. The operation of the relay combination causes the storage in a sender of the digit corresponding to the key depressed at the manual exchange. As the tuned relays may be operated by transmitter current, a start signal is transmitted prior to the digits and this effects the restoration of any storage relays which may have been operated by extraneous currents.

4-frequency signalling, which provides 15 different combinations, may also be used for the provision of supervisory facilities over long repeatered trunk circuits.

Q. 7. *Draw a group selector circuit of a modern type. Point out the significance of any improvement contained in the circuit.* (35).

A. 7. The required diagram is shown in the sketch. The circuit provides for 20 outgoing trunks on each level. The rotary make-drive principle is used, thus permitting the two trunks upon which the wipers are standing to be tested in a definite order, for the primary choice must be engaged before the secondary choice can be tested. As only one spark quench circuit can be in use at one time, a common 200Ω spool is used. During release of the selector, it is busied by the release magnet springs, Z1.



Q. 8. Describe the system of observing service adopted in an automatic exchange area and explain how the statistics differ from those in a manual area. (35).

A. 8. Selected subscribers' lines are intercepted at the main distribution frame and extended to tapping equipment associated with a junction outgoing to the centralized observation switchboard, a telephonic repeater being included in the outgoing junction relay-set. At the observation switchboard, the junctions are terminated upon relay groups and are associated with the observation equipment by means of junction finders controlled by a position allotter. Each position has number display equipment, so that the number dialled by the observed subscriber can be seen, and supervisory lamps to indicate the different stages of a call.

The statistics differ from those in a manual area in giving data as to the manner of dialling, the time taken by the called sub. to reply, the time for which busy or N.U. tones were held by a calling sub., and, in a Director area, the time taken for the completion of calls over C.C.I. equipment at the manual exchanges.

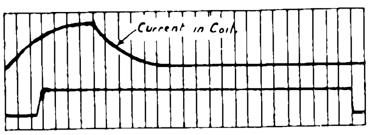
Q. 9. How does spring-load affect the design of a relay? What are the characteristics of the magnetic circuit of a good impulsing relay? (40).

A. 9. The basic operate ampere-turns upon which the design of a relay is based depends upon the downward pressure exerted on the armature by the spring assembly. This pressure, in turn, depends upon the number and type of springsets in the spring pile, the thickness of the springs, and their gauging.

The operating and releasing lags of relays used for impulsing must be short so as to reduce the amount of impulse distortion occuring under the wide range of circuit conditions in which the relays are required to be used. The armature, therefore, has a short travel to obtain fast operation. The effects of residual magnetism are minimized by the introduction of air gaps in the magnetic circuit, either at the hinge of a pin-type armature or by means of a brass washer inserted between the core and the heel end of the yoke. A large residual screw adjustment, of the order of 9 mils, is specified to obtain a considerable gap between the armature and core when the relay is operated.

Q. 10. How are slugs, short-cricuited windings and spring tension used to affect the time of operation of a relay? Draw a curve showing typical operating lags and releasing lags of relays as indicated by an oscillograph. (40).

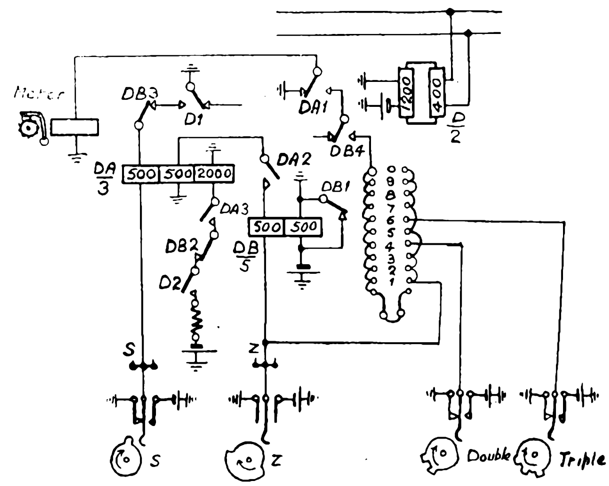
A. 10. To increase the operating time of a relay, the spring tension is increased so that the current in the coil has to rise to a greater value to cause the operation of the relay. A copper slug fitted on the armature end of the core also increases the operating time of a relay; the current induced in the slug by the rising magnetic field to be set up in opposition to the main field; the growth of the flux through the armature is therefore delayed. A short-circuited winding produces the same effect and has the advantage that, by spitable circuit arrangements, the short circuit may be removed and the relay made fast-operating at will.



The required curve is shown in the sketch.

Q. 11. How is double-metering effected in a Director Area? (40).

A. 11. The method of effecting double and triple metering in a Director Area is shown in the sketch. A vertical marking bank on the 1st code selector provides meter discrimination conditions; in the example shown, levels 1, 2, 3, 5, 7, 8, 9,



and 0 are used for single metering, level 4 for double metering and level 6 for triple metering. Thus calls to the second unit fee area are routed over level 4 and calls to the third unit fee area over level 6.

Q. 12. Give the modified form of Ohm's Law that is applicable to calculations of the instantaneous value of an impulsing current. If 50 volts be applied to a relay having an inductance of 750 millihenries and a resistance of 500 ohms, calculate the time in milliseconds needed for the current to rise to 50 milliamperes. (40).

A. 12.

$$I = \frac{E}{R}\left(1 - e^{-\frac{Rt}{L}}\right)$$

where I = the current in amperes.

E = the electro-motive force in volts.

R = the resistance in ohms.

L = the inductance of the circuit.

t = the time, in seconds, from the closing of the circuit.

and $e = 2.71828 \ldots$

$$.05 = \frac{50}{500}\left(1 - e^{-\frac{500}{.75}t}\right)$$

$$0.5 = 1 - e^{-\frac{500}{.75}t}$$

$$e^{-666t} = 0.5$$

From Tables:

$666t = 0.694 \quad \therefore \; t = .001 \ldots$ second.

$\simeq$ 1 millisecond.

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