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VI. TELEPHONY, FINAL; SECTION 2, TRANSMISSION. QUESTIONS AND ANSWERS.

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

Q. 11. Circuits between zone centres are lined up to zero-transmission equivalent. Explain how this efficiency is obtained and maintained. Explain how the correction of the change of attenuation with frequency is effected. In what circumstances are echo suppressors fitted? (40).

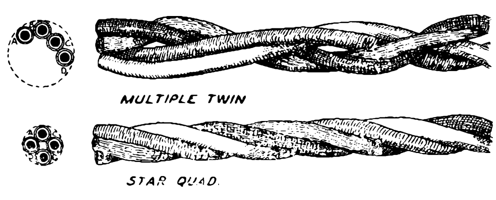
A. 11. Zero transmission equivalent is obtained by the use of 4-wire repeater circuits kept stabe in the idle condition by 600-ohm terminating impedances which are switched out of circuit when the line is taken up for a call. Echo suppressors are usually associated with zero circuits, except in the case of the shorter lines which, even when connected in tandem, are reasonably free from echo defects. The British Post Office uses underground cable circuits, which are substantially free from changes in conductor resistance. The line transmission equivalent is therefore constant except for seasonal mean temperature effects on the longer lines, which are corrected periodically by the readjustment of repeater gains. Circuits are maintained at zero overall transmission equivalent by periodical overall transmission testing, gain readjustments being made from time to time to compensate for change in the repeater gains due to ageing of valves.

An equalizing network is associated with the input transformer, or intervalve transformer, of 4-wire repeaters used on coil-loaded cable circuits: the former is the arrangement usually adopted, a rising gain characteristic being obtained to annul the rising loss characteristic of the line over the range of frequencies from approximately 0.6 to 0.8 of the cut-off frequency of the line. The input type of equalizer depends for its action upon the effective capacitance over the above frequency range of the transformer input due to the self-capacitance of the secondary winding. A condenser of small capacitance is also connected in parallel with the secondary. A tapped inductance coil, shunted in part by a condenser to control the effective inductance of the coil, is connected in series with the primary of the transformer to give series resonance with the effective capacitance of the primary at a frequency equal approximately to that of the line. As the frequency is increased and the resonant condition is approached, the voltage across the two parts of the series resonant circuit is greater than the voltage applied to the whole, and the voltage across the transformer secondary therefore increases, giving the rising characteristic; the slope of this characteristic may be regulated by the condenser across the tapped inductance.

Echo suppressors are used whenever the transmission time is long enough to give rise to trouble due to echo effects. With the system of deviated routing adopted in connexion with Demand Trunk working, there is a possibility of several trunk circuits being connected together in which event their combined transmission time might be such as to cause trouble from echo effects. Accordingly, it is the practice to fit echo suppressors to comparatively short lines in order to prevent this trouble.

Q. 12. Give a sketch to show the arrangement of cable conductors in (a) star quad, and (b) multiple twin formation. Describe a method of measuring cross-talk. State the circumstances in which cross-talk measurements require corrections. (40).

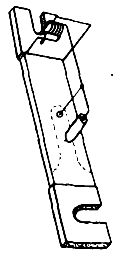
A. 12. Cross-talk can be measured by a potentiometer arrangement in which a source of constant p.d. of mixed frequency, to give an approximation to speech conditions, is connected across a resistance and also to the disturbing circuit. A receiver may be connected either to the disturbed circuit or to the slider of the potentiometer. The effect of this arrangement is that a known fraction of the disturbing voltage may be tapped off and connected to the receiver. A two-way switch

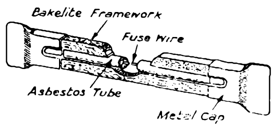


effects the necessary changes in the connexion of the receiver, and the slider is adjusted until the noise heard in both positions of the receiver is judged to be the same. In practice, the potentiometer is graduated either in decibels or in millionths of the disturbing voltage.

When the disturbed circuit has not the same impedance as the disturbing circuit, the ratio of the voltages does not represent a true power ratio and in these circumstances a correction to the cross-talk readings will be necessary.

a small coloured bead which is carried forward out of alignment with the other springs of adjacent fuses when the fuse is blown; the back spring, when thus released, connects the live bus bar to an alarm circuit, thus calling attention to the failure.





(*c*) The flat type of fuse consists of an asbestos tube which contains the fuse wire; this tube is carried by a light bakelite framework, on each end of which a metal cap with a knife edge is pressed.

Q. 12. *Give a brief explanation of the following terms:— (a) duplex working, (b) two-line simplex, (c) desiccation, (d) combiner arm, (e) screened conductor, (f) microfarad, (g) self-induction.* (40).

A. 12. (*a*) *Duplex working* is the name given to a multiple-way system in which the circuit is arranged for simultaneous operation in opposite directions over a single circuit.

(*b*) *Two-line simplex* is the name given to the operation of a teleprinter circuit in which a metallic loop is used to obviate the need for a battery at the Out station.

(*c*) *Desiccation* is the process whereby moisture in a paper core cable is removed by the application of dry air or carbonic anhydride to the cable under pressure.

(*d*) *A combiner arm* is a galvanized iron brace used to brace the arms together in cases where wooden arm exceeding 48 inches in length are fitted on single poles.

(*e*) *A screened conductor* is a paper-insulated conductor surrounded by a helical wrapping of copper tape, which acts as an electrostatic screen and prevents interference with other circuits in the cable by the circuit carried on the screened conductor.

(*f*) *A microfarad* is the practical unit of capacity and is one millionth of a farad.

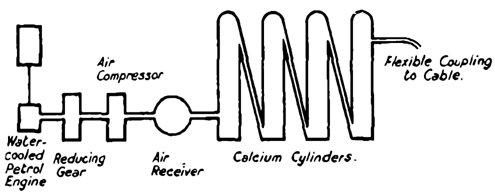
(*g*) *Self induction* is the name given to the generation of an E.M.F. in a circuit due to changes in the strength of the current flowing in that circuit.

VIII. TELEGRAPHY, FINAL; QUESTIONS AND ANSWERS.

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

Q. 1. *Describe with the aid of sketches a petrol-driven desiccator.* (30 *marks*).

A. 1. The petrol-driven desiccator comprises a water-cooled petrol motor, air compressor, air receiver, four cast-iron cylinders to contain calcium chloride bags, petrol tank, water tank, and the necessary gearing and connexions, the whole being mounted on a four-wheeled truck. Both sets of wheels are provided with square section spiral springs, and also with bolts or jacks to remove the weight of the machinery from the springs when the engine is running. A canopy is provided to protect the plant from the weather.



The normal speed of the engine is 700 r.p.m. and of the compressor 300 r.p.m.; the capacity of the compressor at this speed is 10 cubic feet of free air per minute to a pressure of 30 lb. per square inch. The engine is provided with a delicate governor which prevents racing when the load is removed.

The air from the compressor is passed into the air receiver, where it is cooled. It then passes through the four desiccating cylinders in turn and, in passing over the calcium contained in cheese cloth bags in these cylinders, a large part of the moisture contained in the air is absorbed by the calcium. The dried air passes on through a flexible connecting pipe into the cable being desiccated. The calcium bags each hold about 4 lb. of calcium chloride, which is renewed from time to time as required by the hygrometric condition of the air and the temperature.

Q. 2. *Describe the process of drawing in cables by means of a motor winch. Give a brief description of a motor winch.* (35).

A. 2. The pulling in rope, usually of 3 inches circumference, is drawn through the length of duct either by means of the galvanized iron wire left in the duct when it was laid or by means of sweeps' rods previously pushed through the duct. The rope is joined to a mandrel, a circular brush about 12 inches long, and a test piece of cable approximately 6 feet in length; a second length of rope is fixed to the test cable and the whole train is pulled through the length of duct. The test cable is then examined for signs of damage, any defects found being remedied before the new length of cable is drawn in.

The cable drum is placed adjacent to the jointing point at the end of the length remote from the motor winch, in such a position that the cable is paid into the duct in one continuous curve. The cable end is dressed and fitted with a cable grip to which the pulling in rope is fixed by means of a keystone link. At the other end of the length, the rope is passed through snatchblocks, placed to give clearance, and round the roller on the frame of the motor winch and given three or four turns round the warping drum. The motor having been started up, tension is put on the loose end of the pulling in rope, causing it to grip the warping drum which is revolving slowly. Hand signalling between the two ends of the length serves to enable the time and speed of pulling in to be regulated. To cease hauling, it is only necessary to slack off the loose end of the pulling in rope, which then slips on the warping drum.

As the cable enters the duct, it is coated with petroleum jelly which not only acts as a lubricant but also serves to protect the lead sheath from corrosive action.

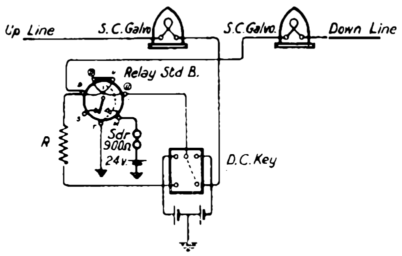
The motor winch consists of a two-cylinder, water-cooled petrol engine, petrol tank, water tank, reducing gear, and a warping drum mounted vertically and having two portions, one for low rates of pulling in and the other for higher rates. The whole is mounted on a rubber-tyred, four-wheeled truck. The engine is fitted with a governor to prevent racing when the load is removed. A horizontal roller is fitted on the end of the chassis close to the warping drum over which the pulling in rope is fed to the drum.

Q. 3. *Give a brief description of the method of laying cables direct in the ground, using a mole-drainer.* (35).

A. 3. The mole-drainer consists essentially of a wheeled framework or chassis to the lower side of which is attached a steel blade, or coulter, of up to 24 inches working length and 1 inch thickness. At the bottom of the coulter is a solid

Q. 6. *Draw a diagram of a double current set at an intermediate station working on universal batteries. Indicate clearly what alteration is necessary, if the down line is very short in comparison with the up line.* (35).

A. 6. The required diagram is shown in the sketch. Where



the resistance of the down line is small compared with that of the up line, the battery and the relay are each reversed, as also are the positions of the up and down lines, a resistance coil being inserted between the relay and the left side of the key.

Q. 7. *Explain briefly the following systems and indicate the circumstances for which each system is most suitable:—(a) single current working, (b) double current working, (c) central battery working, (d) universal battery working, (e) loop battery working.* (40).

A. 7. (*a*) *Single current working* is a system of telegraphy in which signals are transmitted by uni-directional currents; it is most suited to short lines on which the traffic is not very heavy.

(*b*) *Double current working* is a system of telegraphy in which signals are transmitted by reversing a current that is normally on the line during transmission. It is used on the longer and more heavily worked circuits.

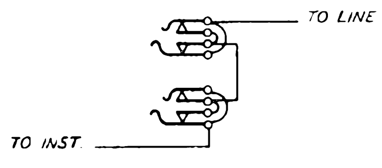
(*c*) *Central battery working* is the name given to a telegraph system in which the signalling power is located at a Central Office. It is used in connecting a Head Office to a number of sub-offices located in the surrounding area.

(*d*) *Universal battery working* is a method of power supply to all the telegraph sets in one office, in which one common power plant is used. It is employed at large offices at which it would otherwise be necessary to provide individual batteries for each telegraph circuit.

(*e*) *Loop battery working* is employed for telegraph circuits worked on underground cable loops, a separate battery being required for each circuit. This arrangement can, however, be obviated by using an H relay circuit which permits the use of earthed batteries on loop circuits.

Q. 8. *Draw a diagram showing the wiring of the line and instrument jacks on a telegraph test board. For what purposes are the " grouping jacks " and the " intermediate return jacks " provided?* (35).

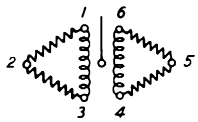
A. 8. The connexion of the line and instrument jacks on a telegraph test board are shown in the sketch. The " grouping jacks " comprise two sets of three jacks and two sets of four jacks, the jacks in each set being commoned. The grouping jacks are used for grouping wires together; for example,



No. 1 instrument may be forked to lines 2, 3, and 4 by plugging No. 1 instrument jack, and Nos. 2, 3, and 4 line jacks to the first, second, third, and fourth jacks of one of the groups of four. The " intermediate return " jacks are provided to enable a Wheatstone special set to be used as an intermediate set when required; the shorter line is plugged into the " intermediate return " jack, so disconnecting the earth from U-circle of the relay and connecting an adjusting resistance to the short line.

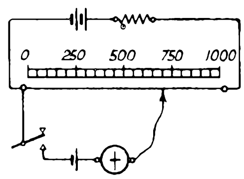
Q. 9. *Sketch and describe the construction of a moving coil differential milliammeter. How would you test its differential properties?* (30).

A. 9. The differential milliammeter is essentially a moving coil galvanometer with an equal-division current scale on either side of zero. The instrument has two coils, the wire for each being wound on the former side by side. The connexions of the instrument are shown in the sketch. The instrument may be tested for differentiality by connecting a battery, through a resistance, to terminals 1 and 6, and connecting terminals 3 and 4 together. The current flowing in the two coils is the same, but their magnetic effects are equal and opposite; the milliammeter therefore shows no deflection. Terminals 1 and 4, and 3 and 6 should be connected together, and the battery applied to the two sets of strapped terminals; since the resistance of the two coils is equal, the current divides equally between them, and their magnetic effects oppose, resulting in no movement of the pointer.



Q. 10. *Explain how you would use a simple slide wire potentiometer to measure the E.M.F. of a cell in terms of a cell of known E.M.F. Why is a secondary cell used in preference to a primary cell for supplying the current in the slide wire?* (30).

A. 10. The slide wire is connected to a secondary cell and series resistance, as shown in the diagram. If the slide wire is of uniform resistance, the potential falls uniformly along it.



One end of a standard cell, connected in series with a galvanometer, is attached to the zero end of the slide wire, the other terminal being connected to the slider which is then moved until a point is found where the difference of potential from 0 to that point is equal to the E.M.F. of the standard cell; this point is indicated when the galvanometer shows no deflection. The divisions of the slide wire may now be calibrated; assuming that the E.M.F. of the standard cell is 1.434 volts and that the slider reads 730 divisions when the galvanometer shows no deflection, then one division of the slide wire is equal to 1.434/730 volt.

The standard cell is now replaced by the cell to be tested and the slider again moved until the galvanometer shows no deflection. The E.M.F. of the cell under test is then obtained by multiplying the reading in the second test by the calibration value obtained from the first test. Assuming that the reading in the second test is 570 divisions, then the E.M.F. of the cell under test is

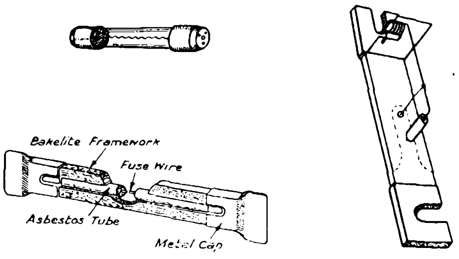
$$\frac{1.434 \times 570}{730} = 1.119 \text{ volts.}$$

A secondary cell is used in preference to a primary cell for supplying the current in the slide wire since it is essential for the accuracy of the test that the current should not vary during the period of the test, otherwise the potential along the slide wire would vary, rendering the test inaccurate. The resistance in series with the secondary cell is for the purpose of reducing the current to a small value such that the slide wire is not heated appreciably.

Q. 11. *Sketch and explain the construction of (a) a glass tube fuse, (b) an alarm type fuse, (c) a flat type fuse used on hinged fuse mountings on main distribution frames.* (35).

A. 11. (*a*) The glass tube fuse, usually of the 3-ampere type, consists of a fine crimped phosphor bronze wire contained within a glass tube 2 inches long, the ends of the tube being closed by two copper caps cemented with shellac. The fuse wire is passed through two central holes in the caps and soldered.

(*b*) The alarm type fuse consists of a short length of fuse wire fitted between two springs, the front wire spring carrying a small coloured bead which is carried forward out of alignment with the other springs of adjacent fuses when the fuse is blown; the back spring, when thus released, connects the live bus bar to an alarm circuit, thus calling attention to the failure.



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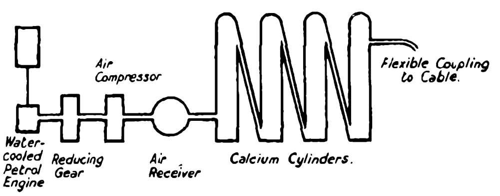

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A. 3. The mole-drainer consists essentially of a wheeled framework or chassis to the lower side of which is attached a steel blade, or coulter, of up to 24 inches working length and 1 inch thickness. At the bottom of the coulter is a solid steel cylinder, or "mole," 3 inches in diameter and having a wedge-shaped nose. The leading end of the chassis is provided with means of attaching the hawser of a tractor-winch. The armoured cable is fixed to the mole through a "mechanical fuse" having a breaking stress less than that which would cause damage to the armoured cable.

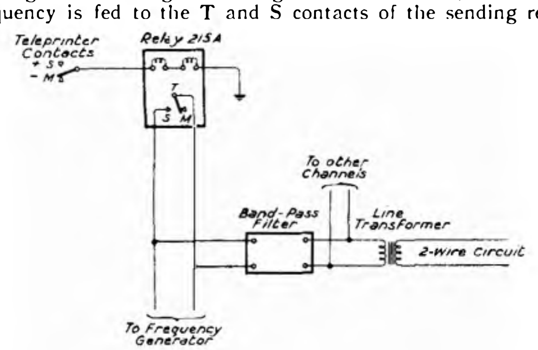
The mole-drainer is hauled by a tractor-winch which moves forward, paying out the hawser as it progresses, until it reaches the point from which hauling is to take place. Two I-section anchors are then lowered to the ground and, when the tension on the hawser increases, dig into the ground and hold the tractor against the pull of the hawser. As the mole-drainer moves forward, the coulter and mole dig into the ground and the mole pushes the surrounding earth to one side, leaving a drain into which the cable is drawn. The coulter leaves a narrow slot in the ground, but this closes naturally after a few days. For negotiating curves in the route, the hawser is passed through a block forming part of a portable anchor for guiding the hawser.

Q. 4. *Give a general description of the principles of voice frequency telegraphy. Give a brief description and outline diagram of any voice frequency telegraph system with which you are familiar.* (40).

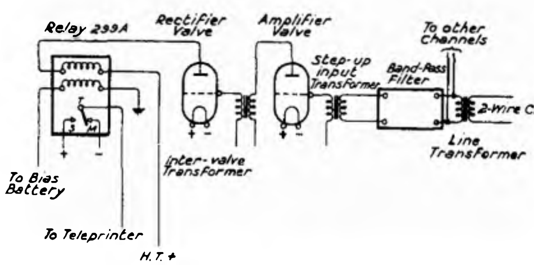
A. 4. Voice frequency telegraphy is a method of transmission which enables telephone circuits to be used for telegraph purposes. The various systems consist essentially of means of converting the direct current signals from the telegraph transmitters into an alternating current within the voice frequency range (200-3,000 p.p.s.), and for receiving the voice frequency current and converting it into direct current signals for the operation of the telegraph receivers. Since the transmission over the line is by voice frequency current, a telephone line of almost any length, repeatered if necessary, can be used.

The multi-channel voice frequency telegraph system adopted by the Post Office has a maximum capacity for 18 channels. Where, however, the cut off point of the line does not permit the use of the higher frequencies of transmission, the system is limited to 12 channels. These figures apply to a 4-wire circuit; where a 2-wire line is used, the capacities are reduced by half, *i.e.*, to 6 and 9 channels.

The frequencies used for transmission are spaced at 120 p.p.s. and range from 420 p.p.s. to 1,740 p.p.s. for the 12-channel system and to 2,460 p.p.s. for the 18-channel system. The 18 frequencies are derived from a multi-frequency generator of the inductor alternator type. An outline diagram of a sending and receiving circuit is given in the sketch; the channel frequency is fed to the T and S contacts of the sending relay,



SENDING CIRCUIT.



RECEIVING CIRCUIT.

which is operated by the direct currents from the telegraph transmitter, a teleprinter in the case shown. When the relay tongue is on the spacing contact, the frequency supply is short-circuited; when the short circuit is removed, the channel frequency passes through the band pass filter and line transformer to the 2-wire line, where it merges with the channel frequencies from other channels which may be marking at the same instant. At the receiving end, the channel frequency passes through the receiving band-pass filter and is amplified and rectified, the rectified current operating the receiving relay which, in turn, operates the telegraph receiver; the diagram shows a teleprinter connected to the channel.

The band-pass filters ensure that the channel frequency is reasonably pure when it passes into the line and is diverted into the correct receiving channel on arrival at the receiving end.

Q. 5. *Explain clearly why accurate synchronism of speed is necessary for multiplex working and not for start-stop working. What percentage of speed error is permissible for Creed teleprinter working? Describe a method of verifying the speed of a teleprinter motor.* (35).

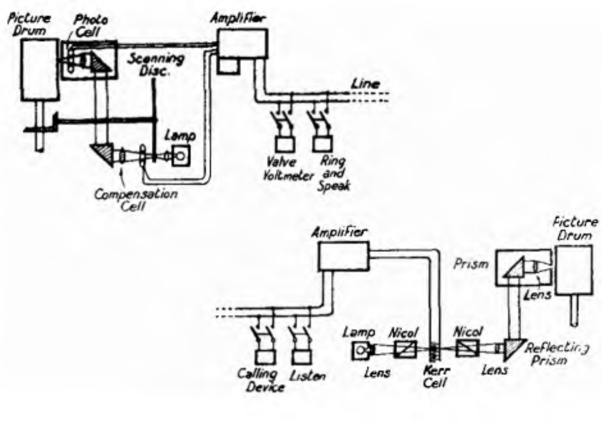
A. 5. In multiplex working, the distributing arms revolve continuously and any difference in speed increases the phase displacement of the arms continuously; this is corrected by signals sent over the line periodically, but the speeds of the two arms must be sufficiently close to one another to enable correction to be effected. In start-stop working, the slight difference in speed of any two units working together is prevented from accumulating by arranging that the receiving shaft shall run slightly faster than the transmitting shaft, and that, therefore, the receiving shaft shall come to rest a little in advance of the transmitting shaft. Thus, although the transmitting shaft may revolve continuously, the receiving shaft will come to rest at the end of each revolution for a period which will vary slightly according to the difference in speed between the two. For this reason, no correcting signal or correcting mechanism is required, and there is a greater speed tolerance than in multiplex installations.

The percentage of speed error permissible in Creed teleprinter working is 5 per cent.

The speed of a teleprinter motor is verified by viewing a white patch, painted on the smaller of the two gear wheels associated with the motor, through a stroboscope vibrating at a fixed speed of 630 vibrations per minute. If the white mark appears stationary, the speed of the motor is correct.

Q. 6. *Give a brief description of a system for the transmission of pictures by telegraph.* (40).

A. 6. The Siemens-Karolus system of picture telegraphy consists essentially of a rotating drum carrying the picture, and a photo cell and light spot traversing the drum. The light spot is interrupted by a scanning disc and is concentrated through the centre of the photo cell on to the picture; the amount of reflected light varies according to the photographic density of the spot on which the light falls. The varying



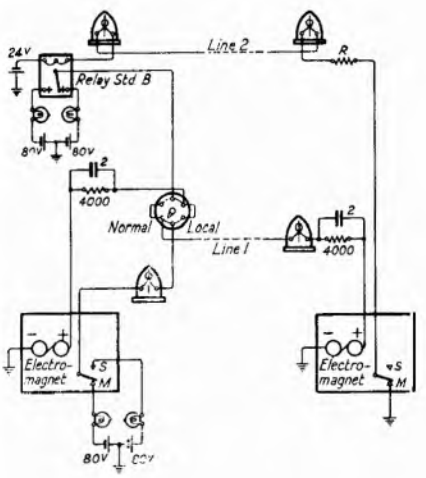
reflected light falls on the photo cell where it generates a minute varying e.m.f. which is amplified and passed to line in the form of alternating current. The light spot describes a spiral around the picture on the drum, the closeness of the spiral being determined by the relative speeds of rotation of the drum and traverse of the light spot.

At the receiving end, a picture drum containing sensitized paper or film is rotated and traversed by a light spot, the rate of traverse being the same as at the sending end, and the speed of rotation of the drum being accurately synchronized with that of the drum at the sending end. The light beam passes through a nicol prism, where it is polarized, then through a Kerr cell, which is a small multi-plate condenser immersed in nitro-benzol, then through a second nicol prism, reflecting prisms, and a lens where the beam is concentrated into a spot of light on the surface of the paper. The input from the line is amplified and connected across the terminals of the Kerr cell; when polarized light is passed between the electrodes of this cell, the plane of polarization of the light is changed as the voltage across the electrodes changes. The device thus acts as an electric light-shutter, the varying potential applied to the cell being the varying alternating picture potential supplied from the line, after amplification.

Means are provided for obtaining accurate synchronism both in speed and phase between the apparatus at the sending and receiving ends of the line, and also for receiving the picture either in the form of a positive or as a negative by using a second photo cell placed in the path of the interrupted light beam so that it receives a constant amount of interrupted light; the output of this second photo cell may be adjusted and may be either added to or subtracted from the output from the picture photo cell.

Q. 7. *Draw a neat diagram of a central battery two-line simplex circuit for Creed tape teleprinter working. Show both head office and out office sets and explain how both machines can be tested " in local " (i.e., by so connecting the transmitter to its own receiver that the " sent " signals are reproduced on the receiver).* (35).

A. 7. The required diagram is shown in the sketch. The teleprinters may be tested " in local " by turning the 6-terminal 2-position switch at the Head Office to " local." The Out station transmits in the normal manner, but the signals

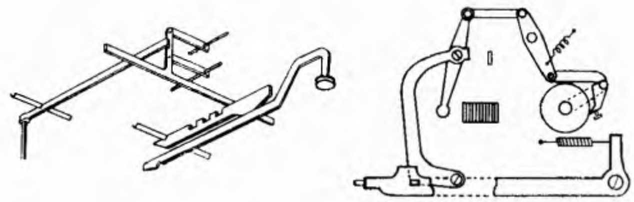


are repeated from the relay at the Head Office back along line 1 to the electro-magnet at the Out Station. Simultaneously, the contact tongue of the Head Office teleprinter is connected to the electro-magnet of the same machine. As the Out Office is unable to communicate with the Head Office after requesting for a test " in local," it is the practice to restore the switch to normal after a period of not more than five minutes.

Q. 8. *Give a brief description of a Kleinschmidt keyboard perforator. Sketch and explain both the punch selection device and the paper feed device.* (35).

A. 8. The keyboard is of the 4-bank type and contains 41 keys; a space bar runs along the length of the keyboard nearest to the operator. A combination key is provided whereby any two keys in the keyboard may be connected to form one character. One solenoid controls both the perforation and the paper feed.

Each character key lever is immediately over an intermediate notched lever underneath which run a number of tee levers suspended by a system of parallel links; only one of the

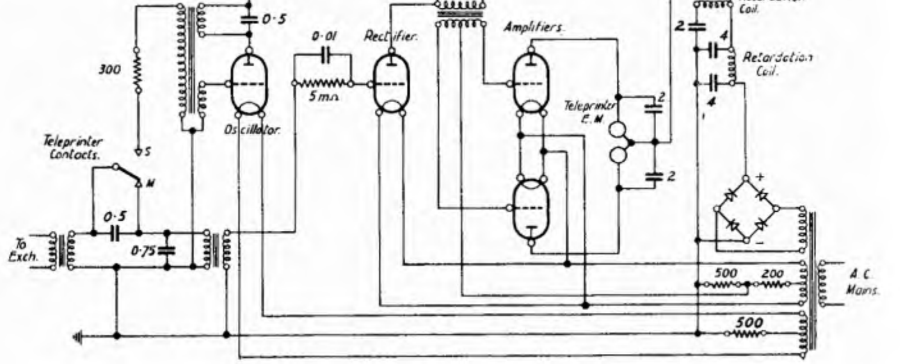


tee levers is shown in the sketch. The punch controllers are attached to horizontal levers let into small slots in the side of the vertical portion of each tee lever. The depression of a tee lever raises the punch controller, interposing it between the punch hammer and the punch head. The work of selecting the punches is thus performed by the depression of the key.

The paper feed is variable and depends upon the length of the letter or character punched. The sketch shows the variable paper feed mechanism. A bell crank lever, pivoted to the frame, and rocked by a solenoid (not shown) controls a feed operating lever also pivoted to the frame. To the lower end of this lever is pivoted a floating lever the upper end of which banks against the lug of the last punch selector forming a letter. The floating lever is connected by a link to a two-armed intermediate lever, the upper end of which is joined by a link to the rocking arm carrying a feed pawl. When the solenoid is energized, the punch hammer lever is rocked in a clock-wise direction, and it operates the feed lever by means of a lug on the feed lever which enters a slot formed in the punch hammer lever. The motion of the lower end of the feed operating lever continues until it comes up against a stop. In its travel, it carries the floating lever until the head of this lever banks against the final lug of the character selected. This lug acts as a fulcrum, causing the floating lever to move the intermediate lever in a clock-wise direction. The feed pawl arm is thus drawn round in a counter-clockwise direction, setting the pawl for the subsequent feeding operation. The extent of the movement of the pawl depends upon the length of the letter. When the solenoid is de-energized, the floating lever flies back to a stop (not shown) and the feed wheel is operated under the combined effect of the spring on the intermediate lever and the spring that retracts the feed mechanism.

Q. 9. *Draw a diagram, and give a brief description, of an A.C. mains operated valve oscillator and amplifier detector for operating Creed page teleprinters (Teleprinters No. 7A) at a single frequency suitable for transmission over a telephone network.* (40).

A. 9. The required diagram is shown in the sketch. The



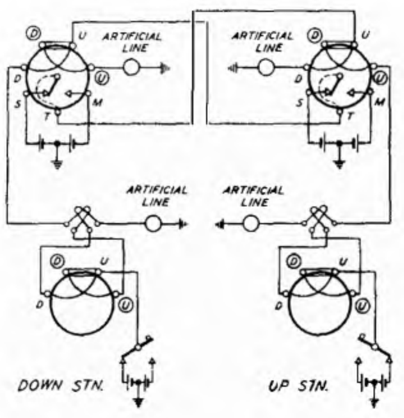
transmitting portion comprises a valve oscillator having one coil of a transformer in its anode circuit, the coil being tuned to 300 p.p.s. by an 0.5 μF condenser. The coupling between grid and anode is provided by the second coil of this transformer, whilst the third winding couples the oscillator output to the line, *via* the line transformer, when the transmitter tongue moves to spacing. A 300Ω non-reactive resistance is inserted in series with the output winding to prevent overloading of the valve, and the output to line is adjusted by an adjustable resistance in the anode circuit to give 3 volts across a line having a resistance of 600Ω. A portion of the output is bypassed to the receiving portion *via* a transformer to give a local record of the signals being sent to line.

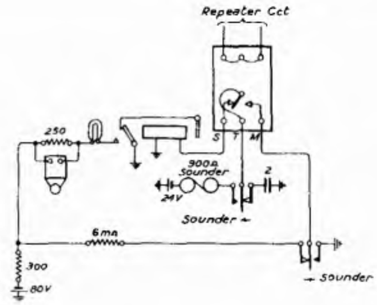
The receiving portion consists of a rectifier valve and two push-pull amplifiers. The rectifier is coupled to line through a transformer, the 0.5 μF condenser being short-circuited by the transmitting tongue of the teleprinter resting on the marking stop. The grid of the rectifying valve is normally biassed to a point at the bottom of its operating curve when a minimum current flows in its anode circuit. An incoming signal produces a rise in current in the anode circuit comprising the primary winding of the transformer which is provided with two secondary windings, one end of each being connected to the grids of the push-pull valves and the other to the respective grid returns. The anodes of these valves are each connected through one coil of the teleprinter electromagnet to the positive of the high tension supply. The increase in the current flowing in the rectifier anode circuit due to an incoming 300 p.p.s. signal causes a momentary current in the secondary windings of the transformer. The grid of one of the push-pull valves becomes momentarily positive and an increased current flows in the anode circuit of that valve and the coil of the electromagnet associated with it, moving the relay armature to the spacing stop. The grid of the other push-pull valve is made more negative by the same anode current and its current is consequently slightly reduced. On cessation of the signal the reduction in detector anode current produces pulses in the opposite direction in the secondary windings of the transformer. The potentials of the grids of the push-pull valves are thus reversed, with the result that a momentarily increased current flows through the other coil of the teleprinter electromagnet, moving the relay armature to the marking stop. By these means, a double current effect is obtained.

Q. 10. ***Draw an explanatory diagram of (a) a duplex repeater, (b) a repeater alarm. Explain the operation of the repeater alarm.*** (35).

A. 10. The upper sketch shows the connexions of a duplex repeater and the lower the connexions of a repeater alarm. When the relay tongue is on the marking stop, the 80-volt battery charges the 2 μF condenser, which is discharged through the drop indicator when the tongue reaches the spacing stop. In the normal conditions of operation, the amount of the discharge through the drop indicator is insufficient to operate it. When, however, the attention of the repeater clerk is required, the distant station holds the transmitting key down

DX REPEATER





for a period of from 15 to 20 seconds. This time suffices to charge the condenser fully and, when the key is released and the relay tongue moves to the spacing stop, the full discharge passing through the drop indicator causes the shutter to fall and close the local alarm circuit consisting of the trembler bell and calling lamp.

Q. 11. ***Explain the following terms:—(a) cadence, (b) diplex, (c) sub-audio frequency, (d) composite circuit, (e) attenuation, (f) distortion, (g) Murray loop, (h) leak working.*** (40).

A. 11. (*a*) *Cadence* is the name given to a signal for the operator of a Baudot or similar telegraph keyboard as to when to depress a signal-group of keys.

(*b*) *Diplex* is the name given to a modification of the quadruplex system whereby two messages in one direction and one message in the other direction may be transmitted simultaneously.

(*c*) *Sub-audio frequency* is a frequency below the frequency band required for the satisfactory transmission of speech and is usually comprised within the range 0-100 p.p.s.

(*d*) ***A composite circuit*** is a circuit in which are obtained simultaneously either one telegraph and one telephone channel from one line-wire and earth, or two earth-return telegraph channels and one telephone channel from two line-wires; segregation being effected by means of inductive coils and condensers.

(*e*) *Attenuation* is the decrease in magnitude of the transmitted power, voltage, or current due to a line or apparatus. Quantitatively, the attenuation, which may be negative, is expressed in nepers or bels by comparing the magnitude of the received with that of the sent power, voltage, or current.

(*f*) *Distortion* is the change in shape of a transmitted wave which occurs between any two points of a transmission system.

(*g*) ***Murray loop*** is the name given to a particular localization test for the location of earth or contact faults on line-wires.

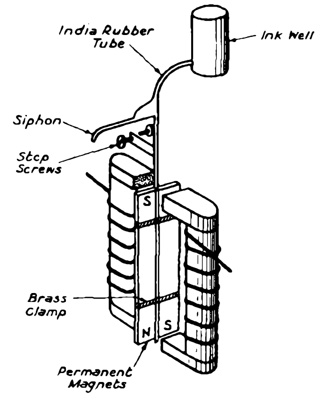
(*h*) ***Leak working*** is a method of working omnibus telegraph circuits in which the stations are connected between the line and earth.

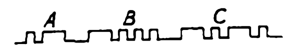
Q. 12. ***Enumerate all the points in connexion with the maintenance of a secondary cell battery that are of importance to ensure its long life.*** (30).

A. 12. The cells should be discharged as regularly as possible and should be given the required percentage of overcharge at intervals. The specific gravity of the cells should be regularly read before and after charge, and the figures recorded. Excessive gassing should be avoided, as this disintegrates the active material and results in an accumulation of deposit in the bottom of the boxes and a decrease in the capacity and life of the plates. On a normal charge, only about 10-15 per cent. more should be put into the cells than has been taken out, and at intervals of about a fortnight an overcharge should be given so as to reduce all the sulphate, even up the specific gravity, and keep the plates in good condition. The level of the electrolyte should be maintained, by the addition of distilled water, at about half an inch above the tops of the plates when the cells are quiescent.

Q. 13. Describe, with the aid of sketches, the construction of an Undulator, and explain why it is particularly suitable for submarine cable working. Draw a diagram of the letters "a b c" as received on an Undulator slip. (35).

A. 13. The undulator consists essentially of a moving system of permanent magnets clamped to a frame which carries a siphon. The magnets are arranged between the poles of two electro-magnets as shown in the sketch. The siphon consists of a glass tube connected to an ink well by a short length of india rubber tube. Stop screws serve to limit the extent of the movement of the siphon, the tip of which is in contact with a paper slip drawn past at a constant speed. The undulator is particularly suitable for submarine cable working because, being polarized, the extent of the movement of the siphon does not depend upon the strength of the line current flowing through the coils. As soon as the line current rises to a value sufficient to cause the movement of the armature from the spacing to the marking stop, the effect of the permanent magnets is to move the armature over fully in that direction. The signal received on the slip is therefore square-shaped, as





shown in the sketch, instead of being in the form of a wavy line.

IX. MAGNETISM AND ELECTRICITY; QUESTIONS AND ANSWERS

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

Q. 1. State the units of measurement of the following:—Electromotive force, resistance, quantity of electricity, electrical power. How is it possible to measure a quantity of electricity?

A.1. The absolute unit of electromotive force is acting when one erg per second is supplied for the maintenance of the absolute unit of current in the circuit. The practical unit of electromotive force is the volt and is that potential difference which will send a current of one ampere through a resistance of one ohm.

The absolute unit of resistance is defined as the resistance of a circuit through which one absolute unit of electromotive force will send one absolute unit of current. The practical unit of resistance is the ohm and is the resistance of a column of mercury of uniform cross-section, having a mass of 14.4521 grammes and a length of 106.3 cms.

The absolute unit of quantity of electricity is the coulomb which is that quantity of electricity passing a given point in the circuit in one second when the circuit carries a current of one ampere. The practical unit of quantity of electricity is the ampere-hour which is the quantity of electricity passing when a current of one ampere flows for one hour; hence 1 Ah = 3600 coulombs.

The practical unit of electrical power, or rate of doing work, is the watt which is equal to one joule per second, or 10^7 ergs per second.

A quantity of electricity may be measured by means of a ballistic galvanometer if the quantity is small, or by means of a voltameter in the case of larger quantities.

Q. 2. Give brief definitions or explanations of the following terms:—Specific resistance, retentivity, electric lines of force, potential difference, coercive force, electrolysis.

A. 2. *Specific resistance* or resistivity of a substance is the resistance between opposite faces of a unit cube of the substance.

Retentivity is the power possessed by magnetic materials of retaining a proportion of the magnetism after the removal of the magnetizing force.

Electric lines of force are imaginary lines whose direction at all points is that of the electric field, or the force on a unit positive charge.

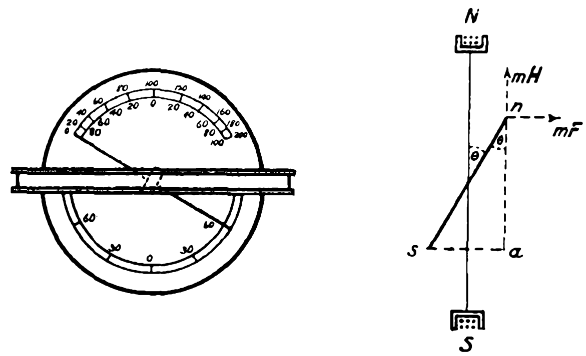
Potential difference is the difference in the electrical pressures at two points in a circuit.

Coercive force or coercivity of the amount of reversed magnetizing force which is required to overcome the retentivity of a magnetic substance in reducing the magnetism to zero.

Electrolysis is the process whereby chemical changes take place in certain conducting liquids when a current is passed through them.

Q. 3. Describe in detail a tangent galvanometer, indicating clearly the effect of the forces acting on the needle of the galvanometer.

A. 3. The tangent galvanometer consists of a coil, consisting of several turns of fairly large radius, placed with its plane in the magnetic meridian and having a small magnetic needle suspended at its centre. The arrangement is shown in the sketch; the needle, however, is shown much larger in size for



clarity. If the magnetic field due to the coil is F gauss, and the horizontal component of the earth's field is H gauss, then, $F = 2\pi ni/r$, where n is the number of turns of wire in the coil, i is the current flowing, and r is the radius of the coil. For a deflection θ, the couple acting on the needle due to H is $Hm \sin \theta$, where m is the magnetic moment of the magnet, The deflecting couple due to the coil is

$$Fm \cos \theta = \frac{2\pi ni}{r} m \cos \theta.$$

In the condition of equilibrium, these two couples are equal, *i.e.*,

$$\frac{2\pi ni}{r} m \cos \theta = Hm \sin \theta$$

$$\frac{2\pi ni}{r} = H \tan \theta$$

or

$$i = \frac{rH}{2\pi n} \tan \theta$$

The quantity $rH/2\pi n$ can be determined and the resulting value is termed the reduction factor of the galvanometer, usually indicated by k. Whence, $i = k \tan \theta$.

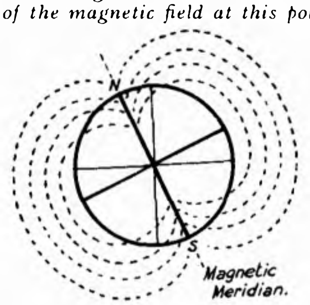
Q. 4. Express the relationship between the resistance of an electrical circuit and the power lost in the circuit when a current is flowing. A dynamo giving an output of 10 kilowatts is sending a current of 50 amperes through a resistance. What is (a) the value of this resistance in ohms, and (b) the voltage of the dynamo?

A. 4. $P = EI = I^2R$ watts.

Where P is the power lost in the circuit in watts, E is the applied voltage, I is the current in amperes, and R is the resistance in ohms.

$$I^2R = 10{,}000 \qquad EI = 10{,}000$$
$$2500\ R = 10{,}000 \qquad 50\ E = 10{,}000$$
$$R = 4 \text{ ohms.} \qquad E = 200 \text{ volts.}$$

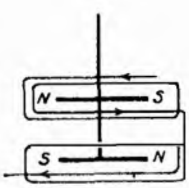
Q. 5. Describe, with sketches, your idea of the lines of force due to the earth's magnetic field, and indicate the " dip " at the magnetic North Pole. What is the horizontal component of the magnetic field at this point?



A. 5. The lines of force of the earth's magnetic field emanate from the poles and radiate around the earth as shown in the sketch. The dip at the magnetic North pole is 90°, the lines being vertical in relation to the earth's surface; the horizontal component of the magnetic field at this point is zero.

Q. 6. Explain briefly upon what factors the sensitivity of a galvanometer depends. Describe by means of a diagram how the use of astatic needles affects the sensitivity of a galvanometer.

A. 6. The sensitivity of a galvanometer depends upon the ratio between the deflecting force due to the current and the opposing force due to the earth's magnetism. The ratio can be increased by increasing the number of turns of wire on the coil, and so increasing the magnetic effect of the current. The effect of the earth's magnetic field upon the needle may be reduced by using an astatic combination (see sketch), in place



of a single needle. Two magnetic needles of equal length and strength are fixed one over the other with their unlike poles adjacent and with their magnetic axes in the same vertical plane. The restoring couple set up by the earth's field on one needle is practically counter-balanced by the restoring couple set up on the other.

For extreme sensitiveness, the moving parts of the galvanometer should be as small and as light as possible.

Q. 7. An electrical measuring instrument having an internal resistance of 500 ohms gives a full scale deflection when a current of 0.01 ampere is passed through it. What voltage, applied to a circuit consisting of this instrument in series with an external resistance of 9,500 ohms, would be required to give a full scale deflection? For what purpose could such an instrument be used?

A. 7. $E = IR = 0.01 \times 500 = 5$ volts.

The potential difference across the measuring instrument when indicating a full scale deflection is 5 volts. If this deflection is obtained when the total resistance of the circuit containing the instrument is 10,000 ohms, then the voltage applied to the circuit is $10{,}000/500 \times 5 = 100$ volts.

The instrument could be used either as a voltmeter indicating 0–5 volts, or, in conjunction with the series resistance, as a voltmeter with a range of 0 – 100 volts.

Q. 8. Describe, with sketches, an electrostatic voltmeter. Could such an instrument be used as an ammeter and, if so, how?

A. 8. An electrostatic voltmeter consists essentially of a group of fixed vanes having a group of movable vanes interleaved between them; the movable vanes carry a pointer, which moves over a graduated scale, and are normally retained in position by a spiral spring. The two sets of vanes are connected to the two terminals of the instrument.

An electrostatic voltmeter could be used as an ammeter in conjunction with a shunt of fairly high resistance, say 200 ohms. In the majority of cases, however, the insertion of this resistance in the circuit would materially affect the current flowing and the method could only be used where the resistance of the circuit was large compared with that of the shunt.

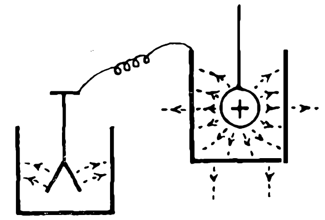
Q. 9. Describe in detail a simple experiment with an electromagnet to show how the magnetic flux varies with changes in ampere-turns and changes in reluctance. Explain also the term " magnetic permeability."

A. 9. A U-shaped electromagnet with a movable yoke is fixed with its limbs pointing downwards. A known value of current is passed through the coils, and a soft iron yoke to which is attached a pan for the retention of weights is applied to the lower pole pieces. The weight in the pan is increased until the soft iron yoke is pulled away from the pole pieces. The experiment is repeated with increasing values of current and it will be found that the weight required to pull the yoke away increases almost as the square of the current. If, now, the reluctance of the magnetic circuit be increased by inserting a gap of non-magnetic material between the upper yoke and the pole pieces, and the experiment repeated with the same values of current, it will be found that the weight required to pull the lower yoke away is much less than in the previous cases. Thus, increase in the ampere-turns increases the magnetic flux, until the saturation point of the iron is approached; similarly, increase in the reluctance of the magnetic circuit decreases the magnetic flux.

Magnetic permeability, denoted by μ, is the ratio of the flux density, B, to the magnetizing force, H; it is not a fixed quantity, but depends, among other things, upon the amount of magnetism already present in the material and the retentivity.

Q. 10. Explain briefly what is meant by an " induced electric charge." Describe an experiment to show that the total induced charges on a body are equal to the inducing charge.

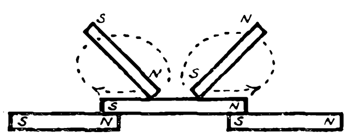
A. 10. An induced electric charge is a charge of electricity on a body due to its location in an electrostatic field emanating from a second charged body. To show that the induced and inducing charges are equal, a hollow metal container, a charged sphere, and an electroscope are required. The electroscope is connected to the hollow container and the sphere is carefully lowered into the container without touching the sides. The



leaves of the electroscope diverge due to the charge induced on the outside of the container. The charged sphere is now allowed to touch the inner surface of the container, and the leaves of the electroscope are seen to remain without any change in divergence. The experiment proves that the induced charge on the inner surface of the container is equal to the charge of the sphere, and that when the sphere is inside the container, the induced charges are equal to the inducing charge.

Q. 11. *Describe a method of magnetizing a compass needle by means of four bar magnets. State three means by which the magnetization of a piece of steel may be destroyed.*

A. 11. The compass needle is placed between the poles of two of the bar magnets as shown in the sketch. The other

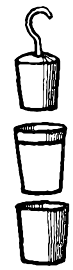


two magnets are held one in each hand and moved round in the direction shown by the arrows, the compass needle being stroked by the magnets during their passage from the centre towards the ends.

The magnetization of a piece of steel may be destroyed (i) by striking its end violently with a hammer a number of times, (ii) by the application of a reversed magnetizing force of suitable value, and (iii) subjecting it to the magnetic field of a solenoid supplied with alternating current gradually decreasing in strength.

Q. 12. *Describe, with sketches, a Leyden jar. What is the effect of the thickness of the glass on its capacity? Two condensers when connected in series are found to have a capacity of* 2.4 *microfarads. The capacity of one of the condensers is known to be* 4 *microfarads; what is the capacity of the other? If the condensers are connected in parallel, what will be the capacity?*

A. 12. A Leyden jar usually consists of an outer and inner vessel coated up to a certain height on the inside and outside, respectively, with tinfoil, and a centre vessel of glass (see sketch). The thicker the glass separating the two conducting



surfaces of the Leyden jar, the less its capacity.

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} \quad \therefore \quad \frac{1}{C_2} = \frac{1}{C} - \frac{1}{C_1}$$

$$\frac{1}{C_2} = \frac{1}{2.4} - \frac{1}{4.0} = \frac{10-6}{24} = \frac{4}{24}$$

$$C_2 = \frac{24}{4} = 6 \text{ microfarads.}$$

If the condensers are connected in parallel, the capacity will be $6 + 4 = 10$ microfarads.

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