SUPPLEMENT

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II. TELEPHONY, INTERMEDIATE: QUESTIONS AND ANSWERS.

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

Q. 9. Indicate, by means of a sketch, the arrangement of the principal parts of a measuring instrument of the moving-coil type. State the factors which determine the angle through which the coil turns when a current of given value passes through it. Why are the scale divisions of uniform width throughout the range of the instrument? (35).

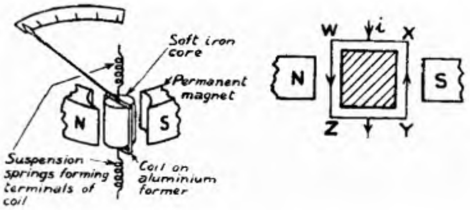
A. 9. Sketch (*a*) shows the principal parts of a measuring instrument of the moving-coil type.

The factors which determine the angle through which the coil turns when a current of given value passes through it are

(i) The number of turns of wire on the coil,

(ii) The field strength, H, due to the permanent magnet, and

(iii) The rigidity of the suspension.



(*a*) (*b*)

Let l be the length of one turn of the coil, XY = WZ in sketch (*b*) and h be the width WX = ZY. Then the force on XY due to a field H of the magnet when a current i is flowing in the coil is iHl in a backward direction. An equal forward force is exerted on WZ, and the torque due to this couple is $iHlh$. This is the total torque on one turn, as the horizontal portions of the coil do not experience any force; if n is the number of turns, the total torque on the coil is $niHlh$. Writing $lh = A$, the " developed area " of the coil, the torque is $niHA$.

The purpose of the soft-iron core is to concentrate the lines of force in its interior, and so make the field as nearly radial as possible. This is true for small deflections, but for larger deflections, the vertical portions of the coil enter a field which is more nearly transverse with the result that the torque becomes $niHA \cos \alpha$, where α is the deflection.

The restoring torque exerted by the suspension is proportional to the deflection and may be written $k\alpha$, where k is a constant. Equating this to the torque on the coil, then for small deflections,

$$i = \frac{k}{nAH}\alpha = K\alpha$$

where $K \equiv k/nAH$ is the galvanometer constant. For large deflections

$$i = \frac{k}{nAH \cos \alpha}\alpha$$

Thus, neglecting the special case for large deflections, the deflection depends directly upon the strength of the current. It is possible, therefore, to make the scale divisions of uniform width throughout the range of the instrument. For laboratory instruments, however, the effect of variations in the dimensions of instruments during manufacture have to be taken into account, and it is customary to engrave the scales of such instruments by hand after calibration against a standard instrument. The scale divisions of such instruments are not absolutely uniform, but for instruments where a high degree of accuracy is unnecessary, uniform scale divisions are used.

Q. 10. State the general conditions which must apply in order that telephone circuits may be free from disturbance due to inductive effects. Indicate, briefly, how the essential requirements are met as regards (a) line plant, and (b) circuit design. What reasons are there for preferring the transposition system to the twist system on open lines? (40).

A. 10. In order that telephone circuits may be free from disturbance due to inductive effects, the line must consist of a metallic pair and it should not parallel any high tension power lines to any great extent. The two wires of a pair must be electrically similar, and the telephone receivers must be located at neutralizing points.

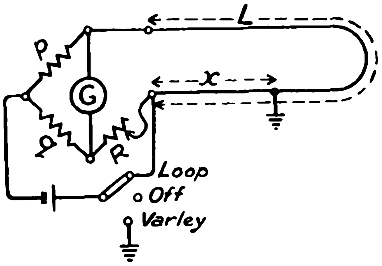
(*a*) With regard to line plant, the requirements are met by running all wires on either the transposition or the twist system with the object of neutralizing the currents induced in each wire. The lead sheath of an underground cable does not provide a sufficient screening effect under certain circumstances, and where a line unavoidably parallels a high tension power line, it may be necessary to insert transformers in the line at short intervals to prevent disturbances passing from one length to the next as well as to prevent the induced voltage from reaching a dangerous value. Incidentally, by running an earth wire on the pylons supporting the high tension line, the disturbance may be reduced by nearly one-half due to the effect of the currents induced in the earth wire re-acting on the telephone line.

(*b*) In circuit design, the conditions are met by making each wire of a pair electrically similar. For this purpose, matched impedances are used in the A and B wires. Divided cord circuits are used to obviate the cumulative effects of unbalanced circuits. By these means, it is ensured that, given homogeneous lines, the telephone receivers are located at the electrical centre of the loop, that is, at the neutralizing points.

The transposition system is preferable to the twist system because the wires are run straight and can therefore be erected more speedily. Transposed lines are also easier to fault, as the wires in the centre of the span can be seen more clearly. Further, when erecting a single pair of wires, it is only necessary to provide one arm at each pole in place of the two required by the twist system.

Q. 11. *Sketch the connexions required for making a bridge test for the position of an earth fault of low resistance on one wire of a telephone circuit. Establish a formula for the distance of the fault from the testing station. Explain, briefly, why it is necessary, if the earth fault is of high resistance, to make tests from both ends of the line.* (40).

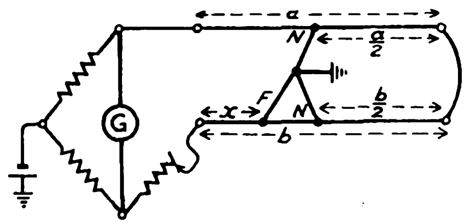
A. 11. The connexions required for making a bridge test for the position of an earth fault of low resistance on one wire of a telephone circuit are shown in sketch (*a*). The loop resist-



(*a*)

ance, L, is first measured, and in the condition of balance $L = \frac{pR}{q}$; if $p = q$, then $L = R$, where p and q are the resistances in the adjustable ratio arms, and R is the resistance of the adjustable arm when balance is obtained. The positive pole of the battery is then disconnected from the bridge and connected to earth ; this is conveniently done by means of the three-position switch. When the bridge is re-balanced, $x = \frac{qL - pR_1}{p + q}$ and if $p = q$, then $x = \frac{L - R_1}{2}$ where R_1 is the resistance of the adjustable arm in the second test. The value x is, of course, expressed in ohms and is the resistance along the wire from the testing point to the fault ; this value is expressed in linear measure from a knowledge of the make-up of the line under test.

The conditions when testing for the position of a high resistance earth fault, F, are shown in sketch (*b*). The more closely the resistance of the fault approximates to the normal insulation resistance, N, of the line, the greater the error introduced in the test ; the normal insulation resistance may be regarded as a lumped resistance to earth located at the centre of the line, and, in the conditions shown in sketch (*b*), the test would indicate a point somewhere between F and N as the



(*b*)

position of the fault. Similarly, a test taken from the other end of the line would indicate a similar error and by combining the two formulæ for the position of the fault, the portions giving rise to the error, viz., F and N, can be eliminated and an expression obtained which includes a correction factor due to the normal insulation of the line affecting the true position of the fault.

Q. 12. *A sinusoidal voltage, having a periodicity of* 800 *cycles per second, and a constant maximum value, is applied to a long telephone line which has uniform transmission characteristics. The maximum voltages at points one mile apart are in the ratio* 5 : 4, *and the phase difference is* 0.2 *radian. What would be the voltage ratio and phase difference over a distance of three miles? State the relationship between the frequency of the transmitted wave, its wave length, and its velocity of propagation, and find the velocity in miles per second.* (40).

A. 12. With a voltage ratio of 5 : 4, then 0.8 of the maximum voltage sent into the line at the beginning of the first mile is received at the end of that mile ; this received voltage is sent into the second mile where it is again attenuated to 0.8 of its value at the beginning of the second mile. The voltage received at the end of the second mile is therefore $0.8 \times 0.8 = 0.8^2 = 0.64$ of the voltage sent into the first mile. The received voltage is sent into the third mile and is again attenuated in the same ratio, with the result that the voltage received at the end of the third mile is $0.8 \times 0.8 \times 0.8 = 0.8^3 = 0.512$ of the voltage sent into the first mile.

The phase displacement over each mile of line is 0.2 radian. Hence, the phase difference over three miles of line is $3 \times 0.2 = 0.6$ radian.

As the frequency (f) is the number of waves per second, and the wave-length (λ) is the distance between two consecutive wave crests, the product of these two quantities gives the distance travelled in one second, that is, the velocity of propagation (v). Thus, $v = f\lambda$, whence $f = v/\lambda$ and $\lambda = v/f$.

In the case quoted, the wave moves through 0.2 radian for every mile of its travel. Hence, the distance travelled in moving through one complete cycle, that is, through $360° = 2\pi$ radians, is the wave-length in miles. Taking $\pi = 3.14$, this distance is $2\pi/0.2 = 31.4$ miles. Hence, the velocity of the wave is

$$v = f\lambda = 800 \times 31.4 = 25{,}120 \text{ miles per second.}$$

RADIO COMMUNICATION : PRELIMINARY. QUESTIONS AND ANSWERS.

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

Q. 1. *State the methods which are adopted to reduce the self capacity of receiving inductances. In two similar coils having the same number of turns, the linear dimensions of one coil are in all cases double the corresponding dimensions of the other. How will their inductances compare?*

A. 1. If a coil is wound as a long multilayer solenoid, the layers being wound backwards and forwards on each other, the self capacity will be high. The self capacity may be materially reduced by

(*a*) Sectionalizing the winding, each section being wound as a solid coil no special endeavour being made to reduce its self capacity by a special arrangement of turns.

(*b*) By means of a wave winding with or without air spacing between turns, the coil being in the form of a flat pancake.

(*c*) By the use of a single layer solenoid with air core or iron core such as ferrocart.

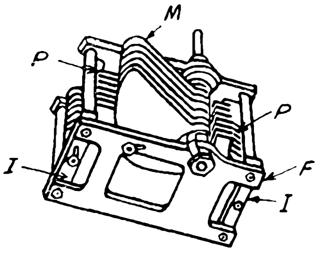
(*d*) Iron cored coils with dust iron or permalloy cores.

In early receivers basket coils, a simple form of wave winding, and pile wound coils were utilized.

If two coils have the same number of turns and one has twice the physical dimensions of the other, the inductance of the larger coil will be double that of the small coil since L varies as $\frac{A}{l}$ where A is the area of the coil and l the length.

Q. 2. Describe with a sketch the construction of a variable condenser for receiving purposes.
What is meant by—
(a) straight line capacity condenser
(b) square law capacity condenser
(c) straight line frequency condenser?
What are the particular advantages of each of the above types and under what conditions will they operate in the intended manner.

A. 2. A variable condenser is shown in the sketch. It consists of a framework F on which are mounted a group of fixed plates P which are insulated from the frame by the insulating strips I. The moving plates M are mounted on a spindle and assembled with the frame so that they interleave with the fixed plates. A reliable connexion between the moving plates and the frame may be obtained by means of a pigtail or cup washers. Rotation of the plates is effected by a suitable knob which may be of the slow motion type. A dial and pointer are provided to indicate the setting of the condenser.



A straight line capacity condenser is one in which the capacity, apart from the residual capacity at zero setting, is proportional to the angular setting as indicated on the dial. The moving plates of such a condenser are semi circular.

A square law capacity condenser is one in which the moving plates are so shaped that the capacity is proportional to the square of the angular setting as indicated on the dial.

A straight line frequency condenser is one in which the capacity is inversely proportional to the square of the setting as indicated on the dial; so that, if the condenser is used with a fixed coil, uniform increases in angular setting of the dial will represent uniform increases in resonant frequency.

The straight line-capacity condenser is most useful when the variable condenser represents only a fraction of the capacity in the circuit. In such a case, small increments of setting will be proportional to increments in wave-length, *i.e.*, the condenser will become very nearly a straight line-wave-length condenser over a limited range of wave-length. This type of condenser is straight line capacity except at the limits of its range.

Square law-capacity or straight line frequency condensers have the advantage that wave-length or frequency settings are evenly distributed throughout the length of the scale. Their calibration, in terms of wave-length or frequency is disturbed however if they are used in series or parallel with other condenser, or unless due allowance is made for the self capacity of coils with which they are used.

Q. 3. What is the impedance at a frequency of 900 kilocycles per second of a circuit consisting of a condenser of 0.0002 microfarad capacitance in series with a coil of 200 microhenrys inductance and 25 ohms resistance?

A. 3.

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

$$\omega = 2\pi f = 2\pi \times 9 \times 10^5 = 5.655 \times 10^6$$

$$\omega L = 5.655 \times 10^6 \times 2 \times 10^{-4} = 1131 \text{ ohms}$$

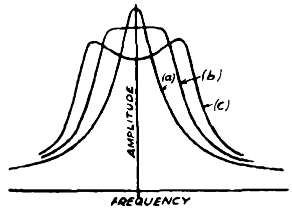
$$\frac{1}{\omega C} = \frac{1}{5.655 \times 10^6 \times 2 \times 10^{-10}} = 884 \quad ,,$$

$$\omega L - \frac{1}{\omega C} = 247 \quad ,,$$

$$Z = \sqrt{25^2 + 247^2} = 248.2 \text{ ohms}$$

Q. 4. What advantage is derived from using a coupled circuit in a receiver? How is the response of the receiver to incoming signals modified as the coupling is gradually increased from zero to a maximum?

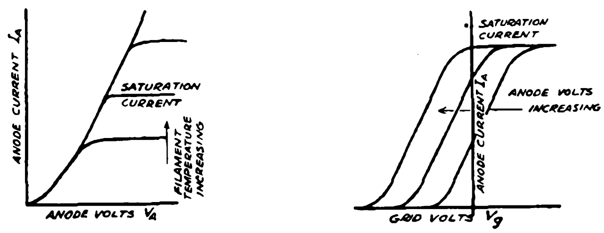
A. 4. A coupled circuit in a receiver may be utilized to increase the selectivity of the receiver either by loose coupling if a narrow bandwidth is permissible, as in telegraph reception, or by the use of a suitable tight coupling if a wide bandwidth with selectivity is required, as in telephony reception. These effects are shown in the sketch, curve (*a*) being the response with very loose coupling, curve (*b*) with a medium coupling, and curve (*c*) with tight coupling.



A coupled circuit has a further advantage that it can be used as a method of volume control provided that selectivity and bandpass action are not interfered with.

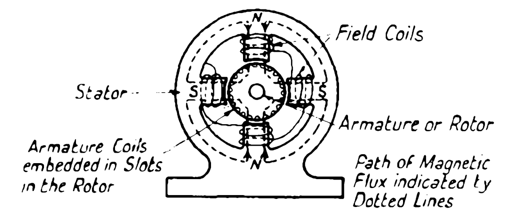
Q. 5. Draw typical examples of the following characteristic curves:—
(a) The anode voltage anode current curves of a diode for different filament currents.
(b) The anode current grid voltage curves of a triode for different values of anode voltage.

A. 5. Typical characteristic curves are shown below.

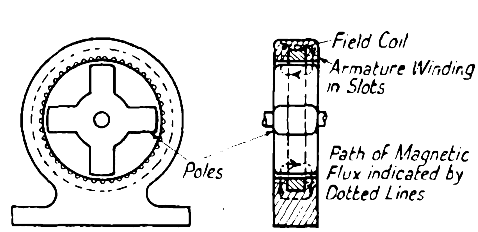


Q. 6. Describe with sketches—
(a) A rotating armature type alternator.
(b) An inductor type alternator suitable for a frequency of 500 cycles per second.
If the shaft of the machine rotates at 3,000 revolutions per minute, how many poles are necessary in each machine?

A. 6. (*a*) A rotating armature type alternator is shown in the upper sketch. It consists essentially of a stator with a number of poles wound with coils to provide a magnetic field, the coils being wound so that alternate poles are north and south. Several pairs of poles may be provided. A laminated iron armature is fitted with coils embedded in slots, the coils being joined in series to form one or more continuous windings which are brought out to slip rings.



Rotary Armature Type Alternator



Section of Alternator

Inductor Type Alternator

The field system is fed from a D.C. supply and an alternating e.m.f. is induced in the armature conductors as these are rotated in the magnetic field.

A conductor will pass through a complete alternation of flux in passing from one N pole to the next, *i.e.*, every pair of poles. The frequency of the e.m.f. is thus $f = p.n.$ where p is the number of pairs of poles and n the revolutions of the armature per second.

(*b*) An inductor alternator is shown in the lower sketch. In this case the field coil consists of a circular coil wound in a slot cut round the stator, the armature coils being wound in slots also cut in the stator. The magnetic circuit of the field system is completed by the rotor which consists of a shaft fitted with a number of pole pieces or a cylinder with slots cut in it.

A D.C. potential is applied across the field winding and this will set up a magnetic field as indicated. The lines of force cutting a conductor will vary with the reluctance of the air gap between rotor and stator. This reluctance will vary through one complete cycle as one pole and then the next passes a conductor. The frequency of the alternator is thus $f = 2\ pn$ where $2\ p$ is the number of poles. It will be observed that this type of alternator has the advantage that it has no windings on the rotor.

If $f = 500$ and the speed of the machine 3000 r.p.m., *i.e.*, 50 revs/sec, then for a rotating armature type alternator

$$p = \frac{f}{n} = \frac{500}{50} = 10$$

i.e., there will be 10 pairs or 20 poles.

For an inductor alternator there will be 10 poles only.

Q. 7. The primary circuit of a spark transmitter consists of an inductance of 1 microhenry and a condenser of 0.025 microfarad. If the condenser is charged to 20,000 volts peak value when the spark occurs, what will be the maximum instantaneous value of current which flows through the inductance, neglecting any losses in the circuit?

What will be the frequency of the oscillation?

A. 7. If I = the maximum instantaneous value of the current and V = the peak voltage to which the condenser is charged.

Then $\frac{1}{2}\ CV^2 = \frac{1}{2}\ LI^2$

$$\text{or} \quad I = V\sqrt{\frac{C}{L}} = 2 \times 10^4 \sqrt{\frac{2.5 \times 10^{-8}}{10^{-6}}}$$

$$= 3162 \text{ amperes}$$

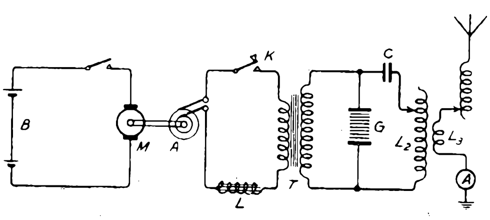
If f is the frequency of the oscillation

$$f = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{10^{-6} \times 2.5 \times 10^{-8}}}$$

$$= \frac{10^7}{9.83} = 1.007 \times 10^6 \text{ cycles per second.}$$

Q. 8. Describe with a diagram the construction and working of a $\frac{1}{4}$ kilowatt spark transmitter suitable for marine use. What are the advantages of spark sets over I.C.W. sets for marine emergency purposes?

A. 8. A typical $\frac{1}{4}$ kilowatt spark transmitter is shown in the sketch below. It consists of a small motor alternator M.A.



operated off a bank of accumulators B. The alternator would be of the inductor type, designed for a frequency of 500 cycles/second at the normal speed of the motor. The output of the alternator is connected to the primary of a step up transformer T through a low frequency resonating choke L, and the transmitting key K. A quenched spark gap G and the primary circuit C and L_2 are each connected across the secondary of the transformer. The aerial circuit is coupled to the primary circuit through the coupling coil L_3.

When the key is depressed an A.C. voltage is applied across C and L_2 in parallel with G. As the instantaneous A.C. voltage increases from zero to a maximum C will be charged continuously until the breakdown voltage of the gap is reached. As soon as the gap breaks down a damped oscillatory discharge is set up in the primary circuit CGL_2. Since the primary is coupled to the aerial the discharge will be transferred to that circuit. Any transfer back into the primary is prevented by virtue of the fact that the gap becomes non conducting, *i.e.*, is rapidly deionised.

This process is repeated during each half cycle of the A.C. wave. The note frequency will thus be 1000 cycles per second.

The output from the transmitter can be varied by adjusting the number of sections in the quenched gap.

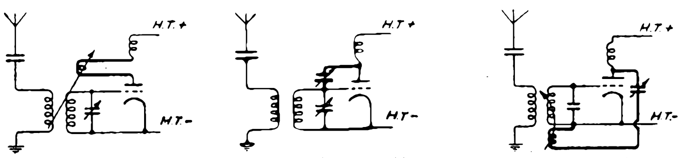
A spark set for emergency purposes possesses the advantage of simplicity and reliability over an I.C.W. set. The I.C.W. set involves the use of additional components including valves, the life of which is limited. Further the ratio of peak aerial current to R.M.S. aerial current in a spark set is very much greater than in an I.C.W. set and thus for a given aerial power the range obtainable is greater unless heterodyne reception is used. On the other hand the efficiency of a valve transmitter is approximately double that of the spark set.

One further advantage of the spark set for emergency work is that its radiated power is spread over a wide spectrum and thus it will " spread " over a very wide band in the receiver.

Q. 9. Describe three methods in which a thermionic valve can be used for detection. Explain the action of the valve in each case.

A. 9. Detection may be carried out using (*a*) a two electrode valve, (*b*) a three electrode valve as an anode band detector, or (*c*) as a cumulative grid detector.

(*a*) A diode as detector is shown in sketch (*a*). If a modulated radio frequency voltage is applied across a diode current will flow only when the anode is positive to the cathode. This current consists of a radio frequency component, a D.C. component and an audio frequency component. If a condenser and resistance in parallel are connected in series with the valve, the radio frequency current will be bypassed by the condenser and the D.C. and A.F. currents will set up voltages across the combination C.R. The voltages may be separated and utilized as required.



Inductive Reaction | Capacitive Reaction | Condenser Controlled Magnetic Reaction

(*a*) (*b*) (*c*)

(*b*) The triode as an anode bend detector is shown in sketch (*b*). The grid bias is adjusted so that the valve is operating on the bottom bend of the anode current-grid voltage characteristic and a resistance R is included in the anode circuit. When a modulated voltage is applied to the grid, the increase in anode current on the positive half-cycle of grid input will considerably exceed the decrease on the negative half-cycle. The anode current will thus consist of R.F., D.C., and A.F. components, the last of which will set up a voltage across R proportional to the modulation.

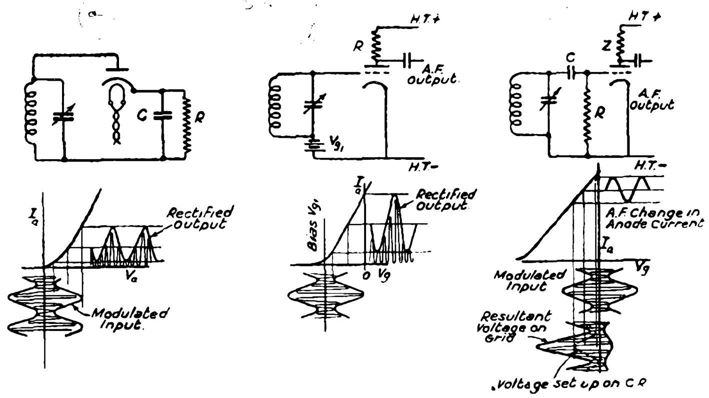
(*c*) The cumulative grid detector is shown in sketch (*c*). Grid current flows through a valve only when the grid is positive to the cathode. The cumulative grid rectifier may be regarded as a diode rectifier the diode consisting of grid and cathode combined with a stage of low frequency amplification. When an input is applied, grid current will flow during the positive half-cycles of grid voltage and a rectified voltage is set up across C.R. This voltage being applied to the grid of the valve will set up variations of anode current and hence D.C. and A.F. voltage variations across the anode circuit impedance Z.

The curves show a modulated input voltage, the rectified voltage set up across the grid leak R and condenser C, the resultant voltage applied to the grid and the A.F. change in anode current which is due to the A.F. voltage set up across C.R.

Q. 10. *Why is retroaction used in some types of receiver? Indicate by diagrams three ways in which retroaction can be applied to a receiver and mention any disadvantages attending its use.*

A. 10. Retroaction has the effect of decreasing the equivalent resistance of the circuit to which it is applied. It enables both the sensitivity and the selectivity of a receiver to be increased, thus permitting weak stations to be received without interference. It has the disadvantages that the receiver becomes critical and is liable to self-oscillate. If the retroaction is introduced into the aerial circuit and self-oscillation occurs, then interference will be caused to nearby receivers which are tuned to the same wave-length.

If telephone reception is concerned, this increase in selectivity by reducing the bandwidth of the receiver may introduce distortion.



Three methods of introducing reaction are shown in the above diagrams.

III.—TELEPHONY, FINAL, 1934: SECTION I, AUTOMATIC TELEPHONY. QUESTIONS AND ANSWERS.

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

Q. 1. *A count was made, at regular intervals of three minutes during the busy hour, of the number of switches in use in a full availability group. If the average of the 20 readings was 3, estimate the number of occasions on which the first choice switch was found to be in use.* (30 *marks*).

A. 1. The average of the 20 readings may be taken to represent, approximately, the average number of calls in progress simultaneously, and this is numerically equal to the traffic flow in traffic units. In the case given, therefore, the group of switches carried 3 traffic units and if the traffic lost were of negligible amount, this would also be the traffic offered to the group.

If A traffic units are offered to a group of switches and the traffic carried by the first switch is a, then $A - a$ is the traffic passed on to later choices.

The occupancy of the first switch is a, and assuming pure chance traffic, a is the proportion of traffic passed on, since this is the traffic originated when the first switch is engaged. Hence, the traffic passed on is $a \times A$. The same result may be reached by the following alternative argument:—

Let C = total number of calls arriving in the busy hour
c = number of calls taken by the first switch
T = average duration in hours,

then the occupancy of the first switch is $a = c\text{T}$ hours. If the traffic is pure chance, a call will be offered to the group on the average during each interval 1/C hours. Hence, the number of calls arriving when the first switch is busy will be $c\text{T}/\frac{1}{\text{C}} = c\text{CT}$. Therefore the traffic passed by the first switch $= c\text{CT} \times \text{T}$ (traffic units). If CT = A, then this traffic is aA. Whence,

$$\text{A} \times a = \text{A} - a$$

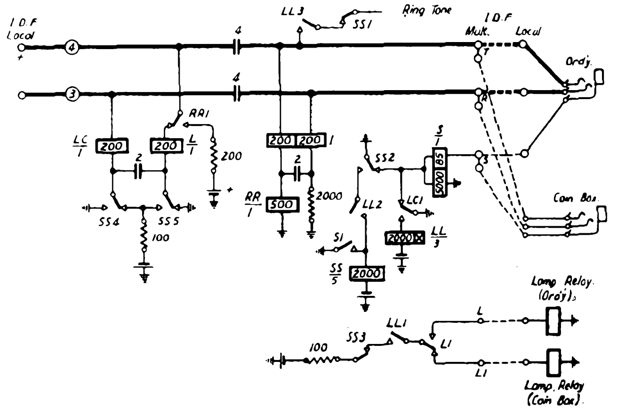
and $$a = \frac{\text{A}}{\text{A} + 1} = \tfrac{3}{4} \text{ traffic unit.}$$

Hence, the switch is occupied during $\frac{3}{4}$ of the busy hour, and it is reasonable to assume that, if 20 observations were made, it would be in use on 15 of these occasions.

Q. 2. *A subscriber connected to the main automatic exchange in a non-director area dials " 0 " and his line is extended to the auto-manual switchboard. Sketch and describe the circuit arrangements of the " 0 "-level relay equipment. Why is the " manual hold " facility provided on this equipment?* (30).

A. 2. The diagram shows the connexions of an 0-level circuit incoming to a sleeve control switchboard from a satellite exchange. The circuit provides for discrimination between a call from an ordinary subscriber and one from a call office, so enabling a common group of junctions to be used for both classes of traffic.

When an ordinary subscriber calls, relays L and LC operate from the loop applied in the D.S.R.; **LC1** operates relay LL and **L1** prepares the circuit of the calling lamp relay (ordinary lines). **LL1** closes the circuit of the lamp relay; **LL2** prepares a circuit for relay SS; **LL3** connects ringing tone. For a call from a call office, earth is applied to the −ve wire in the D.S.R. and relay LC only operates; with the non-operation of relay L, the coin box lamp relay remains in circuit.



The operator answers by inserting a plug into the jack; relay S operates from the battery on the S-wire and **S1** closes the circuit of relay SS. **SS1** disconnects ringing tone; **SS2** provides for the retention of relay S under the control of relay LL; **SS3** disconnects the calling lamp relay; **SS4** and **SS5** reverse the battery and earth applied to the incoming wires, so providing for the operator hold facility in the D.S.R.

Should it be necessary to re-ring the calling subscriber, relay RR is operated by the battery applied to the T-wire in the cord circuit when the ringing key is operated; **RR1** connects positive battery to the +ve wire to operate the re-ring relay in the D.S.R.

When the calling subscriber clears, relay LC releases and LC1 short-circuits the 5,000-ohm coil of relay S, so causing the clearing signal to be given on the cord circuit supervisory lamp. The battery applied through relay L to the +ve wire. however, provides for the retention of the circuit under control of relay SS by operating relay I in the D.S.R. Relay SS is controlled by relay S which, in turn, is operated by the cord circuit. Manual hold conditions persist, therefore, until the operator removes the plug from the jack.

The purpose of the operator hold, or manual hold as it is sometimes termed, is to enable an operator to trace a call which may have been abandoned. The operator is able to hold the circuit and the engineering staff is thereby able to trace the call back to the originating line.

Q. 3. *State the requirements that have to be met in the case of a relay which must respond to dialled impulses and which also forms part of the transmission bridge in a selector circuit. Explain how each of the requirements is met in modern relay design.* (30).

A. 3. A relay which must respond to dialled impulses and which also forms part of the transmission bridge of a selector circuit must meet the following conditions:—

(i) High impedance at speech frequencies.
(ii) Lowest d.c. resistance consistent with (*a*) the maximum permissible transmitter current for a line of zero loop resistance, and (*b*) the wattage which the relay will stand without damage.
(iii) Correct balance of the transmission bridge.
(iv) Lowest possible operating lag.
(v) Lowest possible releasing lag.
(vi) The operating and releasing lags should be as nearly equal as possible to minimize impulse distortion.
(vii) Satisfactory operating and releasing under all practical line conditions, *e.g.*, long line, and low insulation of line.

The first requirement is met by giving the coil a full winding for the required resistance and so obtaining the maximum number of turns, and by increasing the permeability of the core by the addition of a nickel-iron sleeve over the soft iron core.

The second requirement is governed by the general design of the system and depends upon the transmission standards adopted and the voltage at which the system is to work, as well as upon the design of the relay in regard to its heat-dissipating powers.

The third requirement is met by providing double wound coils, the two windings being arranged so that the length of the mean turn on each is the same. The winding generally adopted is the " sandwich " type, although two coils separated by spool cheeks may also be used.

The remaining requirements are in respect of the operating characteristics of the relay. All sources of eddy current loss, such as copper slugs, copper spool cheeks, and short-circuited windings are eliminated as far as possible, and heavy spring pressures are used to ensure quick release. The operating air gap is made only sufficient to operate the contact springs satisfactorily because the greater the air gap the greater the reluctance of the magnetic circuit and also the greater is the effect of the rise in spring pressure as the relay operates, both of which adversely affect the operating lag. The relay is given as many turns as possible (required for (i) also), and to keep the releasing lag as low as possible an isthmus armature is frequently used to restrict the magnetic flux to a value as little as possible above that required to operate the relay.

The foregoing requirements are to some extent opposed to one another. Although a high impedance is desirable, the inductance of the coil must not be too great otherwise the operating lag of the relay is increased. Further, the impedance cannot be raised by too great an increase in the resistance, as this conflicts with (ii). Hence, in the design of an impulsing relay, a compromise between these requirements is necessary.

With regard to adverse line conditions, a residual screw is provided in the armature to prevent the relay from holding with low excitation such as occurs under low insulation line conditions. This also facilitates making the fine adjustments necessary to meet the exacting conditions imposed by such line conditions.

Q. 4. ***What facilities, in addition to those afforded by ordinary final selectors, are provided for on final selectors designed to deal with traffic to private branch exchanges having not more than ten exchange lines in each case? Sketch and describe the special circuit arrangements which provide these facilities.*** (30).

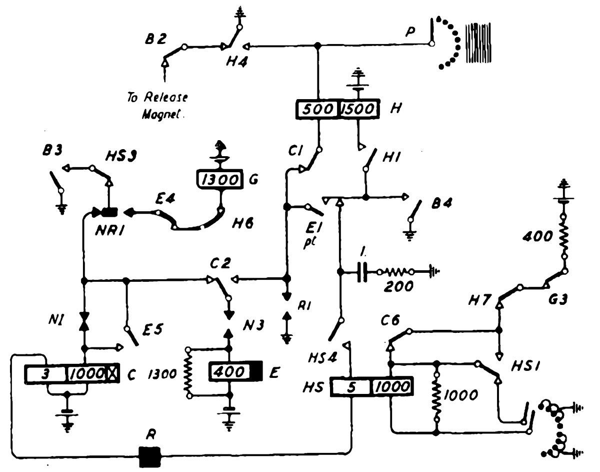
A. 4. The additional facilities provided by a P.B.X. final selector catering for groups of not more than 10 lines are :—

(i) If the first line in a group is busy, steps the wipers to the bank contacts of the next line in the group in search for a free line. Only if all the lines in the group are busy does the selector connect busy back to the incoming lines.

(ii) Provides night service facilities to any line in a P.B.X. group with the exception of the first.

The special circuit arrangements which provide these facilities on a P.B.X. 2-10 lines final selector are shown in the diagram. The selector is provided with a metal arc and two wipers arranged one behind the other; the metal arc is connected to earth and contact screws are inserted through tapped holes in the arc in those positions corresponding to all the lines in a P.B.X. group except the last.

On the completion of the rotary impulse train, the wipers are standing on the bank contacts of the first line in the group. Relay E is disconnected at R1 and, together with relay C, is commencing its slow-release period.



If the first line in the group is free, relay H operates on its 500-ohm coil through C1, **E1**, and **B4** to earth; **H1** locks the relay and switches the line through to the ringing circuit.

If the first line is busy, the P-wire is earthed and relay H is unable to operate. On the release of relay C, relay HS operates from the 400-ohm battery, G3, H7, C6, 1000-ohm coil, leading wiper to earth on the P.B.X. arc. This relay causes hunting start conditions to be set up by disconnecting relay G at **HS3**, to prevent its operation during hunting, and preparing a circuit for the rotary magnet through **HS4**. On the release of relay E, the rotary magnet circuit is closed through E1, and the wipers are stepped to the bank contacts of the next line in the group. When the rotary interrupter springs close, relay E re-operates, relay C having re-operated in series with the rotary magnet. The rotary magnet is thereby disconnected, and relay H is connected to the P-wire of the next line. If this line is busy, the cycle of operations recurs. In this manner, the wipers are stepped round the bank contacts of the group of P.B.X. lines until either a free line is found or all the lines are found engaged.

If all the lines in the group are busy, then when the wipers step to the last line, relay HS is released since the leading wiper steps off a contact screw leaving the circuit disconnected. The hunting circuit is now disconnected, and relay G is reconnected to perform its function of connecting busy back to the incoming lines. Relay H is unable to operate, and when relay E releases, relay G operates to the earth at **B3**.

Under night service conditions, any line, other than the first in a group, may be dialled. In these conditions, relay HS is either short-circuited by the leading and trailing wipers or is disconnected at the leading wiper. Hence, if the line is busy, this relay is unable to operate and the selector therefore functions as a regular final selector in respect of night service lines.

Q. 5. *Four switches are arranged as a full availability group. If the traffic offered to the group in the busy hour is* 0.7 *traffic unit, what grade of service is given?* (35).

A. 5. The grade of service, B, given when A traffic units are offered to a full availability group of *x* switches can be calculated from Erlang's formula, *i.e.* :—

$$B = \frac{\frac{A^x}{\underline{|x}}}{1 + A + \frac{A^2}{\underline{|2}} + \frac{A^3}{\underline{|3}} + \ldots + \frac{A^x}{\underline{|x}}}$$

Applying this to the case where 0.7 traffic unit is offered to a full availability group of 4 switches,

$$B = \frac{\frac{0.7^4}{\underline{|4}}}{1 + 0.7 + \frac{0.7^2}{\underline{|2}} + \frac{0.7^3}{\underline{|3}} + \frac{0.7^4}{\underline{|4}}}$$

$$= \frac{\frac{0.2401}{24}}{1.7 + \frac{0.49}{2} + \frac{0.343}{6} + \frac{0.2401}{24}}$$

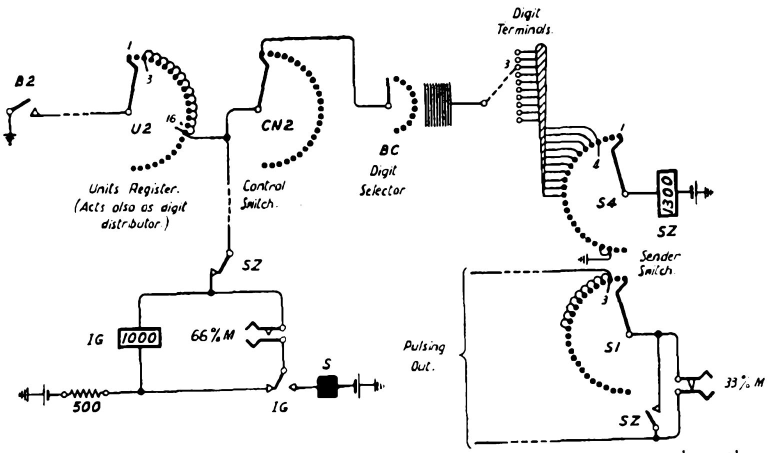
$$= \frac{0.01}{1.7 + 0.245 + 0.057 + 0.01}$$

$$= \frac{0.01}{2.012}$$

$$B = \frac{1}{201} \text{ (or 0.005 very nearly).}$$

Q. 6. On receipt of the " B " and " C " digits of the exchange code a director switch proceeds to transmit the impulse trains required for routing the call. Explain, with the aid of a simplified circuit diagram, how the first routing digit is produced and sent out by the director. Assume that the digit is 3. (35).

A. 6. A simplified circuit diagram of the portion of the director concerned in pulsing out the first routing digit is given in the sketch. When the C-digit has been received, the wipers



of the units digit register, which is now functioning as a digit distributor, are stepped to the third bank contacts in readiness for the receipt of the thousands digit. The earth at **B2** is now extended through U2 wiper to relay IG, which functions as an impulse guard relay and prevents the connexion of the sender switch driving magnet until the magnet impulsing springs are open. If the earth is applied at a time when the springs are closed, relay IG is short-circuited and does not operate until the springs open at the end of their 66 mS make period. With the operation of relay IG, the sender switch driving magnet is brought under the control of the springs and thereafter steps its wipers once with each break of the magnet impulsing springs.

The earth from **B2** is also extended through CN2 wiper, the BC-digit selector wiper, and the translation field to digit terminal 3, whence it is connected to the 6th bank contact of S4 arc. Immediately the wipers of the sender switch are stepped to the 3rd bank contacts, the loop impulse springs are connected to the pulsing out loop and, since the loop and magnet impulse springs are driven by the same means, for each loop impulse sent out, the wipers of the sender switch step forward one bank contact. When three loop impulses have been sent out, the wipers are stepped to the 6th bank contact and the earth on this contact in **S4** arc is extended to relay **SZ** which operates. The loop impulse springs connected to the pulsing out loop are short-circuited, so terminating the first routing digit and, by means not shown in the diagram, the sender switch wipers are stepped round to a position in readiness for the pulsing out of the next digit. The control switch wipers are also stepped forward to the next bank contacts.

Q. 7. In some recently developed automatic telephone systems, common equipment, associated with the individual switching stages, is employed during the setting-up of connexions. Discuss the advantages and disadvantages of employing this common equipment, and describe, briefly, the principal features of any new system in which this method of control is used. (35).

A. 7. In the step-by-step systems developed up to recent times, each selector contains a quantity of relays which are concerned only with the positioning of the wipers and do not perform any function thereafter. Recently, various common control systems have been developed in which apparatus required for positioning selector wipers is provided on a common basis and is only brought into use during such positioning. On an average, one common control is provided for each group of eight individual selectors of the same rank.

The advantages of such systems arose primarily from the reduction in the number of relays required. This reduces the first cost of an exchange and also enables a reduction to be made in the space required for an exchange of given size.

The circuit arrangements, however, are more complicated owing to the necessity for linking up the common control with individual selectors. This leads to increased difficulty in tracing faults. Furthermore, it is necessary to apply an artificial busying condition to those free selectors in the group served by one common equipment whenever that equipment is in use; there is, therefore, a slight increase in the holding time of each selector and this gives rise to a slight increase in the number of selectors required to carry a given amount of traffic.

The common control principle is somewhat difficult to apply to switching stages having a transmission feed, owing to the widely varying holding times of busy calls. Where, however, the switching operations in a particular rank of selectors are concerned solely with positioning the wipers, common control can be advantageously applied.

Q. 8. The number of trunks required to carry the traffic from a particular level in an automatic exchange having been ascertained, what points have to be considered in order that the best grading scheme may be determined? What considerations limit the size of gradings? The busy hour traffic from a 10-contact level of a group of selectors distributed evenly over 16 shelves requires 62 trunks. Suggest a suitable grading for the case. (35).

A. 8. In order to obtain the best grading scheme, it is necessary to determine in the first place the minimum number of groups. If this be N, then the rough rule is:—

$$N = \frac{\text{Number of outlets} \times 2}{\text{Availability}} = \frac{62 \times 2}{10} = 12.4 \text{ or } 13$$

to the nearest whole number, taking the case quoted as an example.

The grading must be smooth, however, so that N must have a number of factors, and 13 does not fulfil this condition. A further requirement is that the traffic flow from the groups shall be as uniform as possible. As there are 16 uniformly loaded shelves in this case, and 16, moreover, has a greater number of factors than 14 or 15, it is clear that the nearest suitable value for N is 16.

This point having been decided, the next step is to find the smoothest grading to 62 outlets from 16 groups, the availability being 10.

A 16-group grading can be arranged having 16, 8, 4, 2, and 1 outlets for choice. Let there be a of the 16 outlets, b of the 8 outlets, c of the 4 outlets, d of the 2 outlets, and e of the 1 outlet. Then:—

$$16a + 8b + 4c + 2d + e = 62 \quad \text{...............(1)}$$

Also, since the availability is 10,

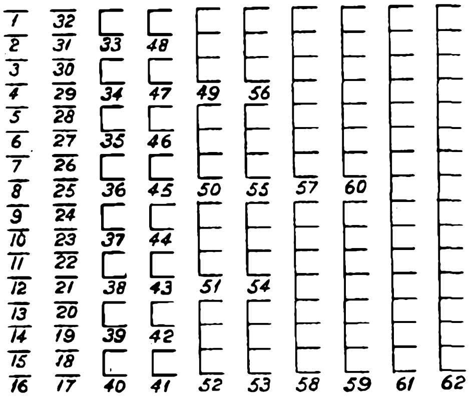
$$a + b + c + d + e = 10 \quad \text{...............(2)}$$

Subtracting (2) from (1), $15a + 7b + 3c + d = 52$.

From this, the following points are apparent:—a cannot be greater than 3: if $a = 3$, then b cannot be greater than 1, and c, d and e must be zero. Try $a = 2$ and use suitable values for b, c, d, and e.

a	= 2	(32)	= 2	(32)	= 2	(32)
b	= 1	(8)	= 2	(16)	= 3	(24)
c	= 4	(16)	= 2	(8)	= 0	(0)
d	= 3	(6)	= 2	(4)	= 1	(1)
e	= 0	(0)	= 2	(2)	= 4	(4)
		(62)		(62)		(62)
Sum of successive differences	8		0		8	

It is evident that the ideal case is the second in which the sum of the successive differences is zero. This grading is therefore smooth and is shown in the sketch.



The considerations governing the size of gradings are :—

(i) *Maintenance aspect.* Large gradings lead to difficulty in tracing calls on the later common choices.

(ii) *Cross-talk on Commons.* If a large number of bank contacts be commoned together, the capacity between adjacent contacts is sufficient to cause cross-talk. A limit of 1250 banks in multiple is imposed to minimize this.

(iii) *Overload capacity.* Large gradings, although more economical from a switch point of view, have not the same overload capacity as they are more sensitive to variations of load than small gradings.

Q. 9. In what circumstances is it advantageous to provide automatic routiners at an automatic exchange? State the precise function of each of the following items :—

(a) access equipment,
(b) continuous routine key,
(c) step-on key,
(d) reset key.

Mention any three types of fault on a group selector which may be brought to notice by automatic routining, and state the probable cause of the fault in each case. (40).

A. 9. It is advantageous to provide automatic routiners at an automatic exchange whenever the number of selectors exceeds 900. Routiners for other types of apparatus are installed wherever the quantity is sufficient to justify routining by automatic as against manual methods. It is the exception to install more than one routiner of each type. The advantage of the routiner is that a standard and automatic test is carried out on all apparatus of a given type in sequential order, thus avoiding the human fatigue involved in delicate testing and tedious repetition work, so effecting a saving in plant as well as reducing fatigue.

(*a*) *Access equipment* provides testing links between the routiner and the apparatus on a rack basis. This equipment also provides that testing is carried out in sequential order.

(*b*) *The continuous routine key* enables continuous routine conditions to be applied to any single item of apparatus in the group, thereby enabling the cycle of testing operations to be repeated as many times as may be required in an endeavour to locate a faulty piece of apparatus.

(*c*) *The step-on key,* when operated during the general routine, duplicates the action of the reset key, and, in addition, steps the access switch to the next selector in sequence. The key may be also used to step the access switch to any desired selector should it be necessary to apply continuous routine conditions at any time.

(*d*) *The reset key* provides a means of re-testing the apparatus in the event of a continuous routine being stopped by a fault. When operated, it restores the testing and alarm relays and switches the routiner to normal, at the same time causing the test cycle to be recommenced.

The following three typical faults on a group selector may be brought to notice by automatic routining :—

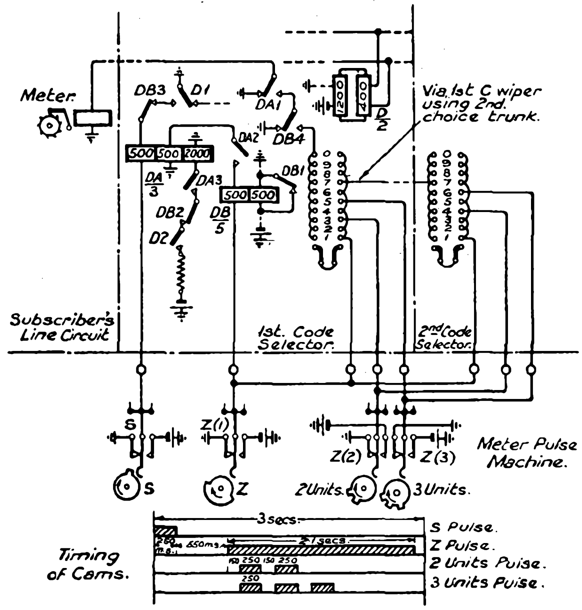
(i) *Non-application of guarding earth on the P-wire.* This causes the routiner to stop and the " private guard " lamp fails to glow. The probable cause of the fault is the failure of relay B contact to make.

(ii) *Wiper reversal.* This fault causes the routiner to stop and the " − ve and + ve continuity " lamp remains alight, whilst the " private guard " lamp fails to glow. The probable cause of the trouble is a reversal in the wiper cord.

(iii) *Relay A fails to operate.* This relay is first tested for non-operation with a voltage of 52 and is then tested for operation with a voltage of 47.5. This fault causes the routiner to stop and the " relay A operate " lamp continues to glow, and the " private guard " lamp also glows. The probable causes of this fault are a high resistance connexion, disconnexion in the relay coils, on the tag or the jack, relay springs out of adjustment, or an incorrect connexion on the switch jack.

Q. 10. Describe a method of providing for the metering of calls for which more than a unit fee is chargeable. Explain how the number of operations of the subscriber's meter is controlled for " single fee " and " excess fee " calls respectively. Illustrate your answer with a circuit diagram, showing only those portions of the exchange circuits which are directly concerned with metering. (40).

A. 10. The diagram shows those portions of the circuits of 1st and 2nd code selectors required for multi-metering, together with the timing of the cams of the meter pulse machine.



For a single fee call, relay D operates and relay DA operates with the next S pulse. The relay locks through **DA3** whilst **DA2** prepares a circuit for the operation of relay DB in series with the centre coil of relay DA. When the Z pulse is received 550 mS later, relay DB operates and relay DA is held. The original operating and the holding circuits of relay DA are broken at **DB3** and **DB2** respectively, and the subscriber's meter is extended through **DA1** and **DB4** to the vertical marking bank and wiper. If the fee required is a single one, then the Z pulse is wired to the vertical bank contact of the level over which the call is routed and the subscriber's meter is operated once. If, however, the fee is twopence, the 2-units pulse is connected to the vertical marking bank contact for the level over which the call is routed—level 3 in the diagram. The subscriber's meter is accordingly operated twice. Similarly, if the fee is threepence, the 3-units pulse lead is connected to the vertical marking bank contact of the level—level 5 in the diagram—and the subscriber's meter is operated three times.

In some cases, control of multi-metering is extended to 2nd code selectors in the manner shown in the diagram. The selectors used are of the 200-outlet type, but only 100 outlets are available as one wire of the second choice trunk is used for extending the metering condition from the vertical marking bank of the 1st code selector to that of the 2nd code selector. In the diagram, level 7 of the 1st code selector is used for this purpose.

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