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II. TELEPHONY, FINAL; SECTION 1, AUTOMATIC TELEPHONY. QUESTIONS AND ANSWERS (*continued*).

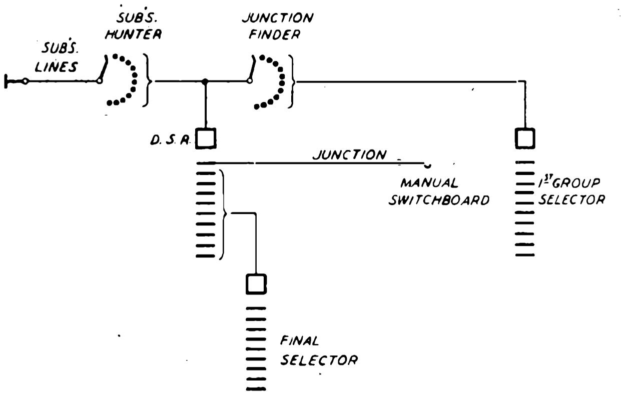
W. S. Procter, A.M.I.E.E.

Q. 10. What advantages are gained by the use of discriminating selectors at a satellite exchange in a non-director area? Describe the sequence of switching operations which occurs in each case when a subscriber on the satellite exchange makes a call—

(*a*) *to a subscriber on the same exchange,*
(*b*) *to a subscriber on the main exchange;*
(*c*) *to the manual operator, by dialling " o."* (40).

A. 10. The use of discriminating selectors at a satellite exchange in a non-director area permits the segregation of traffic to exchange outside the multi-exchange area—O-level traffic—from that to exchanges inside the area. It is therefore possible to provide junctions of high transmission efficiency to carry only the O-level traffic from the satellite exchange, using lower grade junctions for traffic within the multi-exchange area. The resulting reduction in the cost of the junctions forms a considerable part of the economy effected by the use of discriminating selectors.

In addition, the amount of switching plant at the main exchange is reduced by the quantity otherwise required for calls local to the satellite exchange. Similarly the junctions between the main and satellite exchanges are reduced, since



local calls are completed over the banks of the discriminating selectors instead of *via* the main exchange.

It is also practicable to provide direct dialling facilities from a satellite exchange to a near-by manual exchange, although this facility has the disadvantage of restricting the numbering scheme.

The apparatus at a satellite exchange equipped with discriminating selectors is shown in the sketch.

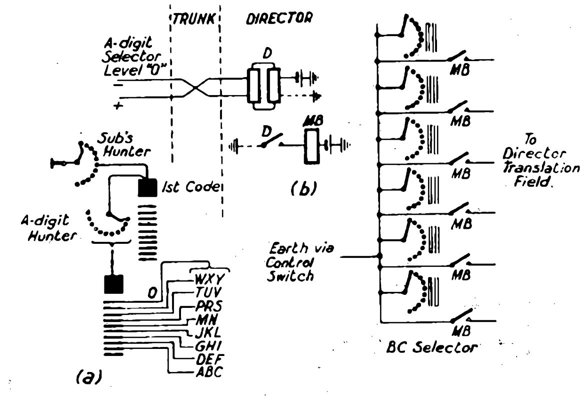
(*a*) When a subscriber makes a call to another subscriber on the same exchange, the removal of the receiver causes the sub's hunter to search for and seize a free discriminating selector and its associated junction finder, which searches for and seizes a free junction to the main exchange. The calling subscriber receives dialling tone from the discriminating selector when a free junction is seized. Assuming discrimination on the first digit, the discriminating selector and the first selector at the main exchange step together to the level dialled. The discriminating selector, however, finds discriminating conditions on the auxiliary bank of the level dialled; this causes the selector to release and return the junction finder to its home position, so releasing the junction to the main exchange and the first selector at that exchange. Thereafter, the discriminating selector functions as a 2nd group selector.

(*b*) The pre-dialling operations described above take place and when the discriminating selector wipers are stepped into the level dialled, the discriminating condition connected to the auxiliary bank causes the selector to remain at the level reached and to function as an impulse repeater for the remaining stages of the call.

(*c*) The pre-dialling operations described in (*a*) above take place. On reaching the O level, the discriminating selector searches for and seizes a free outlet and extends the calling subscriber over the junction to the auto-manual switchboard. The junction finder, the junction to the main exchange, and the 1st group selector at that exchange are released.

Q. 11. When a subscriber on a director exchange dials " o " the call is routed to an operator. Sketch and describe the special circuit arrangements provided, on the A-digit level and in the director, for dealing with such calls. (40).

A. 11. In a director exchange, eight groups of directors are provided for routing calls to other exchanges. Certain of these directors in each group are modified for dealing with o-level calls and are connected to the o level of the A-digit selectors as shown in sketch (*a*). Sketch (*b*) shows the essential



features of the modification; the $+^{ve}$ and $-^{ve}$ wires of the trunk outgoing from the o level are reversed and, when a director is seized from this level, relay D, which is of the shunt field type, operates owing to the reversal of the current flowing in the line winding. Relay D operates relay MB which immediately sets up the necessary translation conditions and causes pulsing-out to commence.

Q. 12. An impulsing relay having a resistance of 400 ohms, and an inductance of 16 henries, is adjusted to operate with a current of 15 milliamperes. What will be the operating lag of the relay when it is connected in series with a non-inductive resistance of 1,200 ohms and a battery of 48 volts? ($Log_{10}\, e = 0.4343$; $log_{10}\, 2 = 0.3010$.) (40).

A. 12.

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

where I = current, in amperes,
E = e.m.f., in volts,
R = resistance, in ohms,
L = inductance, in henries,
t = time, in seconds, from closing the circuit,
and $e = 2.71828 \ldots$

$$\frac{15}{1000} = \frac{48}{400 + 1200}\left(1 - e^{-\frac{100t}{16}}\right)$$

$$\frac{15 \times 1600}{48 \times 1000} = (1 - e^{-100t})$$

$$\tfrac{1}{2} = \left(1 - \frac{1}{e^{100t}}\right) = \frac{e^{100t} - 1}{e^{100t}}$$

$$e^{100t} = 2e^{100t} - 2$$

$$\therefore\ e^{100t} = 2$$

$$100t \log_{10} e = \log_{10} 2$$

$$t = \frac{\log_{10} 2}{100 \log_{10} e} = \frac{0.3010}{100 \times 0.4343}$$

$= .0069$ sec.

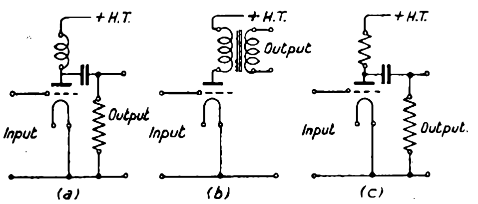
$= 6.9$ milliseconds.

III.—RADIO-COMMUNICATION. GRADE 1, 1933. QUESTIONS AND ANSWERS.

By A. C. Warren, B.Sc., A.M.I.E.E.

Q. 1. Describe, with circuit diagrams, the principles of action of choke-coupled, transformer-coupled, and resistance-coupled, audio-frequency amplifiers. How do the characteristics of each type vary with frequency?

A. 1. Choke, transformer and resistance coupled amplifiers are shown in diagrams (*a*), (*b*) and (*c*). If an impedance Z is



placed in the anode circuit of a valve and an A.C. input is applied to the grid then the anode current will vary in accordance with the grid input. This variation in anode current will set up an A.C. voltage across the anode circuit impedance and this voltage can be coupled to a succeeding stage through a condenser C as in (*a*) and (*c*) or through the transformer as in (*b*).

It can be shown that the amplification of a stage is given by

$$\frac{\delta v_a}{\delta v_g} = \mu \cdot \frac{Z_a}{\rho + Z_a}$$

where μ and ρ are the amplification factor and anode a.c. resistance of the valve and Z_a the anode circuit imepdance.

For case (*a*) we see that

$$\frac{\delta v_a}{\delta v_g} = \mu \cdot \frac{j\omega L}{\rho + j\omega L}$$

This will be equal to μ if $\omega^2 L^2 \gg \rho^2$ that is if $\omega L > 3\rho$, *i.e.*, the amplification of the stage will rise with frequency until $\omega L = 3\rho$ when it will approximate in value to μ and will remain constant.

For case (*b*)

$$\frac{\delta v_{g_2}}{\delta v_{g_1}} = \mu T \cdot \frac{j\omega L_1}{\rho + j\omega L_1}$$

provided the load on the transformer secondary can be neglected. T is the transformation ratio of the transformer. The frequency characteristic is the same as for choke coupling.

Case (*c*)

$$\frac{\delta v_a}{\delta v_g} = \mu \frac{R_a}{\rho + R_a}$$

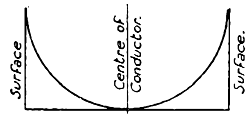
which is independent of frequency.

Note.—These characteristics apply only to pure elements. Self capacities, etc., will disturb them particularly at the higher frequencies.

Q. 2. Show roughly by means of a sketch the current density in a solid cylindrical conductor when carrying a high-frequency current, and explain the reason for any variation in density.

What steps are taken in practice to avoid excessive losses and uneconomical use of material in high-frequency conductors?

A. 2. When a high-frequency current passes through a conductor eddy currents are set up which tend to neutralize the flux cutting the conductor, thus tending to neutralize the current in centre of the conductor. As a result at high frequencies the current flows in the skin only. The current density when carrying d.c would be uniform, but when carrying h.f. current it will be as in sketch. Since the current



Current density in Conductor carrying H.F. current.

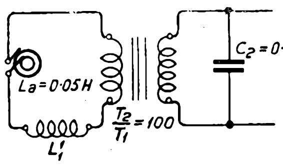
flows in the skin or, at least, penetrates only a small distance, it is usual to employ copper tube, strip or stranded wire, thus increasing the percentage of the copper cross-section carrying current. Stranded wire or litzendraht consists of a large number of strands of fine wire 30-38 s.w.g. frequently stranded $3 \times 3 \times 3$, each strand being enamel and silk insulated.

Q. 3. In a spark transmitter the primary condenser has a capacitance of 0.016 microfarad and is charged from an alternator through a transformer having a step-up ratio of 100.

If the inductance of the alternator is 0.05 henry and the frequency of the alternator is 50 cycles per sec., what additional inductance should be added to the low-tension circuit to produce resonance?

A. 3. The value of inductance L_2 necessary to resonate C_2 to a frequency of 50 cycles per second is

$$L_2 = \frac{1}{4\pi^2 f^2 C_2} = \frac{1}{4\pi^2 \times 50^2 \times .016 \times 10^{-6}} = 635 \text{ H.}$$



This is equivalent to an inductance L_1 in the primary circuit of value—

$$L_1 = \left(\frac{T_1}{T_2}\right)^2 \times L_2 = .0635 \text{ H.}$$

If the alternator inductance $L_a = 0.05$ H, then L_1^1 the added inductance = .0135 H.

Q. 4. In a spark transmitter, what is the effect on the emitted waves of increasing the coupling between the primary circuit and the aerial?

What is the difference in this respect between a quenched spark and an unquenched spark transmitter?

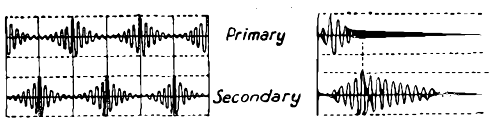
A. 4. In a spark transmitter the oscillation in the primary circuit is transferred to the aerial circuit building up in the latter as it decays in the primary. On reaching a maximum in the aerial it will tend to transfer its energy back into the primary where it will be partially dissipated in conductors and in the spark gap. The process will then repeat itself.

This transfer or beating of energy between the two circuits will become more rapid, and hence the efficiency and effective output lower, as the coupling is increased. It means in effect that two frequencies are being generated which are actually

$$f = \frac{f_0}{\sqrt{1+k}} \text{ and } \frac{f_0}{\sqrt{1-k}}$$

The separation between these two frequencies and hence the frequency spectrum occupied by the transmitter increases with k the coefficient of coupling.

The action is outlined in the sketch. This transfer of energy can be avoided if the spark gap can be rendered non-conducting, *i.e.*, deionised as soon as the first train of oscillations in the primary has ceased.



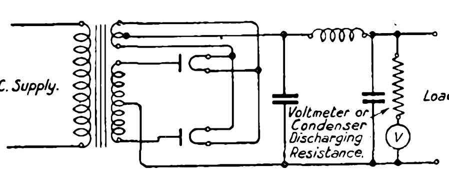
Coupling too tight — Coupling correct

The quenched gap, a large number of small gaps in series with large cooling surfaces, quenches the spark or deionises the gap in this manner and enables a closer coupling and hence greater efficiency to be obtained.

Since the energy cannot surge back into the primary circuit a quenched spark generates only one frequency as against two by the unquenched transmitter.

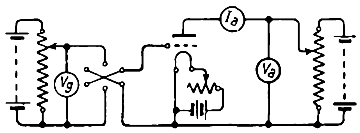
Q. 5. Give a circuit diagram of a full-wave thermionic rectifier complete with smoothing circuit suitable for supplying high-tension direct current to a valve transmitter.

A. 5.



Q. 6. Describe, with a diagram, the method that you would adopt and the apparatus that you would use to determine the grid voltage anode current characteristic curves of a three-electrode valve.

A. 6. The circuit arrangement which would be employed would be as in sketch. Grid and anode supplies would be fed through potentiometers, the grid and anode voltages being measured at this point.

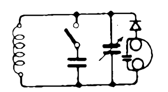


A reversing switch is inserted in the grid supply to enable readings to be taken for both +ve and −ve values of grid voltage. The meter I_a enables the anode current to be read. The procedure would be as follows :—With the anode voltage set to a particular value and maintained constant readings of anode current would be taken for various values of grid voltage. The readings would then be repeated for other values of anode voltage. The values would then be plotted to form a series of curves.

Q. 7. Describe the construction and principle of action of a resonant type wavemeter suitable for measuring the wave-length of a spark transmitter.

What precautions should be taken to minimise error when using the instrument?

A. 7. A suitable wavemeter for the measurement of the wave-length of a spark transmitter consists of an inductance coil, a fixed condenser and variable condenser, and a detector.



In the circuit shown, a rectifier and a pair of telephones have been shown as the detector, but this could be substituted by a neon lamp or by a glow lamp or radio frequency milliameter in series with the inductance coil. The coils and condensers should be of robust design and of such form as to minimise distortion due to temperature or ageing.

Multi range adjustments may be secured by the use of a group of plug in coils or by switching in additional condensers as shown. Readings are taken by tuning the wavemeter to resonance with the transmitter as indicated by maximum signal in the detector. To obtain accurate readings the coupling with the transmitter must be as loose as possible and the wavemeter coil must be kept clear from metal work.

Q. 8. A high frequency fixed type condenser consists of a number of parallel plates uniformly spaced and immersed in oil. It is desired to make the condenser suitable for higher voltage by doubling the spacing between the plates. Assuming that the modified condenser is worked at double the voltage previously used, compare in the two cases :—

(*a*) *The capacitances.*
(*b*) *The total volt amperes taken by the condenser.*
(*c*) *The volt amperes per unit volume of dielectric taken by the condenser.*

A. 8.

(*a*) The capacitance of a condenser varies inversely as the distance between the plates, hence if the spacing is doubled the capacitance will be halved.
(*b*) The volt amperes vary as CV^2, therefore if the spacing and V are doubled the volt amperes will be doubled.
(*c*) Since the volume of dielectric is doubled, the volt amperes per unit volume will be the same in the two cases.

Q. 9. A resistance of 1,500 ohms and an inductance of 5 henries are connected in parallel across a 50 cycles per sec. alternating current supply of 1,000 volts R.M.S. What will be the total current taken from the mains?

A. 9.

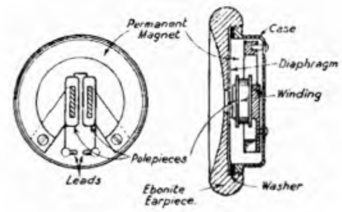
$$I = V\left\{\frac{1}{R} + \frac{1}{j\omega L}\right\} = V\,\frac{\sqrt{R^2 + \omega^2 L^2}}{\omega L R}\ \text{numerically.}$$

$V = 1000 \quad R = 1500$ ohms $L = 5$ H $\quad f = 50$ cycles per second.

$$\therefore\ I = \frac{1000\,\sqrt{(1.5 \times 10^3)^2 + (2\pi \times 50 \times 5)^2}}{2\pi \times 50 \times 5 \times 1500} = 0.92\ \text{A.}$$

Q. 10. Describe the construction of a telephone receiver and explain its action in the production of audible signals. Why is a condenser sometimes connected across a telephone, and when is the use of such a condenser advisable?

A. 10. One type of telephone receiver is shown in the sketch. It consists essentially of a permanent magnet, the two pole pieces of which are brought to the centre of the case. A fine wire winding is wound on formers and fitted upon the pole pieces, the windings being joined in series and brought out to two terminals. A thin stalloy diaphragm is placed over the magnet and is clamped in position, at its edges by the earpiece. The sensitivity of the receiver is increased by the use of a permanent magnet and by the provision of an adjustment permitting the air gap between the diaphragm and the pole faces to be reduced to a minimum.



The diaphragm is being continuously pulled towards the pole faces by the permanent magnet, but if an audio frequency current is passed through the winding it will vary the magnetic flux and hence the tension on the diaphragm thus setting up mechanical vibrations, *i.e.*, sound, at a frequency equal to that of the current and proportional to its amplitude.

A telephone will offer a high impedance to radio frequency currents and hence a condenser is fitted across it to bipass such currents when it is used in series with a rectifier across a radio frequency circuit.

IV. RADIO-COMMUNICATION, FINAL, 1933. QUESTIONS AND ANSWERS

By A. C. Warren, B.Sc., A.M.I.E.E.

Q. 1. A small frame aerial is connected across a calibrated variable condenser. A valve voltmeter is also connected across the condenser.

The frame is placed so that its plane is inclined at 45° to the direction of a distant transmitting station sending a continuous dash on 100,000 cycles per second. Maximum deflection of the voltmeter is obtained when the condenser is adjusted to 1,000 μμF.

The frame is then turned until its plane is in the direction of the transmitting station and the condenser adjusted to give an equal deflection on the valve voltmeter. The capacitance of the condenser is then 990 μμF.

What is the inductance and resistance of the frame aerial circuit?

A. 1. At resonance $\omega^2 LC = 1$.

$$\therefore\ L = \frac{1}{\omega^2 C} = \frac{10^9}{4\pi^2 \times 10^{10}} = .002533\ \text{H.}$$

Let the voltage induced in the frame when untuned but in the direction of the transmitter be e and the current i_1. Then the voltage induced when the frame is at 45° will be $\frac{e}{\sqrt{2}}$ and the current i_1.

The voltage across the tuning condenser will be $\frac{i}{\omega C}$ and since this is equal in the two cases $\frac{i_1 \times 10^{12}}{\omega \times 1000} = \frac{i_2 \times 10^{12}}{\omega \times 990}$

$$\text{or}\quad i_2 = i_1 \times \frac{990}{1000}$$

$$\text{But}\quad i_1 = \frac{.707e}{R} \quad\text{and}\quad i_2 = \frac{e}{\sqrt{R^2 + X^2}}$$

$$\text{Thus}\quad \frac{e}{\sqrt{R^2 + X^2}} = .99 \times \frac{.707e}{R}$$

$$\text{or}\quad \sqrt{R^2 + X^2} = \frac{R}{.99 \times .707}$$

and $X^2 = 1.04\ R^2$

$$\text{But}\ X^2 = \left(\omega L - \frac{1}{\omega C_2}\right)^2 =$$

$$\left(2\pi \times 10^5 \times 2.533 \times 10^{-3} - \frac{10^{12}}{2\pi \times 10^5 \times 990}\right)^2$$

$$= (16.07)^2$$

$$\therefore\ R = \frac{16.07}{1.04} = 15.75\ \text{ohms.}$$

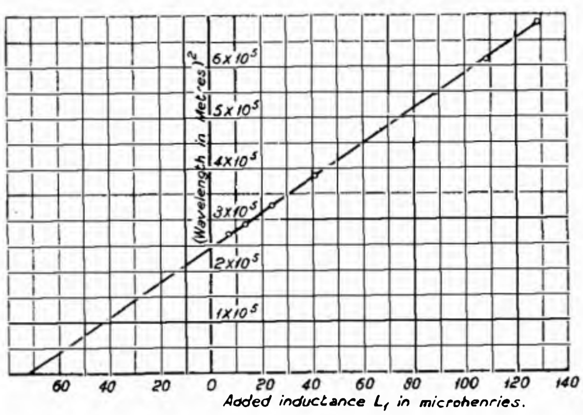
Q. 2. The following measurements were taken on an antenna by adding inductance and measuring the wave-length:—

Added inductance in microhenries.	7.3	13.9	24.5	41.5	66.8	89	109.2	129
Wave-length in metres.	522	541	573	620	688	738	782	826

Determine by means of a graph the inductance, capacitance and natural wave-length of the antenna.

If the effective height of the antenna is 30 metres, what power would be radiated on 600 metres with a current of 10 amperes in the base of the antenna?

A. 2. From the graph of wave-length² plotted against added inductance we see that



L_e the effective inductance = 73 μH

λ_0^2 the natural wave-length² = $2.45 \times 10_5$

i.e., = 495 *metres.*

$$C_0 \text{ the capacity} = \frac{\lambda_0^2}{1885^2 L_0} = \frac{495}{1885^2 \times 73} = 915\ \mu\mu F.$$

$$\text{Power Radiated} = 1584\,\frac{h^2}{\lambda^2}\,I^2$$

$$= 1584\,\frac{30^2}{600^2} \times 10^2 = 396\ \text{watts.}$$

Q. 3. The field strength of a station transmitting on 40 kc/s is measured at a distance of 50 kilometres and found to be 30 millivolts per metre. At a distance of 200 kilometres the field is 2 millivolts per metre. What is the attenuation factor of the wave?

A. 3. The field strength at a point distant (d) from a station is $E = \frac{377hI}{\lambda d} \times 10^3 \times e^{-\frac{\alpha d}{\sqrt{\lambda}}}$ millivolts per metre, where α is the absorption coefficient or attenuation factor.

$$\therefore \frac{E_1}{E_2} = \frac{\frac{1}{d_1} \times e^{-\frac{\alpha d_1}{\sqrt{\lambda}}}}{\frac{1}{d_2} \times e^{-\frac{\alpha d_2}{\sqrt{\lambda}}}}$$

$$\text{then } \frac{30}{2} = \frac{200}{50} \times e^{\frac{\alpha}{\sqrt{\lambda}}(d_2 - d_1)}$$

$$i.e., \frac{\alpha}{\sqrt{\lambda}}(d_2 - d_1) = \log_e 3{\cdot}75$$

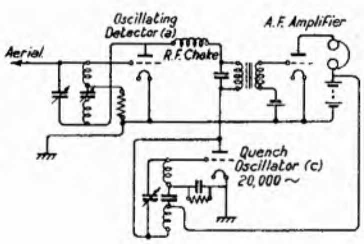
If λ and d are in metres,

$$\alpha = \frac{\sqrt{7{\cdot}5 \times 10^3} \times 2{\cdot}303 \times {\cdot}574}{150 \times 10^3}$$

$$= {\cdot}00076.$$

Q. 4. Describe, with a diagram, the circuit and action of a super-regenerative receiver. State the range of wave-length for which this receiver is most suited and mention any of its advantages and disadvantages.

A. 4. The circuit diagram of a super-regenerative receiver is shown in the sketch; it consists of:—



(*a*) An oscillating detector with cumulative grid rectification, the R.F. choke in the anode circuit being provided to offer a high impedance at the working frequency, but low impedance at the frequency of (*c*).

(*b*) An audio frequency transformer, coupling the output to an audio frequency amplifier or phones.

(*c*) A low radio frequency oscillator, the output of which is placed in series with the H.T. supply to the oscillating detector to provide the regenerative action.

The efficiency of a radio frequency amplifier is increased if retroaction between anode and grid circuits is introduced. At radio frequencies and particularly on short waves it is difficult to introduce this retroaction without the circuit bursting into permanent self oscillation. If, however, the anode voltage is reduced to zero or a small value this oscillation will cease. If, therefore, the anode voltage is varied periodically it is possible to permit the circuit to burst into self oscillation and to quench it say at a low radio frequency rate of the order of 20,000 cycles per second. This variation in anode potential is obtained by injecting an e.m.f. from the quench oscillator in series with the H.T. supply. In this way high amplification of the incoming signal can be effected with stability.

This type of receiver can be utilized most effectively on ultra short-waves—waves below 10 metres in wave-length—where it is extremely difficult to design either superheterodyne or simple receivers. This, its high sensitivity and simplicity are its main advantages. The principle disadvantage is its lack of selectivity.

Q. 5. A circuit consists of two branches in parallel. One branch consists of an inductance L in series with a resistance R; the other branch consists of a condenser C in series with a resistance R.

If $\frac{L}{C} = R$, prove that the impedance of the circuit is independent of frequency and equal to R.

A. 5. If Z is the impedance of the two branches in parallel

$$\frac{1}{Z} = \frac{1}{R + j\omega L} + \frac{1}{R + \frac{1}{j\omega C}}$$

$$\text{But } \sqrt{\frac{L}{C}} = R \text{ or } \frac{\omega L}{\omega C} = R^2,\ i.e.,\ \omega L = \omega C R^2$$

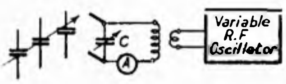
$$\therefore \frac{1}{Z} = \frac{1}{R + j\omega CR^2} + \frac{j\omega C}{j\omega CR + 1}$$

$$= \frac{1 + j\omega CR}{R(1 + j\omega CR)} = \frac{1}{R}$$

$$i.e.,\ Z = R.$$

Q. 6. A three-gang condenser assembly as used for broadcast receivers is provided with trimming condensers and end vane adjustment. Describe the method that you would adopt and the apparatus necessary to adjust the three elements so that they matched accurately at four points in the range.

A. 6. The condenser assembly would be tested with apparatus as in the diagram. A variable radio frequency oscillator



is loosely coupled to a circuit comprising a tuning coil, thermo milliameter or Moullin voltmeter, a fine tuning condenser C and means for switching in the condenser units. One condenser unit is switched in and set to its maximum value C being set at mid-scale. The oscillator is then tuned until the circuit is resonant as indicated by the milliameter A. The next unit is then switched in and C varied to show whether the capacity needs increasing or decreasing. C is then set back to mid-scale and the unit adjusted by the trimmer until resonance is obtained. This process is then repeated for the third unit.

The first unit is switched in once more and set to a different value. With C at mid-scale the oscillator is again adjusted until resonance is obtained. Unit 2 is then switched in and C varied to show whether an increase or decrease in capacity is needed to bring the circuit into resonance. C is reset to mid-scale and the end vane adjusted until resonance is secured. This process is then repeated for unit 3.

The whole process as in the above paragraph is repeated for other points on the scale.

Q. 7. Explain the causes of fading in the reception of short and medium waves. What methods are adopted in practice to minimise the effects of fading?

A. 7. The radiation from a transmitting aerial in the vertical plane is dependent on the dimensions of the aerial. On short and medium waves these may be commensurate with the wave-length and the radiation at an angle to the horizontal increases. There is therefore radiation along the ground (ground wave) which is rapidly attenuated and radiation at an angle which it is found penetrates the Heaviside layer, travels with little attenuation in an ionised medium and then is reflected back to earth from a higher layer. Owing to variations in these layers it is very easy for rays travelling on slightly different paths to arrive at the receiver, thus on wave-lengths of 10-500 metres it is clear that over distances say of 200 kilometres or more components rays may arrive out of phase since they have travelled by different paths as it may only need a variation of .01% in the length of the path to accomplish this. Continuous and non-uniform variation in this medium will thus give rise to interference between the rays, *i.e.*, to irregular fading.

Further, before the ground wave is entirely absorbed both ground wave and sky wave, as the high angle radiation is termed, will arrive at a given point by paths of different length and so will interfere. This interference will cause fading of the signal. It is of two types, selective and unselective fading, that in which frequencies close together (a carrier and its sidebands) fade unequally and that in which all frequencies in a band fade simultaneously.

There are two other phenomena sometimes included as fading. The height of the Heaviside layer and also of the F, or Appleton, layer varies with the time of day and if the radiation is at angle and exceeding a critical value it will penetrate the layer. Thus one wave-length will give satisfactory results to a given point over a portion of the day and may fade out entirely over the remainder. This necessitates the use of several wave-lengths to cover the full 24 hours.

Magnetic storms cause interference on short waves and may cause the field to fade entirely for periods of hours or days.

The effects of fading may be reduced by—

(1) The design of transmitting aerials to have either little or no high angle radiation (sky wave) or little or no horizontal radiation (ground wave).

(2) Diversity reception—the use of several aerials or arrays located, say, 1000 feet apart. The sum of the e.m.fs., induced in these aerials remains practically constant.

(3) Automatic gain control or for telegraphy the use of limiting valves embodied in the receiver.

Q. 8. A steel aerial tower 500 ft. high stands on a square base of 120 ft. side. The weight of the tower including foundations is 400 tons. The wind load on the antenna produces a force at the top of the mast normal to the direction of the wind equal to 0.5 v^2 lb. where v is the velocity of the wind in feet per second. The wind load on the tower itself produces a force in the direction of the wind equal to 1.5 v^2 lb. at a height of 200 ft. from the ground. The foundation of the tower extends 10 ft. below ground.

If the resultant moment due to the above forces is parallel to one of the sides of the square base, what is the velocity of the wind, in miles per hour, which will cause the tower to overturn?

A. 8. The resultant overturning moment will be

$$M = \sqrt{(510 \times 0.5\, v^2)^2 + (210 \times 1.5\, v^2)^2} \text{ lbs. ft.}$$

$$= v^2\sqrt{255^2 + 315^2} = 405\, v^2.$$

This is equal to the restraining moment

$$= 400 \times 2240 \times 60 \text{ lbs. ft.}$$

$$\therefore v^2 = \frac{400 \times 2240 \times 60}{405}$$

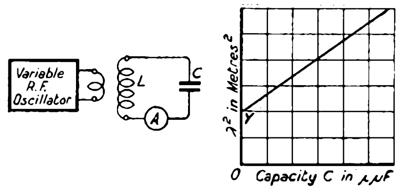
$$\text{or } v = \sqrt{\frac{400 \times 2240 \times 60}{405}} \times \frac{3600}{5280} \text{ miles per hour.}$$

$$= 248 \text{ m.p.h.}$$

Q. 9. How would you determine the natural wave-length of a coil? An oscillatory circuit containing a thermo-milliameter is weakly coupled to a power oscillator and tuned to resonance when the reading of the thermo-milliameter is 20 milliamperes. A resistance of 5 ohms is then added in series with the resonant circuit and the current becomes 4 milliamperes. What is the resistance of the circuit?

If damped oscillations had been generated in the circuit itself by means of a buzzer and the current without the added resistance had been 20 milliamperes, what would have been the reading when the resistance of 5 ohms was inserted?

A. 9. A calibrated local oscillator or wave-meter is loosely coupled to a circuit comprising the coil under test, a thermo milliameter and a standard variable condenser. The resonant wave-length of the circuit is measured for various values of the standard condenser C and a curve is plotted of the wave-length squared against C. This curve should be a straight line and if continued until it cuts the Y axis as in sketch the value of OY will be the natural wave-length of the coil squared.



If R is the resistance of the circuit

$$\frac{E}{R} = .02 \text{ and } \frac{E}{R+5} = .004$$

$$\therefore \frac{R+5}{R} = 5 \text{ or } R = 1.25 \text{ ohms.}$$

If damped waves had been used then

$$I_1^2 R = I_2^2 (R + 5)$$

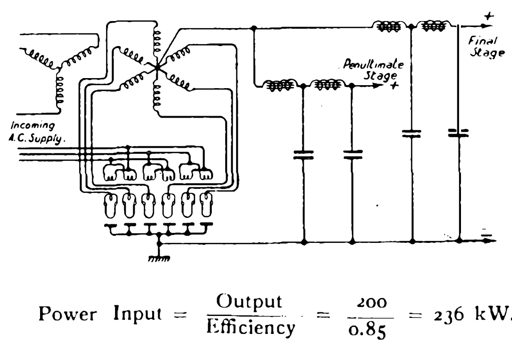
$$\therefore I_2 = I_1\sqrt{\frac{R}{R+5}} = 20 \times \sqrt{\frac{1.25}{6.25}} = 9 \text{ milliamperes.}$$

Q. 10. Give a circuit diagram of a three-phase full-wave thermionic rectifier, using cooled anode valves suitable for furnishing high tension direct current to a high-power valve transmitter. The anodes of the rectifier valves are to be worked at earth potential.

Smoothing circuits are to be shown suitable for supplying the penultimate and final stages of the transmitter.

The output of the rectifier is 200 kW and the efficiency 85 per cent. What will be the current taken from the supply mains at a power-factor of 0.8 if the voltage of supply between phases is 400?

A. 10.



$$\text{Power Input} = \frac{\text{Output}}{\text{Efficiency}} = \frac{200}{0.85} = 236 \text{ kW.}$$

$$\text{kVA Input} = \frac{236}{0.8} = 294 \text{ kVA} = \frac{\sqrt{3}VI}{1000}$$

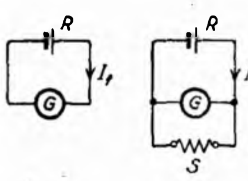
$$\therefore \text{Input Current} = \frac{294 \times 10^3}{1.732 \times 400} = 425\text{A.}$$

V. TELEPHONY, PRELIMINARY, 1933: QUESTIONS AND ANSWERS

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

Q. 1. Describe a method of finding the internal resistance of a Leclanché cell. Explain the theory of the method. (30 marks).

A. 1. A voltmeter is first connected across the cell and the reading, V_1, is noted. A known resistance, S, usually two ohms (per cell), is then connected in shunt with the voltmeter and the reading, V_2, is noted. The internal resistance, R, of the cell is then given approximately by $R = \frac{S(V_1 - V_2)}{V_2}$



Test 1. *Test 2.*

If V_2 does not fall below half V_1, this formula is sufficiently accurate for practical purposes; otherwise, the resistance of the voltmeter, G, needs to be taken into account by using the formula $R = \frac{GS(V_1 - V_2)}{V_2G - S(V_1 - V_2)}$ To avoid errors in the result of the test from the effects of polarization, the potential difference across the shunt should be observed as quickly as possible after the shunt is applied.

Provided that the resistance of the voltmeter is sufficiently great compared with the internal resistance of the cell and the resistance of the shunt, the first reading, V_1, is the open circuit e.m.f. of the cell whilst the second reading, V_2, is the potential difference across the ends of the shunt. These two readings are in the same proportion to one another as the total resistance of the circuit, S + R, is to the shunt resistance, S. Hence,

$$V_2 = V_1 \times \frac{S}{S + R}$$

$$\therefore V_2S + V_2R = V_1S$$

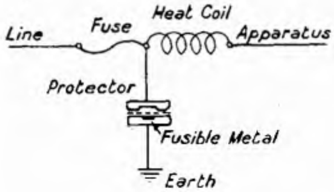
$$V_2R = V_1S - V_2S = S(V_1 - V_2)$$

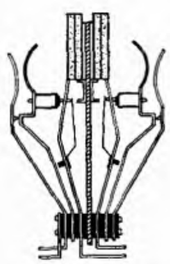
$$R = \frac{S(V_1 - V_2)}{V_2}$$

(Where the resistance of the voltmeter has to be taken into account, the extended formula given above is derived by the method given in the answer to Q.9 on page 8 of the previous Supplement).

Q. 2. State the functions of a main distribution frame, and the precise duty of each of the protective devices provided on the frame. (30).

A. 2. The main distribution frame provides a cross-connexion field, whereby the lines terminated in cable order may be connected to the apparatus in the numerical order of the subscribers' exchange numbers. It also carries the protective devices, and provides a testing point from which faults may be tested and located. The connexion of new subscribers, removal of subscribers from one address to another, cessations, and changes in the external plant due to growth, are effected without interference with the cabling by altering the jumper connexions only. The right-hand sketch shows the





arrangement of the heat coils, protectors, and test jack required for one line; by inserting a plug into the jack, formed by the two outer pairs of springs, testing or other apparatus may be inserted in the line. This equipment is mounted on the apparatus side of the frame, the fuses being fitted on the line side. Connexion between the two is made by 1-pair leads termed "jumpers."

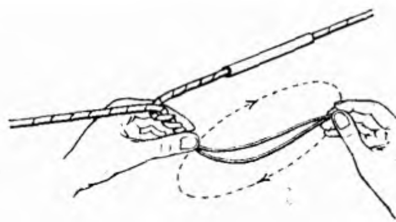
The left-hand sketch shows the arrangement of the fuse, protector, and heat coil connected in each wire. The protector is designed to operate when the line is subject to a voltage of the order of 350 volts, due, say, to contact with a power wire or to a lightning strike. The operation of the protector earths the wire, so preventing damage to the exchange apparatus. The fuse is designed to operate when a current of 3 amperes is experienced for a period of 45 seconds; the blowing of the fuse disconnects the line. The heat coil is designed to operate when a current of 500 mA is experienced for from 60 to 210 seconds, depending upon the type of heat coil.

Thus, if the protector is operated by contact with a power wire, the earthing of the line causes the fuse to blow. Had lightning been the cause, however, it is probable that neither fuse nor heat coil would have been affected. When a current insufficient to blow the fuse is experienced, damage to the apparatus is prevented by the heat coil which either disconnects or earths the line, according to type.

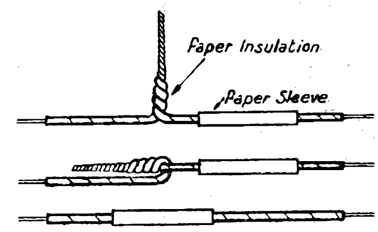
Q. 3. Describe, with the aid of sketches, the process of making a straight-through joint in a 600-pair air-space paper-core cable made up of conductors each weighing 10 lb. per mile. Mention, without any detailed description, what has to be done to seal and test the joint. (30).

A. 3. The manhole in which the joint is to be made is first thoroughly dried out by means of braziers or blow-lamps, and the ends of the cable to be jointed are worked into position; where a considerable amount of bending is required, spring-steel cable-benders are used to facilitate the operation. A lead sleeve of suitable size is placed over one of the ends, and the lead sheath is then removed from each end for the required distance. The outer wrapping of insulating paper is removed and the upper half of the outer layer of wires is tied back over the cable; the other half is similarly tied back underneath the cable. Each of the layers in the cable is treated in this manner.

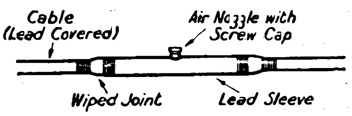
Paper sleeves, which have been thoroughly dried, are then placed over each wire of one of the cable ends. Jointing is commenced with the centre layer. The two wires to be jointed are placed together, and given three or four twists in a length of ½ inch with the paper insulation intact upon both wires. At the end of this preliminary twist, the paper is removed, the conductors cleaned, twisted together, and the surplus wire cut away, leaving about 1 inch of twisted conductors. The "crank handle" method of twisting the wires (see sketch) is



preferable to any other, as it results in a tighter twist towards the tip of the joint; the slackness at the base is beneficial, as it permits the normal expansion and contraction of the conductor to take place without slackening the twist. The joint is completed by bending the twisted portion over parallel to the conductor and drawing the paper insulating sleeve over the exposed twist; the sketch shows the stages in the jointing of two wires. The joints between the wires are staggered along the length of the joint to prevent the completed joint from being too bulky. A certain amount of slackness in the completed joint is desirable, as this facilitates access to the centre and first layer joints on any future occasion.



Each of the conductors having been jointed in this manner, the completed joint is thoroughly dried out and wrapped with insulating paper tied in position with cotton thread. Where an air nozzle is provided in the lead sleeve, a hole is cut in the insulating paper at the point below it. The lead sleeve is pulled over the joint, and the ends dressed down over the cable. The cable sheath and the ends of the sleeve are well cleaned with a scraper, and a band of plumber's black is painted round the sheath and the sleeve to mark the limits of the wipe. Molten plumber's metal is then wiped into position to secure the lead sleeve to the sheath of the cable. The wipe should be quite uniform and without any trace of eccentricity, and perfectly homogeneous. In the sketch, the sleeve is shown

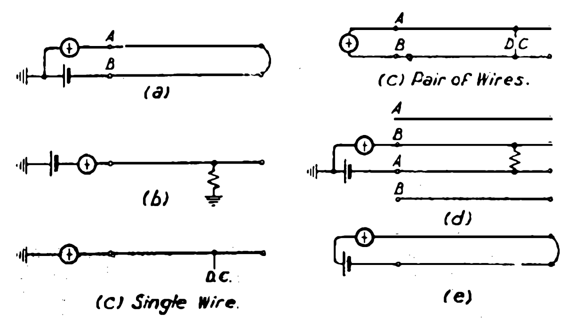


fitted with an air nozzle; this, however, is fitted only as a temporary measure for desiccating purposes and when it is removed the hole is closed by a patch wipe.

The plumbing of the joint is tested by pumping dry air into the cable and painting the wipes with a soap-sud solution; a small hole in the wipe is shown up by the bubbles which arise at the point. The pairs are tested for continuity, and freedom from contacts, crosses, or earths. The conductor resistance is also checked, and, in certain circumstances, a cross-talk test may be made. Lastly, the cable is tested for insulation resistance.

Q. 4. Give diagrams showing the connexions of battery, detector, and line when making simple tests for (a) loop, (b) earth, (c) current, (d) contact, and (e) disconnexion. In what order should the tests normally be made, and how is each type of fault located on overhead lines? (30).

A. 4. The connexions of the battery, detector, and line when making the tests specified are shown in the sketch. Normally,

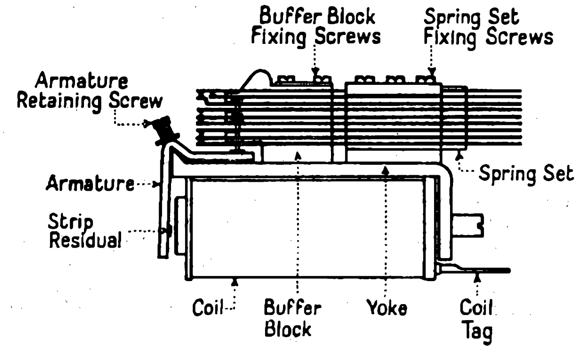


a test for current should be made before a test for earth (low insulation resistance). Otherwise, the presence of an undetected extraneous earth current would give the appearance of low insulation on the line. Next, tests for loop and disconnexion are made and, finally, the line is tested for freedom from contact.

The localization of contacts, short-circuits, earths, and earth currents is made by disconnecting the line at successive testing points until the fault is proved to exist in the section of line between two adjacent points. The localization of a disconnexion is made by disconnecting the line wires and looping them on the side towards the testing office; this is done at successive testing points until the fault is proved to exist between two adjacent points.

Q. 5. Give a sectional sketch and short description of a telephone relay of modern design. State the main considerations which arise in the design of the magnetic circuit. (35).

A. 5. A sectional sketch of the P.O. standard telephone relay is given. The coil is wound on a soft-iron core and the



magnetic circuit is completed through the yoke and the knife-edge armature. The iron is nickel-plated for protection, and the armature is held in position by a retaining screw. The spring set consists of the required number of springs, insulated from one another, and clamped between plates held together by the centre of the three fixing screws. The contacts are of the twin type and the contact material used is silver. The spring set is fixed to the yoke by the two outer fixing screws. The insulation between the springs projects through the mounting plate to reduce the danger of faults being caused by spring tags touching or being bridged by pieces of solder.

A buffer block of white insulating material is placed between the two spring sets, and projections on the fixed springs rest upon shoulders in this block. The springs are tensioned so that the required pressure between the contacts is just sufficient to lift the spring clear of the shoulder, so ensuring that the desired contact pressure shall be obtained when the relay is operated.

The magnetic circuit must be of high efficiency, and to this end the joints in the circuit must be of low reluctance. High magnetic efficiency permits heavy contact pressures to be used and so decreases the risk of contact failure. It also permits the use of large residual air gaps and so lessens the possibility of the armature failing to release. Further, fewer ampere-turns are required to carry a given spring load and, consequently, a winding of higher resistance can be employed, with a saving in current consumption. The knife edge type of relay is extremely efficient, and this magnetic circuit has been adopted for the standard telephone relay. At the front end of the core is welded a round disc of soft iron which provides a pole-face of large cross-section, so reducing the reluctance between the core and the armature. The yoke is provided with an enlarged end which is machined into a knife edge on which the V-bend of the armature fits fairly closely, so ensuring a magnetic joint of low reluctance. The core fixing nut is also of special design to obtain low reluctance at this joint also. Nickel plating is used for protection, as this material is magnetic.

(*To be continued.*)

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