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A PRACTICAL WORK WRITTEN BY EXPERTS

Central Battery System.

A similar result may be achieved in a simpler fashion without the waste of energy involved in the continuously flowing current. This purely British method involves the use of a polarised sounder (Fig. 8). It is similar to the instrument already described, but the yoke of the electro-magnet is replaced by a horseshoe permanent magnet (Fig. 9). In some cases the cores are differentially wound, as is indicated by the four terminals in the previous figure.

Notes on the Polarised Sounder.

It will be seen that by suitably adjusting the tension on the spring the armature will remain depressed due to the attraction of the permanent magnet, which in this position is greater than the pull of the spring, and that when raised will remain raised, because the spring tension is then less than the pull of the magnet on the armature.

Another feature of the polarised sounder is that the upper and lower stops are fixed permanently and are not adjustable, thus leaving the spring tension as the only adjustment.

THE CENTRAL BATTERY SYSTEM.

This is shown in Fig. 10.

At the head office a battery of 80 volts is connected through a 1,000-ohm resistance coil to the line. At each station a 2,000-ohm polarised sounder is connected to the line in series with a 4 microfarad condenser.

How the System Operates.

The depression of a key earths the line, and consequently causes the condenser at each station to discharge through its sounder. This causes the armature to descend, where it remains until the raising of the key removes the short circuit and causes the condensers to be recharged through the sounders.

The direction of the current is, of course, opposite to that of the discharge, and consequently the sounder armatures fly up to end the signal.

It will be appreciated that the spring tension on the sounders must be such as to secure the neutral adjustment previously described.

The system can be worked over fairly long lines with satisfactory results.

MORSE INKERS.

A record of signals can be made by the use of a direct writer. A paper tape is drawn at uniform speed above a wheel revolving in an inkwell and the armature of the electro-magnet, when attracted, raises the inked wheel into contact with the tape, and in this way a permanent record of the signals is secured.

The instrument is, however, chiefly valuable for tuition purposes in showing up defects in signalling (Fig. 11).

THE MORSE ALPHABET.

A · —	H · · · ·	O — — —	U · · —
B — · · ·	I · ·	P · — — ·	V · · · —
C — · — ·	J · — — —	Q — — · —	W · — —
D — · ·	K — · —	R · — ·	X — · · —
E ·	L · — · ·	S · · ·	Y — · — —
F · · — ·	M — —	T —	Z — — · ·
G — — ·	N — ·		

Note.—On the needle instrument the dot of the above alphabet is represented by a beat to the left, and the dash by a beat to the right.

NUMERALS.

1 · — — — —	4 · · · · —	7 — — · · ·	0 — — — — —
2 · · — — —	5 · · · · ·	8 — — — · ·	
3 · · · — —	6 — · · · ·	9 — — — — ·	

ABBREVIATED NUMERALS.

(For use only in the repetition of figures which immediately follows the signalling of the message.)

1 · —	4 · · · · —	7 — · · ·	0 —
2 · · —	5 ·	8 — · ·	
3 · · · —	6 — · · · ·	9 — ·	

Bar of division (/)	— · · — ·
Fractional bar (—)	— · · · · —
Signal to be used between whole numbers and fractions	— — — —

Full stop · — · — · —	*Underline · · — — · —
Break signal (between the address and text, and between text and signature of sender, if any, and for fresh line), — · · · —	*Parenthesis ( ) — · — — · —
Apostrophe (') · — — — — ·	*Inverted " " commas · — · · — ·
Hyphen (-) — · · · · —	Understand or completion of telegram · · · — ·
Interrogation (?) · · — — · ·	Rub out · · · · · · · ·
Exclamation (!) — — · · — —	Go on — — ·
	Wait · — · · ·
	Acknowledgment · · — · — · ·
	Clear of work — · — — ·

Fig. 4.—THE MORSE CODE.

RELAYS.

On long circuits the use of a sounder directly operated by the current sent over the line would necessarily require comparatively high voltages. Moreover, difficulty would arise from variation of current due to leakage on open lines. These considerations, together with the desirability of reducing the number of primary

A

cells, led to the design of the relay, which may be defined roughly as a sensitive form of receiving apparatus operating with a very small current, which makes contacts in consonance with the received signals. This contact brings in a local battery, which operates the actual receiving sounder. Hence the volume of signals on the sounder does not vary with the value of the current flowing through the relay.

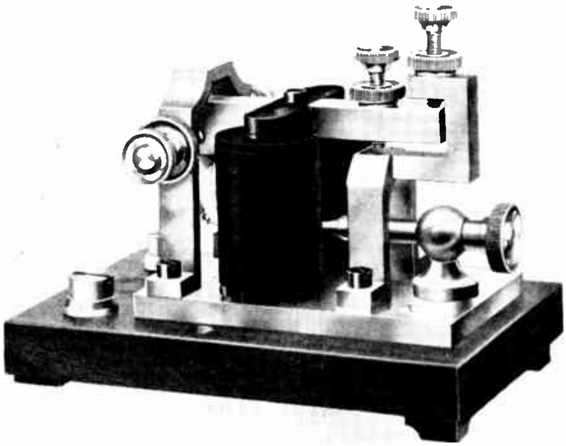

Fig. 5.—ORDINARY MORSE SOUNDER. (*Siemens.*)

Two Classes of Relays.

Relays may broadly be divided into two classes, viz., polarised relays, in which the direction of movement of the tongue depends on the direction of the current through its coils ; and non-polarised relays, which are operated by a current in either direction. The latter type are in general far less sensitive than polarised relays and may generally be described as a modification of an ordinary sounder wound to a high resistance and furnished with a light armature and contacts. Such relays were used very largely in U.S.A. in closed circuit working.

The P.O. Standard Relay.

This has for a long period remained practically unchallenged in design, and is illustrated in Fig. 12.

The coils are wound on soft iron cores which are annealed in an inert gas. The two armatures are carried on a brass axle, which also bears the tongue or contact arm, and are rendered magnetic or polarised by the large horseshoe magnet. The tongue plays between two adjustable contact screws.

Adjusting the P.O. Standard Relay.

Adjustment to the neutral condition is secured when the tongue will remain in contact with either contact screw when moved over to that contact. If after being moved over by hand to the right or marking contact it flies back to the left or spacing contact the relay is said to have a spacing bias. If the tendency is to return to M (Fig. 14) when deflected the relay has a marking bias.

How Direction of Current Affects Relay.

In this relay, since the armatures are polarised (Fig. 13), the direction in which the armatures are urged is determined by the direction of the current.

Recently, more sensitive relays in which high permeability nickel-iron alloy is employed have been designed, but their use is confined at present to special cases such as voice frequency telegraphs.

Differential Winding.

The relay has two distinct windings

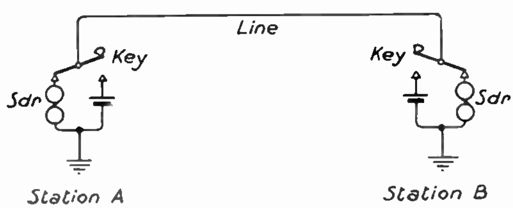

Fig. 6.—DIRECT SOUNDER CIRCUIT.

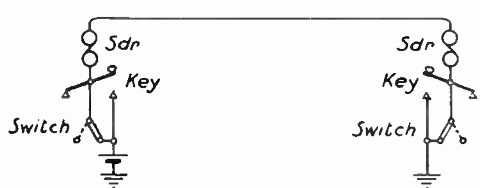

Fig. 7.—CLOSED CIRCUIT SOUNDER.

equal in resistance and number of turns of wire (Fig. 14). Equal currents in these two windings have equal but opposite effects on the cores. Hence a current of, say, 5 milliamps. in the U D coil in the direction U to D will neutralise the effect of a current of 5 milliamps. in the U-circle D-circle coil when it flows in the direction D-circle to U-circle. This principle is known as differential winding and is essential to at least one form of duplex working. This winding has also the advantage that the relay coils may be joined in series or in parallel.

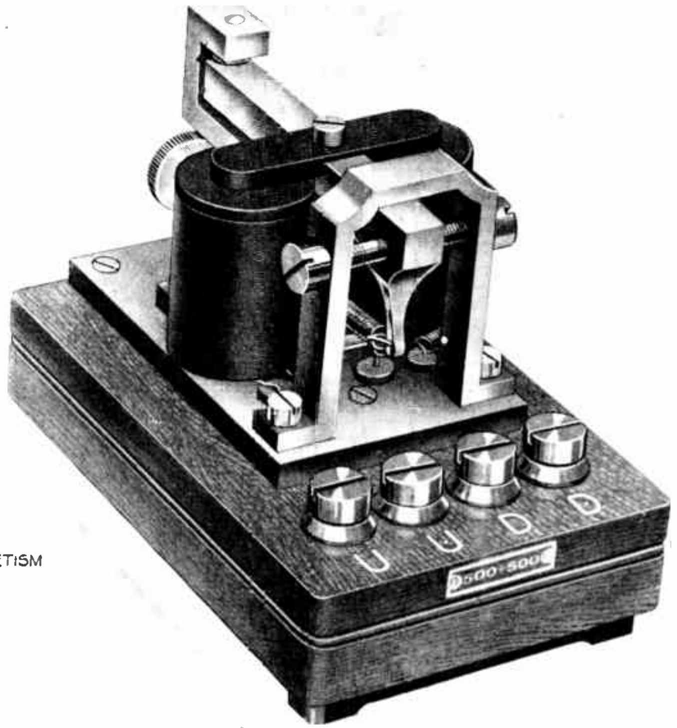

Fig. 8.—POLARIZED SOUNDER. (*Automatic Telephone Manufacturing Co., Ltd.*)

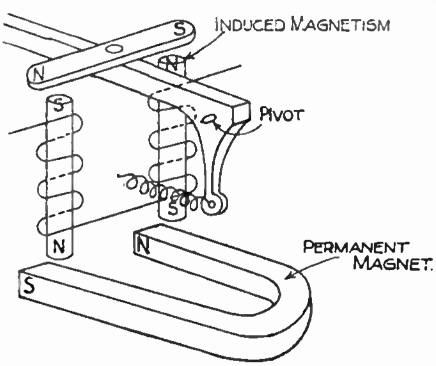

Fig. 9.—PRINCIPLE OF POLARIZED SOUNDER. (*Post Office Technical Pamphlets.**)

In the former case the resistance is, of course, four times that in parallel, but the relay will operate with half as much current.

Advantages of System.

This plan enables the relay to be adjusted to neutrality, which is to its most sensitive condition. Moreover, any cause such as line leakage varies equally both marking and spacing currents and the

DOUBLE-CURRENT SYSTEM.

In this system the intervals or spaces between the signals are filled by a reverse or spacing current. The signalling key is therefore a special form of commutator sending out a current in one direction when depressed and in the reverse direction when it is allowed to rise.

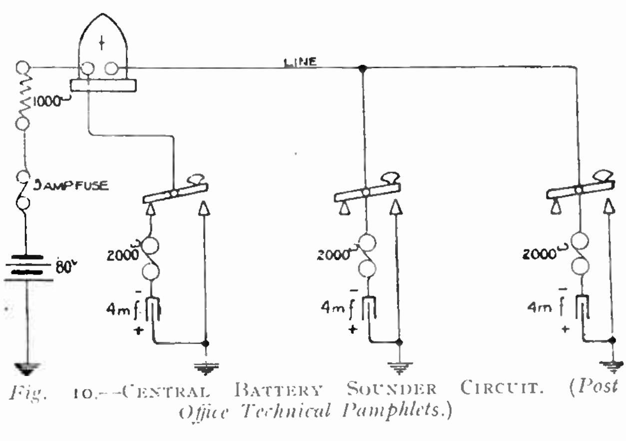

Fig. 10.—CENTRAL BATTERY SOUNDER CIRCUIT. (*Post Office Technical Pamphlets.*)

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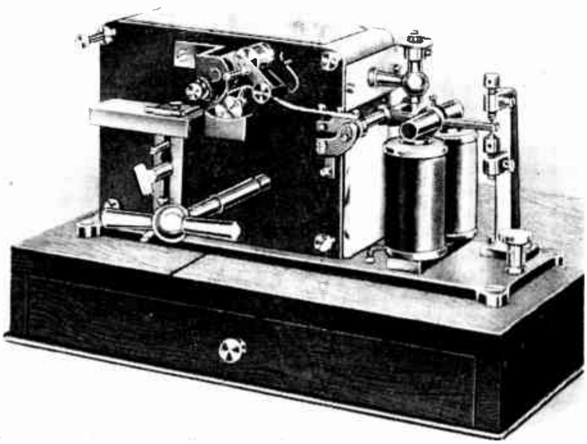

Fig. 11.—MORSE INKER OR DIRECT WRITER. (*Siemens*).

system is largely self-adjusting. It also destroys effects due to residual magnetism in the relay cores.

Since current is flowing in one direction or the other during the whole time signalling is proceeding a switch is necessary to determine whether the apparatus at the station is to be joined up for sending or receiving.

The general plan of the key will be clear from an examination of Figs. 15 and 16.

A Typical D.C. Sounder Circuit.

The connections of a double-current sounder circuit with three offices are shown in Fig. 17. When the switch is turned to send at any one office the relay at that station is cut out of circuit and a spacing current flows along the line and through the relays at the other two stations. Depression of the key reverses the current and both relays are then operated while the key is down.

The local circuit of each relay contains a battery and sounder, the circuit of which is completed when the tongue of the relay moves over to M in response to a marking current in the line coils of the relay.

Galvanometers are added at each station to indicate outgoing and incoming line currents.

DUPLEX TELEGRAPHY.

The traffic-carrying capacity of a circuit can be doubled by duplex working in which messages can simultaneously be transmitted in each direction over a single-line wire.

Two Methods.

There are two general methods of duplexing a circuit, known as the "differential method" and the "bridge method." The latter gives a somewhat higher working speed on very long circuits, but for all ordinary purposes on inland telegraph circuits, the differential system is supreme.

Differential Duplex.

The general principle of the method is illustrated in Fig. 18. It consists essentially in the use of a differentially wound relay. The line is connected to one coil of the relay and an artificial circuit, similar to the line, is connected to the other coil. A condition of balance is obtained such that a current divides between the two coils of the relay in equal proportions, and

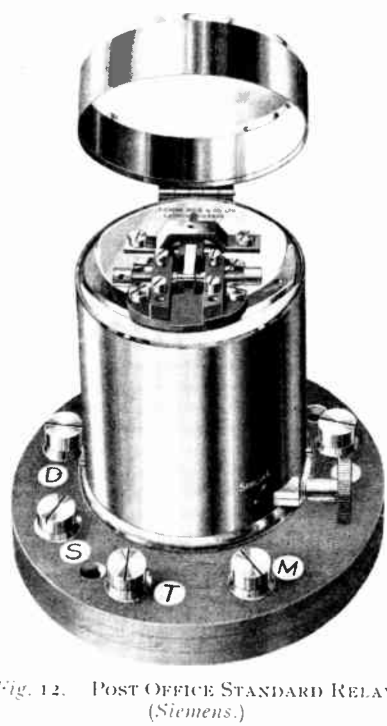

Fig. 12. POST OFFICE STANDARD RELAY. (*Siemens.*)

consequently leaves the relay unaffected.

The half of the current which passes along the line circuit flows through the line coil of the distant relay and produces a signal.

When, however, both keys are simultaneously depressed, the two batteries oppose each other in the line circuit and the current in the second coil, or compensation circuit, produces a signal at each end.

Hence it will be clear that when only one key is depressed the signal is made at the distant end by the current sent along the line, but that when both keys are depressed, a condition supervenes where both the relays are operated as the result of the special condition set up by opposition of the two batteries in the line circuit, thus leaving the compensation circuit free to operate.

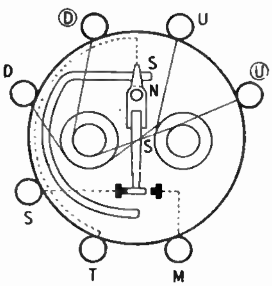

Fig. 14.—CONNECTIONS OF POST OFFICE STANDARD RELAY. (*Post Office Technical Pamphlets.*)

Balancing the Circuit.

In order to balance the circuit, a variable resistance, known as a "rheostat," is included in the compensation circuit, and the operation of balancing is performed with the aid of a differential galvanometer, one coil of which is connected to the compensation circuit and the other coil to the line circuit. The condition of balance is obtained when, on depressing the key, the needle of the galvanometer is unaffected.

In practice duplex circuits are usually worked on the double current system, but the principle of the operation of the circuit is unaffected. It should be added that the balancing arrangements on a long circuit involve the simulation of the capacity of the line, and for this purpose condensers are added in the compensation circuit. Since, however, the capacity of the line is distributed over its whole length, it becomes necessary to use resistances in series with these condensers in order to time the charge and discharge. These timing resistances (Fig. 19) are placed in series with the condensers and are joined in parallel with the rheostat. A switch is usually added which transforms the circuit from differential to simplex conditions during slack parts of the day.

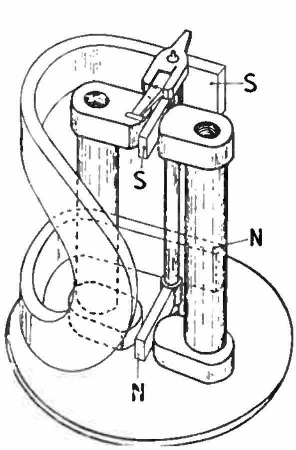

Fig. 13.—PRINCIPLE OF POST OFFICE STANDARD RELAY. (*Post Office Technical Pamphlets.*)

For circuits which are not of very considerable length it is possible to substitute a differentially wound polarised sounder and to work the circuit directly instead of with a relay and local circuit.

Bridge Duplex.

The principle of the bridge duplex method of working is illustrated in Fig. 20. It will be observed that the general arrangement of the circuit bears considerable resemblance to the Wheatstone bridge.

The Ratio Arms.

Two equal ratio arms connect the line and compensation circuits, and the receiving apparatus is placed across the ratio arms.

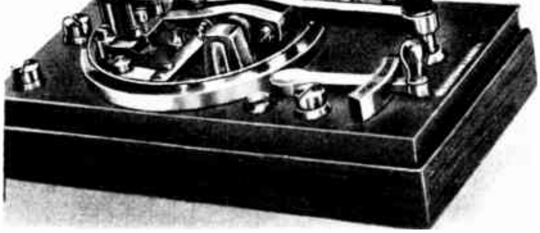

Fig. 15.—DOUBLE CURRENT KEY. (*The India Rubber, Gutta Percha and Telegraph Co., Ltd.*)

Compensation Circuit.

The compensation circuit is made equal to the line and distant receiving apparatus, and consequently a current applied at the apex of the ratio arms produces equal potential across the relay. Hence, in this case, half the current passes through the compensation circuit and half passes to line. This half of the current passing to line flows through the relay at the distant end, but the circuit is somewhat complicated.

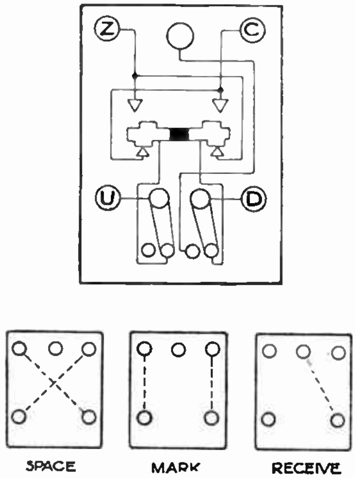

Fig. 16.—Connections of Double Current Key. (*Post Office Technical Pamphlets.*)

Tracing the Circuit.

The path of the line current is through the relay at the receiving end with the lower compensation ratio arm in series with it and the two shunted by the upper compensation arm to earth. A small portion of current flows also from the relay via the rheostat R to earth, i.e., R is in parallel with the lower ratio arm.

What Happens When a Key is Depressed.

Consideration will show that the key at either end, if depressed, will have no effect on the home relay, but will produce a signal on the distant relay.

When Two Keys are Depressed.

When the two keys are simultaneously depressed, the batteries oppose in the line circuit, and consequently the relays at each end are operated by the difference of potential across the lower ratio arm at each end. The path of the current is from the battery along the lower ratio arm, through the compensation circuit back to the battery, with the upper ratio arm and the relay in series joined in parallel across the lower ratio arm.

Why Signalling Condensers are Used.

In practice this arrangement is worked on the double-current system and signalling condensers are placed across the ratio arms in order to quicken the rise of the current and so to increase the speed of working. A shunted condenser is usually placed in series with the receiving apparatus to improve the signal shape. The compensation circuit contains a rheostat for balancing the resistance of the line and distant apparatus with condensers and timing resistances joined across it to simulate the capacity of the line. This system has no advantage whatever over the differential plan, save where the Wheatstone automatic system is employed on long lines. On the contrary, it involves the use of very much higher battery power than the differential system.

QUADRUPLEX TELEGRAPHY.

The quadruplex system provides for the simultaneous transmission of two messages in each direction on a single circuit.

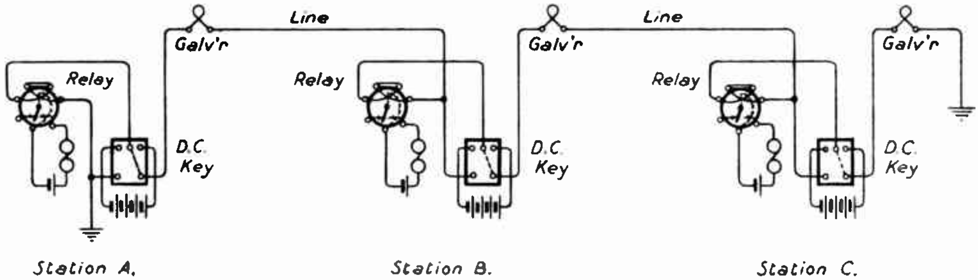

Fig. 17.—A Double Current Sounder Circuit with Three Stations.

The Quadruplex Principle Simply Explained.

The principle of the system lies in the use of currents of differing strength. If two keys are arranged so that one key determines the direction of the current, whilst the other key varies its strength, then by placing a polarised and non-polarised relay in series, it is possible to operate either or both these relays according to which key, or whether both keys, are depressed.

The Polarised and Non-polarised Relays.

The polarised relay will only produce a mark when the current flowing through its coils is in the correct direction. The non-

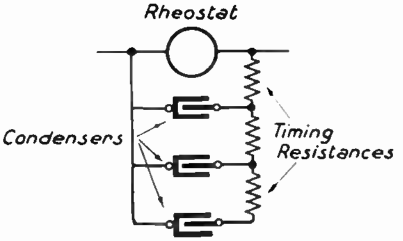

Fig. 19.—Duplex Balancing Arrangements.

polarised relay, on the other hand, will operate provided that the current strength is sufficient to overcome the pull of the spring.

An Ingenious Device.

Hence, by using a ratio of about 1 to 3 in current strengths, and by biassing the non-polarised relay against the normal current, this relay can be operated whenever the current is multiplied by three.

This plan is duplexed on the differential system, and one coil of the non-polarised relay, one coil of the polarised relay and one coil of the differential galvanometer, are connected in the line circuit, whilst the other coils are placed in the compensation circuit, together with the usual balancing apparatus.

A Bird's-eye View of the System.

The general principle of the arrangement will be clear from Fig. 21. The A key, as it is termed, is merely a commutator which determines the direction of the

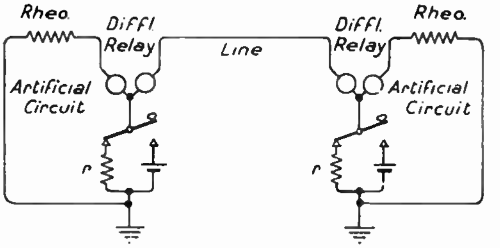

Fig. 18.—Principle of Differential Duplex.

current, whilst the B key determines whether the voltage shall be, say, 24 volts or 80 volts. The home apparatus is unaffected by the current applied from the home keys, and the half of the current which flows along the line to the distant end operates the relays according to its direction and strength. When these keys are simultaneously depressed, similar effects occur to those described in the case of the ordinary differential duplex.

A Difficulty and How it is Overcome.

There is, however, one rather important point in connection with quadruplex working which needs to be explained. It is the break which occurs in the signal on the B side relay when the direction of the current is reversed by the depression of the A key during the progress of a B side signal. There is an interval of time whilst the magnetism in the coils of the non-polarised relay is passing from magnetisation in one direction to magnetisation in the other direction. This difficulty has been met by placing a

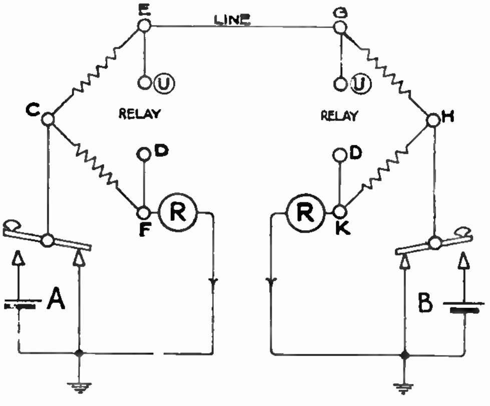

Fig. 20.—Principle of Bridge Duplex.
(*Post Office Technical Pamphlets.*)

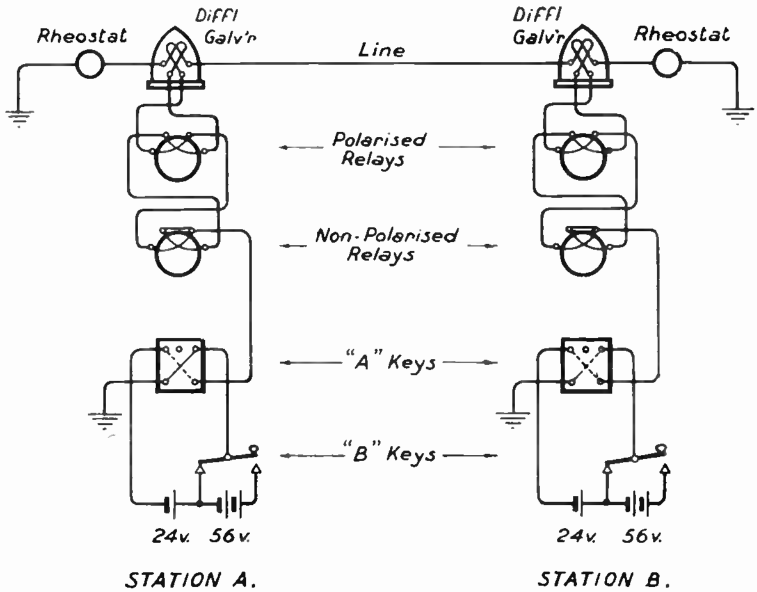

Fig. 21. PRINCIPLE OF QUADRUPLEX.

three keys which perforate a tape for the dots, dashes and spaces of the Morse code. A specimen of the tape is shown in Fig. 24. The centre holes, A, in the tape are used for guiding it through the transmitter. The dot signal, B, is represented by two holes directly in line, and the dash, C, by two oblique holes. The space is formed by a single central perforation.

How the Perforator is Worked.

The original perforator was operated by iron handles tipped with rubber, as shown in Fig. 23, but later developments produced a typewriter keyboard which made all the perforations required for each letter.

condenser and timing resistances across the sounder connected to the local contacts of the B relay. When this break occurs, the condenser discharges through the sounder and continues the mark. This is illustrated in Fig. 22.

WHEATSTONE AUTOMATIC SYSTEM.

The object of the system is to increase the traffic-carrying capacity of the line by the use of machine signalling. The limit of hand sending is round about 30 words per minute, whereas machine sending may rise to as much as 600 or more words a minute. In practice, the usual limit is between 300 and 400, and the average not more than 200. Most circuits permit signals to be sent over them at a far higher speed than is possible by hand sending, but this involves the storage of the signals.

Essentials of the System.

The Wheatstone automatic system consists of a number of perforators, a transmitter to send out the signals on the line and a receiving apparatus to record the signals.

The Perforator.

The perforator (Fig. 23) comprises

The Transmitter.

The transmitter is essentially a double-current key, which is operated mechanically in obedience to the positions of the holes perforated in the tape. By means of a rocking beam two rods, S and M, are driven against the tape alternately (Fig. 27). If the rod encounters a hole in the tape, the rod passes through it and operates the transmitting lever in one direction. This rod is then withdrawn and the other rod rises, and if it encoun-

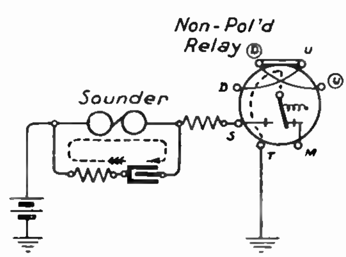

Fig. 22.—LOCAL CIRCUIT OF QUADRUPLEX B SIDE.

ters a hole it reverses the position of the divided lever.

How Dots and Dashes are Transmitted.

In the case of a dot, the movement of the two levers produces the shortest signal. Where a dash is encountered, the marking rod rises, but the other, or spacing rod, encounters unperforated paper and therefore cannot rise, and so leaves the divided lever in the marking position. The marking rod rises once more and encounters the full paper and has, consequently, no effect, and the mark is only ended when the spacing rod rises through the second hole of the dash perforation. This leaves a spacing current on the line, and if a centre hole only appears then neither of the rods can pass the paper, and the divided lever is left in its original position.

Methods of Driving Transmitter.

The transmitter (Fig. 25) is generally driven by a weight, but a motor-driven transmitter is sometimes used on very heavily worked circuits. There is a variable speed gear between the driving motor and the transmitter, and this enables the speed of transmission to be suited to the requirements of the circuit.

The Receiver.

The receiving instrument (Fig. 26) is a very sensitive form of direct writer. Electrically it is similar in design to a standard relay, but the tongue of the relay operates a small inked wheel, and in this way produces the dots and dashes of the Morse code on a tape driven across it. The receiver may be driven by a spring, by a descending weight, or by an electric motor.

How the Receiver Prints the Message.

The spindle carrying the armatures and the lever which controls the movement

Fig. 23.—Wheatstone Perforator. (*The India Rubber, Gutta Percha and Telegraph Works Co., Ltd.*)

of the inked disc is provided also with a contact arm, so that a sounder may be operated in a local circuit. The object of this provision is so that calling signals and instructions can be sent by key from the distant end when the transmitter is not being used.

CREED-WHEATSTONE.

The Wheatstone receiver can be replaced by a receiving perforator which produces at the receiving end a tape perforated precisely in the same way as the tape used to transmit the message. This tape can then be used to send the message to a number of other stations by passing it

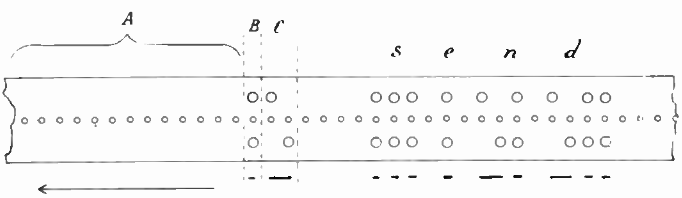

Fig. 24.—Wheatstone Tape and Signals Sent Out.

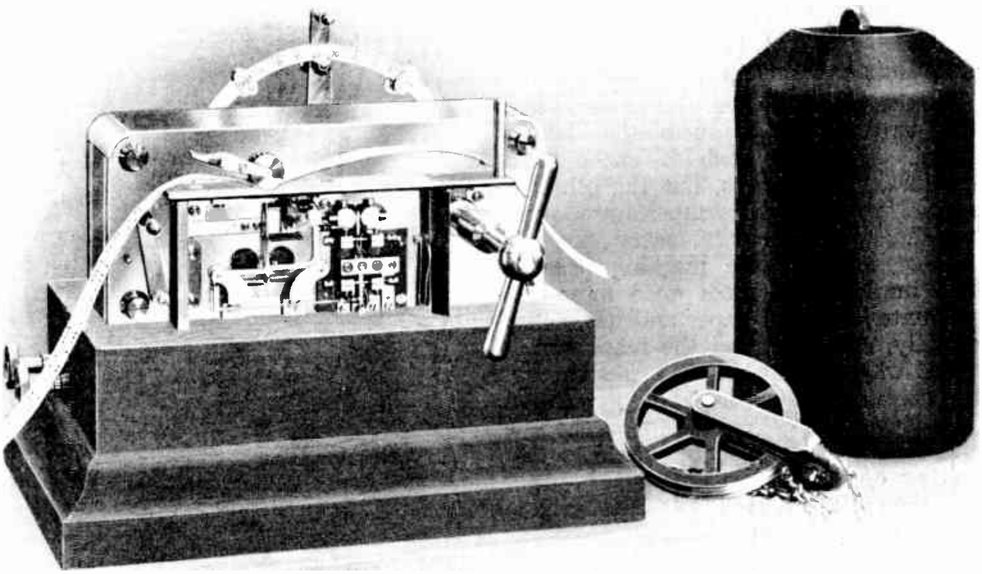

Fig. 25.—WHEATSTONE TRANSMITTER. (*Siemens.*)

through transmitters on those circuits. This presents very considerable advantage where the same message has to be sent to a number of places, and applies particularly to press messages.

By means of an apparatus which is purely mechanical in character, the Wheatstone perforated tape can be caused to print the message in the form of Roman characters on a tape, or in column form on a web of paper.

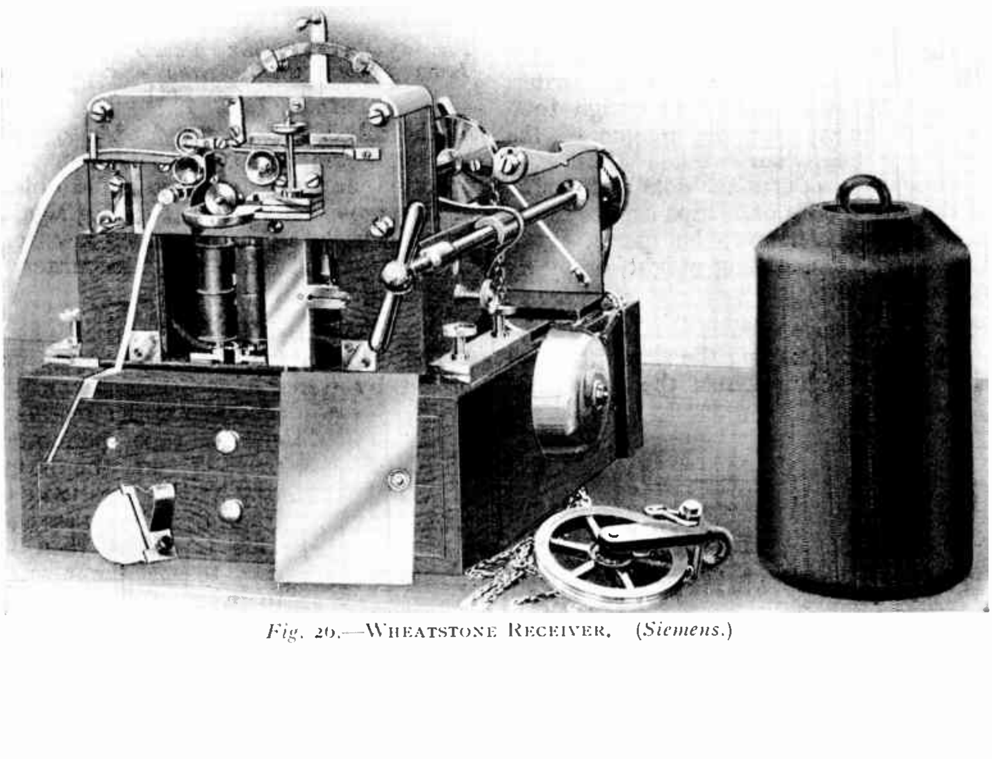

Fig. 26.—WHEATSTONE RECEIVER. (*Siemens.*)

Speed of Working.

The speed at which the receiving perforator can be worked does not exceed 120 words per minute, and the printer at rather less than this rate.

Automatic Telegraphy versus Multiplex Telegraphy.

The disadvantage of all automatic systems lies in the fact that an attendant is required to pass the perforated tapes through the transmitter at the sending end, and an attendant is also necessary at the receiving end to take off and distribute the received slips in order that they may be written up.

Incidentally, it may be remarked that the writing up of messages from an inked tape is far less rapid than when the messages are taken directly from the sounder.

It is these considerations which render multiple and multiplex forms of telegraphy economically preferable.

What is a Multiplex System?

A multiplex system may be defined as one in which several channels of communication are provided over a single circuit, but where the sending telegraphist works directly to the receiving telegraphist.

BAUDOT SYSTEM.

The Baudot is a multiplex system in which two or more channels of communication are provided by giving successively the exclusive use of a circuit, for equal periods of time, to two or more operators.

The System in Outline.

If, for example, four operators can set up signals at the rate of 30 words a minute, and these signals are transmitted automatically by the apparatus, signal by signal, at the rate of 120 words per minute, then a condition by which four sending operators are working to four receiving operators is achieved.

The Original Baudot.

The original Baudot system consisted of transmitting keyboards, the multiplex distributor and the receiving printers.

The alphabet consists of permutations of five currents, and this gives 32 possible combinations. With a device similar to the letter shift on a typewriter all the characters required are provided for.

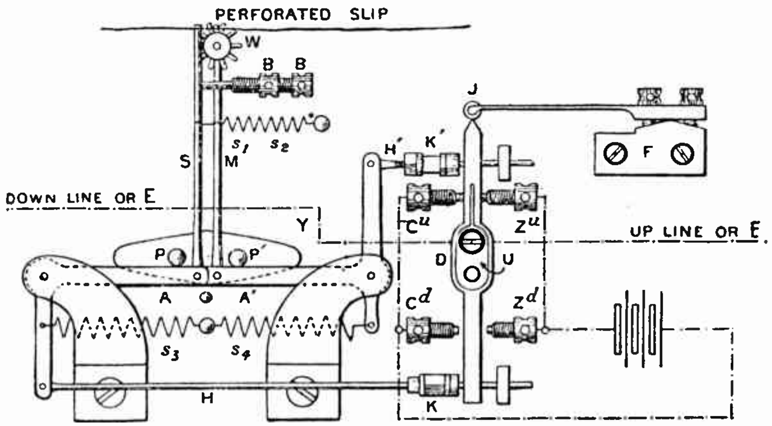

Fig. 27.—Principle of Wheatstone Transmitter. (*Post Office Technical Pamphlets.*)

The Baudot Code.

The code is shown in Fig. 28. Any particular letter or character is signalled by depressing simultaneously the keys indicated in the table. The position of these keys determines the sequence of the currents sent out to line.

Baudot and Morse Codes Compared.

It should be remarked that all letter signals are equal in length, consequently the code is considerably shorter than the Morse code. For example, the word "London" followed by a space occupies 35 units as against the 68 units required for the Morse code for the same word.

How the Operators Keep Time—The Cadence.

Since the signals sent to line by the four operators at the sending end are

Letters	Figures	V	IV	I	II	III	Letters	Figures	V	IV	I	II	III
A	1			●			–	.	●		●		
E	2				●		X	9/	●			●	
Y	3					●	S	7/	●				●
/	1/			●	●		Z	:	●		●	●	
I	3/				●	●	W	?	●			●	●
U	4			●		●	T	2	●		●		●
O	5			●	●	●	V	'	●		●	●	●
							Letter Shift & Space		●				
J	6		●	●			K	(	●	●	●		
G	7		●		●		M	)	●	●		●	
B	8		●			●	R	–	●	●			●
H	'		●	●	●		L	=	●	●	●	●	
F	5/		●		●	●	N	£	●	●		●	●
C	9		●	●		●	Q	/	●	●	●		●
D	0		●	●	●	●	P	+	●	●	●	●	●
Figure Shift & Space			●				*	*	●	●			

Fig. 28.—BAUDOT ALPHABET.

transmitted consecutively, it is essential that the signals shall be set up at the correct time, and this is provided for by an audible signal termed the cadence sent from the distributor. When the keys are depressed to send a signal they are locked by hooks; immediately the distributor has sent out the signals the keyboard is unlocked and the keys are ready for the next signal to be formed.

It will be apparent therefore, that the operators have to work in unison with the audible signal conveyed to them, but in practice this presents no difficulty whatever.

The Distributors Sort Out the Signals.

The currents sent out from the distributor at the sending end are passed to the particular receivers at the receiving end by the distributor there.

How the Messages are Printed.

The five currents constituting the character pass successively through five electro-magnets, which, by the attraction of their armatures, set in motion a purely mechanical selecting device. This selecting device causes the tape to be brought into contact with the inked type wheel when the correct character is directly above the tape.

THE DISTRIBUTOR.

The principle of multiplex telegraphy is illustrated in Fig. 29.

The Principle of Revolving Switch Arms.

If revolving contact arms at the two ends of a circuit move around a series of segments at precisely the same speed, and in phase with each other, it will be clear that the line is successively connected to the same segments at both ends of the circuit and in this way the first five currents sent out will be received on the five electro-magnets of the first receiver. The second five currents will pass to the second receiver, and so on.

It is, of course, quite impossible to arrange for such equality of speed that synchronism between the two distributors can be maintained without the intervention of correcting methods.

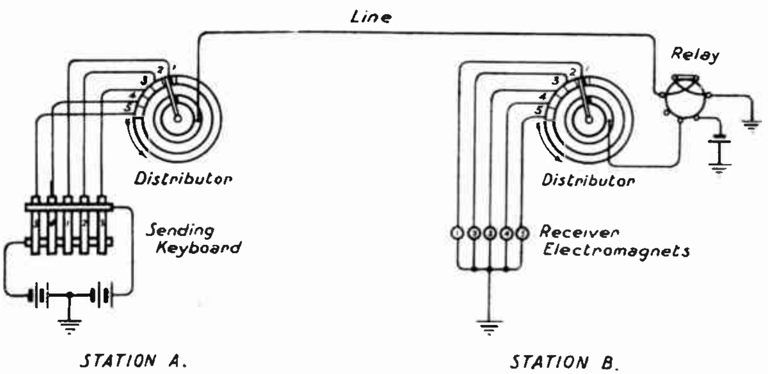

Fig. 29.—PRINCIPLE OF BAUDOT.

How the Arms are Kept "In Step"—The Phonic Wheel.

The plan most generally adopted consists in the use of La Cour's phonic wheel and motor driven either by a reed or a tuning fork. This ensures the greatest possible accuracy and speed.

How it Operates.

One distributor is set to run slightly faster than the other, and immediately the faster distributor has gained a predetermined angular lead, it comes into contact with a segment on the distributor which causes a current to pass through a correcting magnet.

What the Correcting Magnet Does.

The effect of this correcting magnet is to operate an epicyclic gear, which arrests the motion of the rotating contact arm for a space equal to the amount which it has gained, and consequently the distributors are once more in synchronism.

Future Developments.

These arrangements could be very definitely simplified if the distributors at various offices throughout the Kingdom were rotated by current of uniform periodicity, and it is possible that this condition will arise when the Central Electricity Board's grid is complete, since standardisation of frequency is an essential part of the scheme.

MODERN BAUDOT DEVELOPMENTS.

Keyboard Perforators.

In order to avoid the necessity for rhythmic sending, and to attain a higher speed of working, keyboard perforators have been introduced which perforate a tape in accordance with the letters to be transmitted.

The Transmitter.

This tape passes through a transmitter by the side of the keyboard perforator and consequently the operator is enabled to perforate the tape at the speed of typewriting.

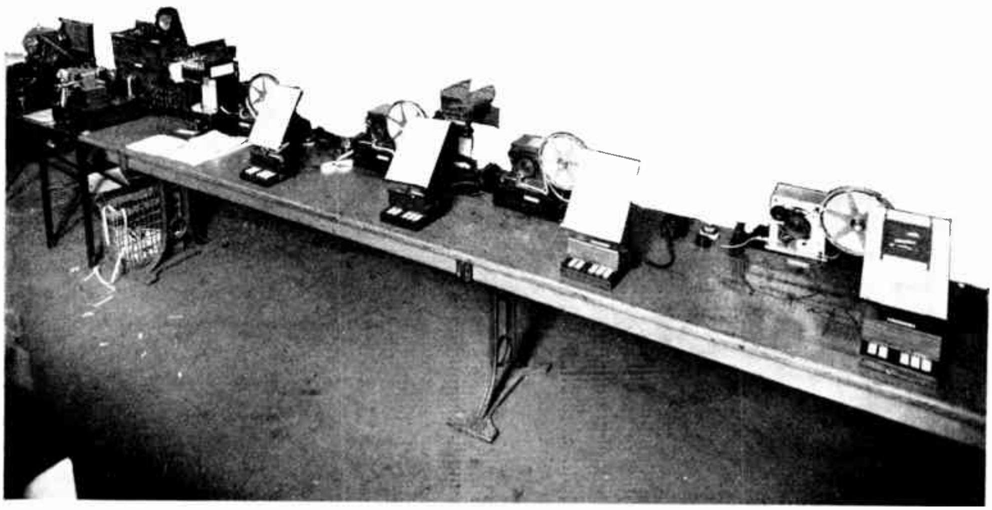

Fig. 30.—BAUDOT QUADRUPLE CIRCUIT.

The Distributor.

The transmitter is directly controlled by the distributor and consequently the operator has merely to observe the length of perforated tape between the perforator and the transmitter.

Invisible Correction of Errors.

This has a further advantage in that in the case of error the perforated tape can be pulled backwards and the wrong signal obliterated by perforating five holes instead of the signal perforated. This invisible correction of errors presents a definite advantage. Fig. 30 shows a manually operated Baudot installation.

and Fig. 31 shows an installation with automatic transmitters and keyboard perforators fitted on two arms.

General Note on Baudot.

The arrangement in this country is usually duplexed, so that eight channels are obtained over the single physical circuit. The Baudot system is remarkably stable, but highly skilled attention is necessary to secure reliability.

VOICE FREQUENCY TELEGRAPHS.

An Old Idea Newly Applied.

Another way in which several channels of communication can be obtained over a single circuit consists in using alternating currents of different frequencies. These various frequencies are applied simultaneously to the line circuit and produce an extremely complex current wave. At the receiving end the various frequencies are sorted out to separate receiving apparatus by electrical filters. These filters consist of arrangements of resistances, inductances and condensers so designed as to pass a particular frequency and to reject all others. The idea is a very old one, but it was only with the advent of the thermionic valve that the plan became practicable. It has the further advantage that the system can be used on ordinary telephone circuits.

How the Frequencies are Obtained.

In the Western Electric Company's system alternating current is provided by a generator for each frequency used. In other systems the frequency required is obtained by setting a valve into oscillation at the required frequency. The system possesses the advantage that the ordinary telephone repeater arrangements can be employed.

Voltages Used.

In general, the pressure applied to the circuit at the sending end is less than 2 volts; consequently there is no interference between voice frequency telegraphs and telephone circuits in the same cable. Consideration will show that a system of this character must necessarily be used on metallic circuits in order to avoid mutual interference.

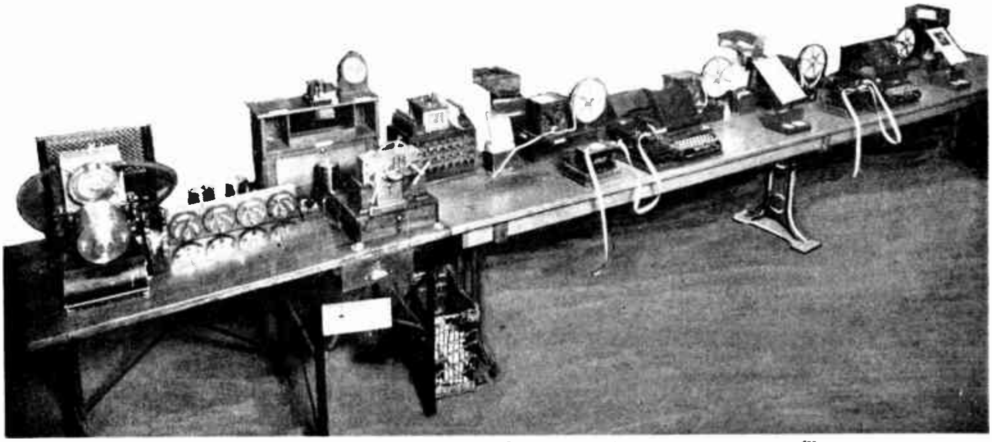

Fig. 31.—Baudot Automatic Circuit with Keyboard Perforators and Transmitters.

START-STOP TELEGRAPHS.

The Transmitter.

The sending portion of these machines comprises a typewriter keyboard, which sends out permutations of five currents of equal length.

The Start-stop Current.

Each character is, however, preceded by a short current, which sets in motion the selecting mechanism at the receiving end, and is followed by a stop current, which prevents one set of five signals from overrunning into the next set. It is the addition of these two currents which are added to the five-unit code

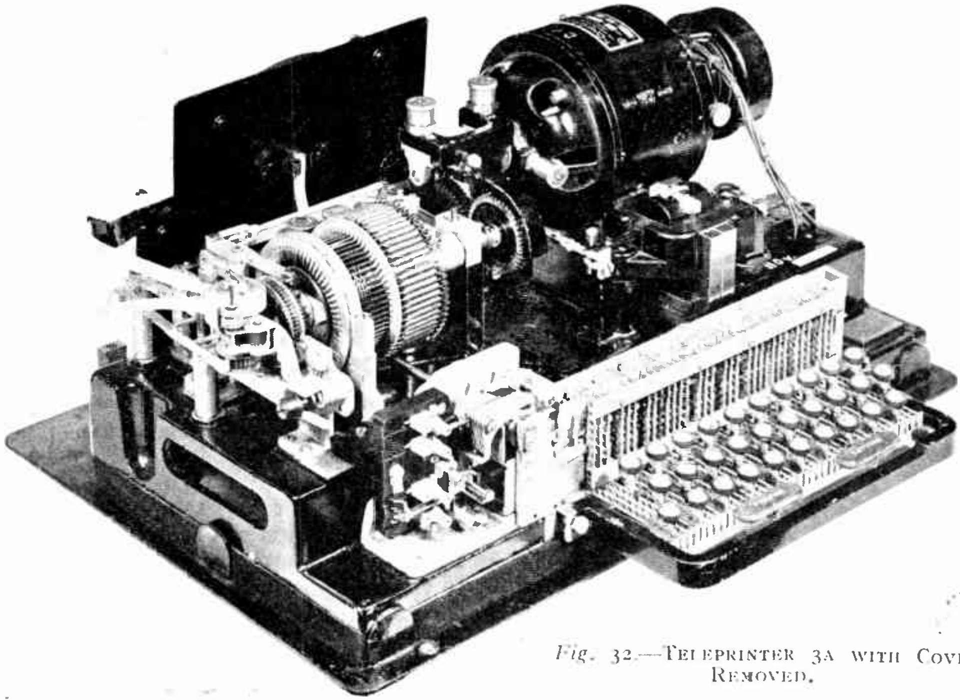

Fig. 32.—TELEPRINTER 3A WITH COVER REMOVED.

which gives the system its generic title. There are several different forms of start-stop machines, but space will permit only the description of the British machine adopted by the Post Office.

The Teleprinter 3A.

It is the invention of F. G. Creed, and is known as a teleprinter (Figs. 32 and 33). Similar machines in U.S.A. are termed teletypes. The machines are operated precisely as a typewriter is operated, and are capable of a speed of 60 words per minute. They are driven by a small electric motor, which runs continuously. Normally, the sending and receiving mechanisms are at rest, and it is only when a key is depressed that they are coupled up by a clutch to the driving motor.

Fig. 33.—TELEPRINTER 3A.

How the Clutch is Operated.

The operation of the clutch is purely mechanical and is operated by a projection on the key lever in the course of its depression. Beneath the upper portion of the key levers (Fig. 35), which lie side by side, there are five bars bearing projections adjacent to each key corresponding to the signal code.

For example, to the left of the R key there are projections on the first, third and fifth selecting bars. Whereas next to the A key there are projections on

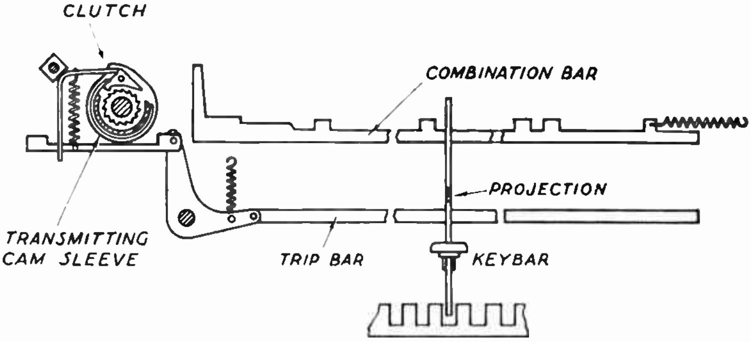

Fig. 34.—Clutch and Transmitting Cam Sleeve.

the third, fourth and fifth bars. In this way the position of the five bars is determined by the key operated, and this in turn, controls the movement of a contact tongue which connects either the positive or negative pole of the sending battery to line. The five currents preceded by the start signal are sent successively to line during the single revolution of the cam sleeve during the final portion of which movement the stop current is finally transmitted.

In addition to the functions already indicated, the cam sleeve also operates a send and receive switch, so that normally the receiving apparatus is joined to line ready to receive signals. Immediately a key is depressed the sending mechanism is substituted, thus avoiding the necessity for a switch to be operated by hand at the beginning and end of each message.

The Keyboard Lock.

The keyboard includes a locking device, purely mechanical in character, which prevents a depressed key from rising until the signals which it has set up on the five selecting levers have been transmitted to line.

Keeping Transmitter and Receiver in Step.

The use of five successive currents to produce five selections in the receiver naturally requires that the sending and receiving apparatus shall operate in unison. To adjust two machines to a close approximation to equality in speed presents no difficulty whatever.

It is only when the difference in speed is cumulative that serious difference in phase results. But the sending teleprinter starts the receiving mechanism and stops it on completion of the signals. Hence any difference in speed is confined to a single revolution, and for this single revolution the phase difference is negligible.

Indeed, a relatively large difference in the speed of the sending and receiving mechanisms can occur before the apparatus fails to function correctly.

The Practical Method.

In practice the receiver is set to run very slightly faster than the transmitter to ensure the definite stoppage of the

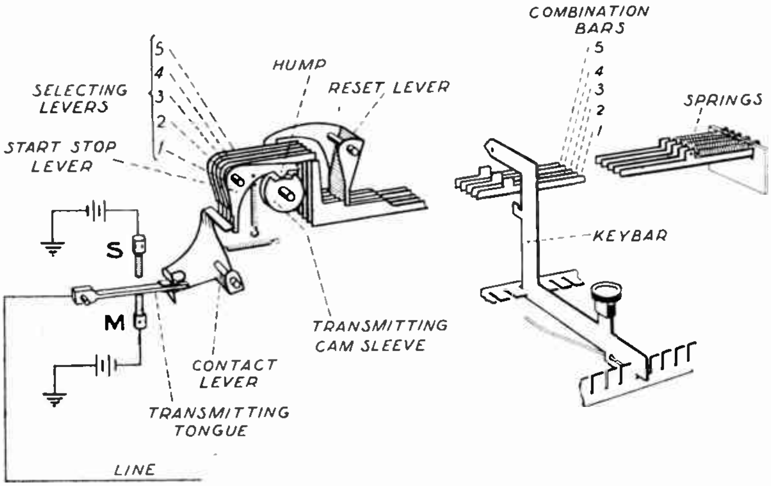

Fig. 35.—Principle of Keyboard.

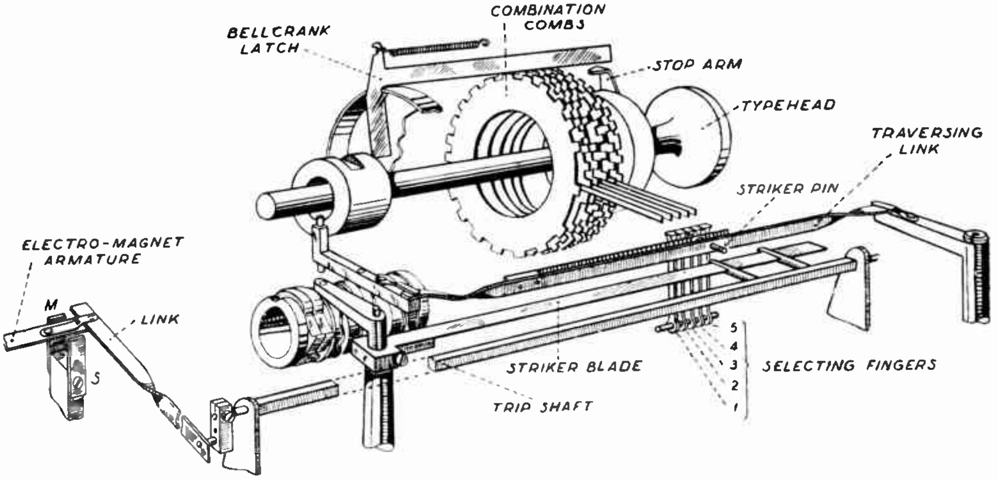

Fig. 36.—SELECTING MECHANISM.

receiver and a start at the beginning of the next series of impulses.

The Driving Motor.

This is of the ordinary commercial type, but its speed is controlled by a centrifugal governor, which operates a contact controlling the introduction or withdrawal of a resistance in series with the field magnet of the shunt-wound motor.

How Messages are Sent.

The seven current impulses, including the start and stop signals, sent along the line pass through the coils of polarised relay and determine the movements of the armature (Fig. 36). This armature carries an extension arm, and these movements are by purely mechanical means translated into the selection of the character and its imprint on the tape.

The term relay generally used in this connection is perhaps hardly appropriate since it consists of a polarised electromagnet which carries no electrical contacts.

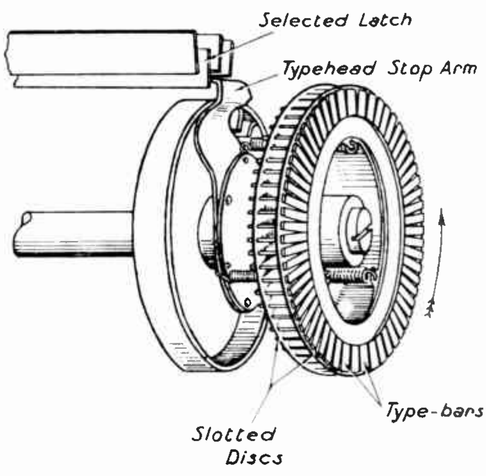

Fig. 37.—THE TYPE HEAD.

The starting impulse operates the clutch and the five code impulses which follow successively position five slotted discs termed combination combs in accordance with the currents received.

This is accomplished by a battery of cams during the revolution of the mechanism. Each combination comb has two positions, the normal position and the operated position, in which it is turned through an angle of about 12 degrees.

How the Type is Selected.

Disposed around the combs there are bars corresponding to the characters on the keyboard, and the five combs are slotted in such a way that when the combs are moved or operated in accordance with the code sent out the bar or latch corresponding to that character can descend, since the slots on all five combs are in alignment. In this way any given character is selected by moving the combs in accordance with the code.

The particular latch selected having fallen

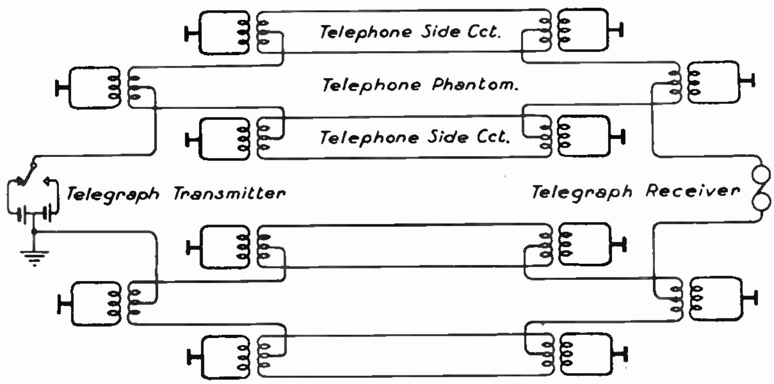

Fig. 38.—Double Phantom Circuit.

Thereafter the characters which alternate on the type head, continue as letters or figures until the shift key is again operated.

into the aligned slots on the combination combs, the type head revolves until arrested by the operated latch.

At this point the selected character is opposite the tape and a blow from a cam-operated hammer prints the character. The operated latch is raised and the combs restored to their normal position in readiness for the next code combination.

The type bars are carried in two radially slotted discs (Fig. 37) under spring tension and printing is effected by a blow on the type bar.

Sixty Characters on Type Head.

There are actually 60 latches placed around the combination combs, and the type head contains the same number of characters. The selection of letter and figure characters is determined by a sixth comb, which bears 30 slots.

How Figures are Selected.

The five code combs will permit two adjacent latches to fall, but the sixth or figure-shift comb permits only one of the two to fall. Two places are left blank on the type head and the receipt of a special code combination moves the figure-shift comb into the letter or into figure position according to whether the letter or figure shift is signalled.

SIMULTANEOUS TELEGRAPHY AND TELEPHONY.

At this point it may be convenient to describe in general terms the trend of modern telegraph engineering. At one time the telegraphs and telephones were entirely separate, and special cables for telegraph purposes were provided. The introduction of telegraph circuits into telephone cables was definitely deprecated owing to the interference with the telephone circuits which resulted from the relatively heavy currents used.

Present-day Trend.

The tendency to-day is to provide any telegraph circuits which are required by adding such channels to telephone circuits. Where telegraph circuits are worked on conductors in a telephone cable, metallic circuit working is essential to avoid interference with telephone speech.

Superposing and What it Means.

A telegraph circuit can simultaneously be worked over a telephone loop by the method known as "superposing." A repeating coil, which essentially consists of a transformer, is interposed at each

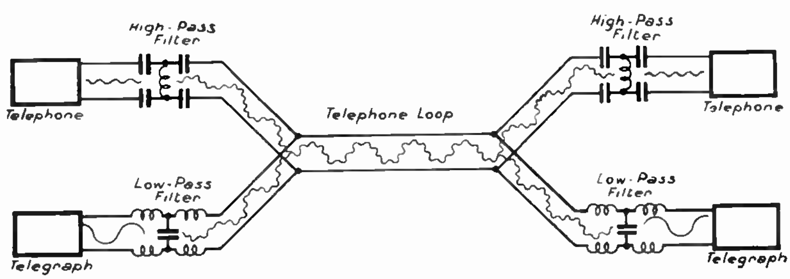

Fig. 39.—Principle of Sub-Audio Telegraph Working.

end of the telephone circuit, and the centres of the windings at each end are connected to the telegraph apparatus.

It is essential that the two lines of the telephone circuit shall be equal in resistance, capacitance and inductance, and in practice this condition is readily fulfilled by many ordinary circuits. The telephone currents pass through the transformers in the ordinary way, whereas the current from the telegraph apparatus divides between the two halves of the line windings and produces no effect on the core of the transformer.

Fig. 40.—TELEPRINTER 7A.

The Double Phantom Circuit.

An example of the application of this principle in daily use is known as the "double phantom circuit." It is illustrated in Fig. 38. It will be observed that six telephone circuits are obtained from four physical circuits, and that a loop telegraph circuit is provided by taking the central points of the phantom telephone circuits of the two pairs.

SUB-AUDIO TELEGRAPHY.

The principle of this method depends upon the fact that for the reproduction of good quality speech on a telephone circuit, the frequencies below 200 periods per second can be cut out without detriment to the speech. For ordinary telegraph working, a periodicity up to about 100 periods per second is ample. By providing filters, the frequencies above 200 are diverted to the telephone channel, while the low frequencies are stopped by a high pass filter. The principle of the arrangement is indicated in Fig. 39, which gives a graphic illustration of the splitting up of the complex wave between the telegraph and telephone circuits.

Fig. 41.—TELEPRINTER 7A WITH COVER REMOVED.

TELEGRAPH SWITCHING.

In the early days of telegraphy, many attempts were made to introduce systems by which the retransmission of messages was avoided by switching the circuits at intermediate points. All these systems, however, have long since been abandoned, but recent developments seem to indicate the possible introduction of some form of switching, either by manual operation or by employing the principles of telephone automatic switching. This plan, however, has not so far been suggested for the use of main line telegraph circuits.

An Interesting System with Possibilities.

A system has been worked out

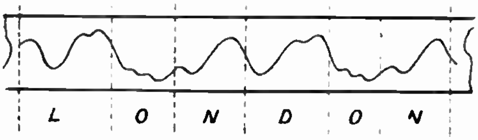

Fig. 42.—SIPHON RECORDER TAPE.

in which subscribers have teleprinter apparatus and, instead of verbal messages or letters, obtain connection with their correspondents and transmit their messages or orders on the teleprinter circuit thus formed. One advantage gained in comparison with a telephone conversation is the permanent record of the message, thus obviating the necessity for confirmatory letters. In the second place, many matters which would ordinarily be dealt with by post would be more quickly transacted, and this speeding up of business methods would, no doubt, have definite economic advantages. It is not possible at this stage to enter into details of the system.

The machine, however, known as the Teleprinter 7A, is arranged to print on a wide band of paper instead of on a paper tape. A unique feature is the provision of a special " who are you " key on the keyboard. When two subscribers are connected together this key can be depressed, whereupon the exchange number of the called subscriber is automatically transmitted back and is printed on the roll of paper associated with the calling machine. This provides a safeguard against a wrong connection.

The mechanical operation of the Teleprinter 7A is the same in essential detail as the description already given of the Teleprinter 3A. Fig. 40 shows the general appearance and Fig. 41 depicts the working mechanism.

POWER PROVISION.

In the case of small or isolated offices, the electrical energy for working telegraph circuits is derived from Leclanché cells. In large offices the power is derived from secondary cells and double-current keys are arranged to select either positive or negative voltage as may be required.

Battery Installation.

The ordinary secondary cell installation comprises a motor generator worked from the town mains for charging the cells. A 24-volt negative battery and a 24-volt positive battery are provided in duplicate, and are used for working comparatively short circuits, and also for operating the sounders in the local circuits of the relays. In addition, voltages of 40, 80 and 120 positive and negative are provided, with two spare 40-volt sets of cells for use during recharging.

The Power Mains.

The power leads pass to the instrument room through fuses at the cells and in the main leads. From these mains the leads of each set are taken through a 1-ampere fuse and in this way a fault on one of the sets will not interfere with the rest.

SUBMARINE TELEGRAPHY.

The problems associated with trans-oceanic cables are of a very different character to those of inland telegraphy. Early trans-Atlantic cables consisted of a stranded copper conductor, insulated with gutta-percha. The object of the stranding of the conductor was to give the cable flexibility. This is the electrical part of the cable and is the same from beginning to end. Over the gutta-percha insulation a spiral brass tape is wound to prevent the teredo worm from boring into the gutta-percha. Over this there is a layer

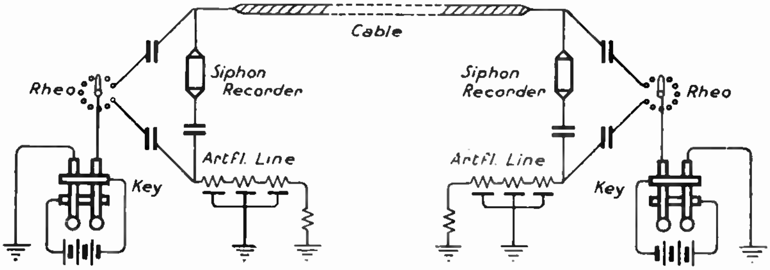

Fig. 43.—PRINCIPLE OF SUBMARINE CABLE DUPLEX (KEY SENDING).

of jute, which forms a bedding for the armouring of iron wires for mechanical protection. The armouring is, of course, lightest for the deep sea portion of the cable and is increased as the depth at which the cable is laid becomes shallower, until at the shore end of the cable this armouring is exceedingly heavy.

Why Unloaded Cables are Obsolete.

The discovery of the nickel-iron alloys has revolutionised the whole problem of the telegraph cable and every unloaded cable may be regarded as obsolete. The new loaded cable gives a working speed of from eight to 10 times that of its predecessor. Moreover, improvements have also been made in the dielectric, with the result that a much lower capacitance is obtainable. A permalloy, mumetal, or perminvar tape is wound around the copper conductor before the dielectric is applied. This adds upwards of 150 millihenrys per nautical mile to the inductance of the cable.

The laying of the submarine cable is a highly technical operation and has a technique of its own. In the same way the localisation and removal of faults on such cables has been developed, but in a work of this kind it is not possible to provide an adequate description.

How Messages are Sent.

The signalling code used on submarine cables is the Morse code, with a current in one direction for a dot and in the reverse direction for a dash. The messages to be sent are first of all perforated on a tape in a similar manner to the Wheatstone arrangements already described. This perforated tape passes through a transmitter, which sends the signals into the cable. At the receiving end they pass through a siphon recorder (Fig. 43) which consists essentially of a specialised form of d'Arsonval galvanometer, to the coil of which a fine tube is attached, one end of which dips into an inkwell and the other end is in contact with the paper tape.

The type of signal received is indicated in Fig. 42. It will be clear that there is a very sharp limit to the voltage which can safely be applied to a long cable, and in general this is usually not more than 50 or 60 volts.

Duplexing a Submarine Cable.

As a conclusion to this part of the subject, it may be interesting to show the arrangements made for duplexing a long submarine cable. The ratio arms consist of two condensers (Fig. 43), and at the apex of the bridge there is a small rheostat for accurate adjustment of the balance.

Compensation Circuit.

The compensation circuit consists of a special form of artificial line in which a zigzag of tinfoil is separated from an earthed full sheet of foil by paraffin paper. The zigzag foil is of such dimensions as to represent not only the capacity, but also the resistance of a unit length of cable. The precise detail of the balance involves many complications, and the operation of balancing a long submarine cable may take several weeks of continuous work by specialists. When, however, this balance has once been obtained, it does not appreciably vary, and the adjustments required from time to time are of a very simple character.

Transmitting Apparatus.

The transmitting apparatus has been shown as a simple commutator and the receiving apparatus as a siphon recorder. It has been found that by taking the earth a long way out to sea where a certain critical depth is encountered ensures that the circuit is fairly free from extraneous disturbances.

Loaded Cable and Duplex Working.

It may be added that there is considerable difficulty in duplexing the loaded cable, and in general such cables are worked simplex. This disadvantage is not so great as would at first sight appear, since owing to the difference in time between the two sides of the Atlantic, the rush hours of traffic do not coincide.

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SILVER, PLATINUM AND THE RARER METALS

AND THEIR USES IN THE ELECTRICAL INDUSTRY

By A. W. JUDGE, A.R.C.Sc., D.I.C., Whitworth Scholar.

IN other articles we have described the more common metals used for electrical purposes; we shall now consider the rarer metals that have important applications in electrical engineering, commencing with silver and concluding with an account of some of the metals used in lamp manufacture.

SILVER.

Silver is a pure white metal capable of taking an excellent polish. It is very ductile and can be beaten out into thin sheets without fracture; it is necessary, however, to anneal the metal by heating it to a red colour when hammering out.

The most important property of silver is its very low electrical resistance; it is the best electrical conductor of the metals. To give an idea of its low resistance it can be stated that this is only 90 per cent. of that of copper—the best known commercial electrical conductor.

Similarly, silver is an excellent heat conductor. Thus, if the heat conductivity of silver be taken as being 100, that of copper is 94 and aluminium 57.

Where Silver is Used.

Silver is used in electrical work for contacts where very small currents have to pass, as in electric clocks. Silver wire is also used for conductors in delicate electrical apparatus and instruments. It is sometimes alloyed with platinum for electrical wires that have to pass through glass walls. Silver is also an ingredient of silver solder. The very best solders contain from 50 to 70 per cent. silver, the remainder being copper and zinc. A typical silver solder contains 20 parts silver, 45 parts copper and 30 parts zinc.

Silver is a heavy metal, its specific gravity being 9.52; it is thus about 9 per cent. heavier than copper (specific gravity, 8.8).

PLATINUM.

This expensive metal is used in electrical work chiefly for electrical contacts and wires passing through the walls of glass vessels.

Platinum is a light coloured metal, rather greyer in appearance than silver. It takes a fine polish and is practically unaffected by atmospheric corrosion influences.

It is an extremely heavy metal, the specific gravity, in the cast state, being 21.5, i.e. about 2½ times the value for copper. It has a fairly high electrical resistance, viz., about 6 times that of silver.

Platinum-Iridium Contacts.

Platinum, owing to its high cost, is not generally used in the pure form for contacts, but it is alloyed with another metal known as *iridium*. Platinum-iridium contacts are used for light contact breakers in electrical apparatus and instruments, magnetos, cut-outs, etc.

Platinum, having about the same coefficient of expansion as glass, a piece of platinum wire can be fused into, or through, glass to give a gas-tight connection. Many electrical instruments having glass tubes with platinum wire conductors have been used in the past. One typical example is that of a column of mercury in a sealed glass tube, with a platinum wire contact above the mercury. The rise of the mercury in the tube makes contact and thus completes an electrical circuit; fire alarm thermometers are made on this principle.

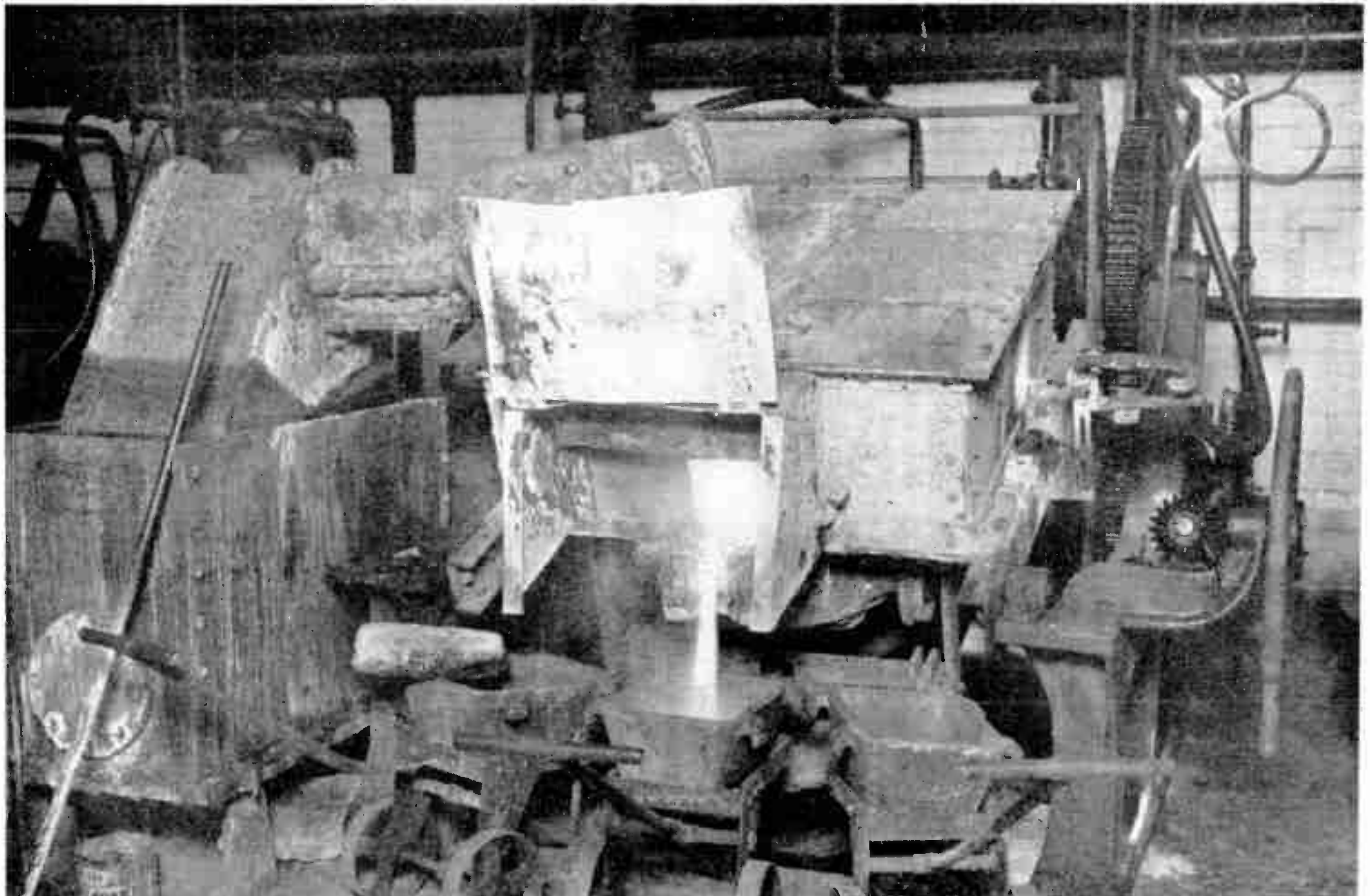

Fig. 1.—AN OIL-FIRED SMELTING FURNACE. (*The Mond Nickel Co., Ltd.*)

Pouring a charge of Clydach Concentrate. This concentrate contains a relatively large proportion of silver and lead and receives an initial smelting operation in the course of which lead is used as a collector of the precious metals.

BERYLLIUM.

This is an interesting metal that is actually lighter than aluminium and has as good an electrical conductivity as silver. Unfortunately, however, owing to its present high cost of production, it cannot be used commercially.

COBALT.

This is a brilliant silver-white metal having properties somewhat similar to iron; it is the next most magnetic metal, after iron. Cobalt is also a constituent of a well-known tool steel and of the metal cutting alloy Stellite.

Cobalt plated iron and steel articles are now being used for outdoor electrical parts exposed to corrosive influences.

Alloyed with chromium in certain proportions it gives an alloy known as *Cochrome*, used for resistance heating elements, in place of nichrome, in electric stoves and heaters.

IRIDIUM.

This hard steel-grey metal actually belongs to the platinum class. It is insoluble in acids and can only be melted in the electric furnace. Iridium is used for hardening platinum for electric contacts, watch and compass bearings and incidentally for pen points.

OSMIUM.

This is a bluish white metal and the heaviest of all metals; it has a specific gravity of 22.5. It has an extremely high melting point, viz., 2,500° C. Osmium, for this reason, is sometimes used for electric lamp filaments.

SELENIUM.

This is a steel grey metal having properties resembling those of sulphur. It melts at 217° C. and burns readily in air when further heated.

It possesses the property of altering its electrical conductivity when exposed to light variations. For this reason the *selenium cell*, as it is termed, is used for television, talking pictures and similar apparatus where light variations are converted into electrical resistance changes and vice versa.

THORIUM.

This is a greyish-white crystalline metal with the appearance of nickel. It has radio-active properties somewhat like uranium.

Thorium is largely used in the manufacture of gas mantles to increase the incandescent properties. In electrical work it is mixed with other rare earths such as zirconia and yttria to make the filaments of *Nernst lamps*.

TUNGSTEN.

This is a most important metal in the mechanical and electrical engineering fields. It is usually produced as a grey metallic powder having a very high fusion point (3,540° C.). In electrical work the tungsten electrode bulb of the Pointolite type (widely employed for projection purposes) is well known. It is also used in X-ray bulbs as the anti-cathode. Tungsten is also an important element in tungsten steel magnets.

ZIRCONIUM.

This hard crystalline lustrous substance is used for electrodes and some of its alloys are used for electric lamp filaments; these show a lower electric power consumption per candle-power than most metal filament lamps.

Zirconium salts are also used to coat fire-clay cylinders to produce incandescent units for lighthouse lamps and optical projectors of the "lime light" class. Zirconium is better than lime or magnesia for this purpose, as it gives a more brilliant illumination.

MERCURY.

This liquid metal has several useful applications in electrical work notably for automatic change-over contacts (in tilting glass bulbs), for mercury vapour lamps—used, on account of their rich ultra-violet rays, for medical and photographic work, for electric contacts in special apparatus electric fire alarms, etc.

NICKEL AND ITS ALLOYS

IN ELECTRICAL ENGINEERING

By A. E. Hanson

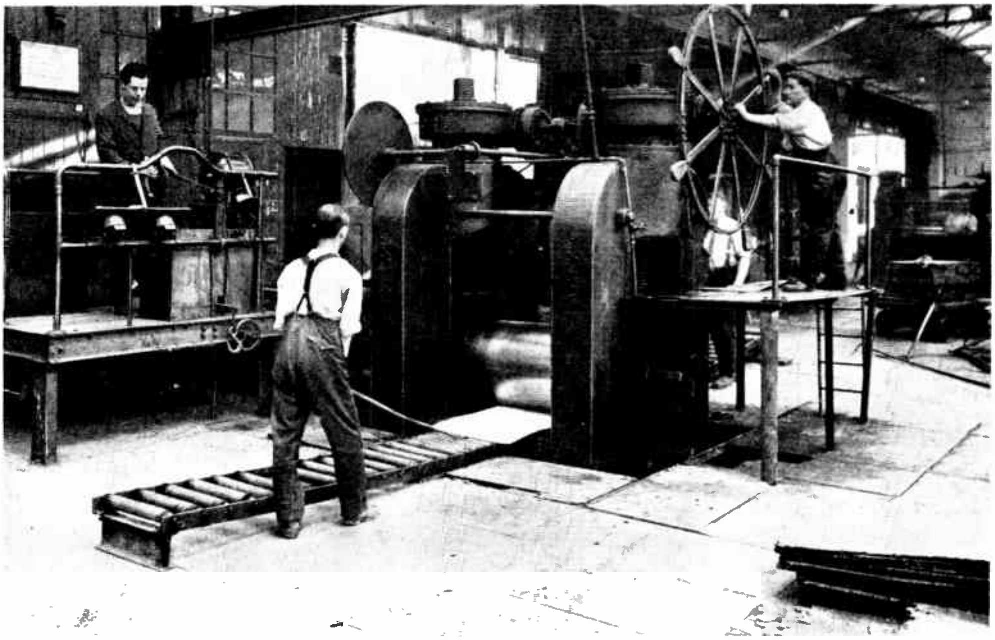

Fig. 1.—Reversing Mill for Rolling Sheet Nickel. (*Henry Wiggin & Co., Ltd.*)

PURE nickel and nickel-bearing alloys are used for numerous purposes in the electrical industry. The most important alloys are those belonging to the nickel-chromium group, which are employed chiefly because of their remarkable heat-resisting properties.

Properties of Nickel.

Nickel is a silvery-white metal that is malleable, ductile, somewhat magnetic, harder and stronger than iron and resistant to abrasion. It is highly resistant to the action of air, water, non-oxidising acids and to oxidation at high temperatures. Nickel has a magnetic transformation point at about 320° C. The melting point of nickel is 1452° C. Its specific gravity is about 8.8 and its electrical resistance about seven times that of copper.

Uses of Nickel.

Pure nickel is used in the electrical industry for the components of wireless valves. The purity of nickel and the fact that it can be heated to high temperatures for the purpose of freeing it from occluded gas without risk of deformation or the liberation of substances harmful to the valve are the main reasons for employing it for anodes, grids, electrode-supporting wires and other components. Practically

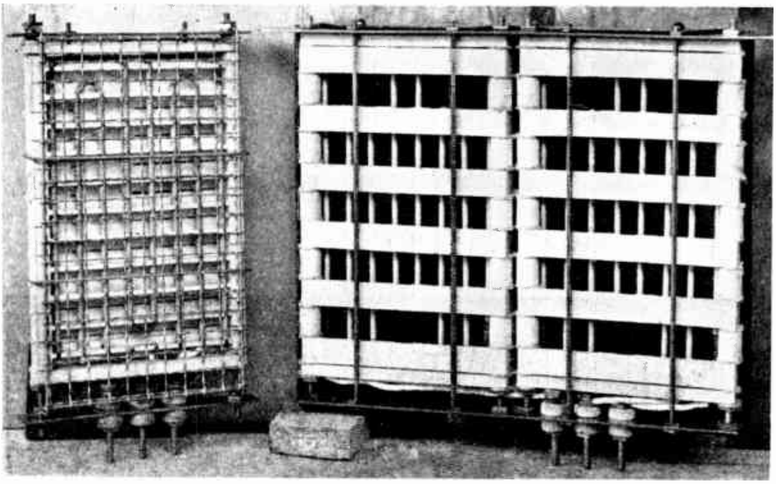

Fig. 2.—Nickel-chromium Alloys in the Form of Wire or Tape are Almost Universally Employed for Heating Elements. (*Automatic Electric Co., Ltd.*)

principle of which is the oxidation and reduction of metals in an electrolyte which neither combines with nor dissolves either of the active materials or their oxides. The active material of the positive plate is usually nickel hydrate or nickel hydroxide, while that of the negative plate is either iron oxide or cadmium oxide. The electrolyte is a solution of potassium hydrate.

The nickel-iron type cells are extremely robust and will withstand vibration that would ruin the ordinary lead accumulator. For this reason they are widely used on railway coaches, 'buses, electric trucks and on ships at sea. Practically speaking, they are foolproof, for they are not harmed by irregularity of operation, over-

all receiving valves as well as low-power transmission valves employ nickel for the internal structural parts.

A nickel-iron alloy containing 40 per cent. nickel, coated with copper, is used for glass-to-metal joints. The overall expansion of this wire is approximately that of glass, while the copper provides the necessary conductivity.

Other uses for nickel include sparking plug electrodes which are made from pure nickel, or from nickel containing 3 per cent. of manganese.

Early Uses of Nickel.

One of the early uses of nickel in the electrical industry was in the manufacture of the nickel-iron type of storage battery, the fundamental

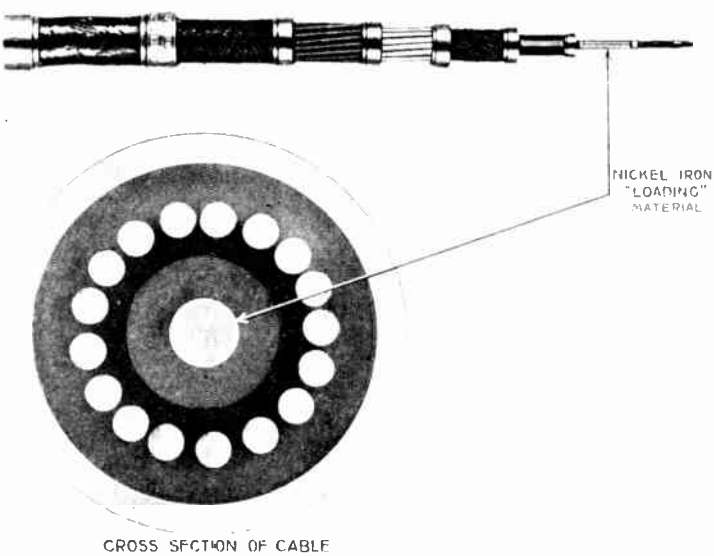

Fig. 3.—Submarine Cable, Showing Arrangement of Nickel-iron Loading.

charging, short-circuiting or long periods of idleness.

Nickel-Iron Alloys.

There are many nickel-iron alloys in use but perhaps the most interesting is the alloy which contains approximately 78.5 per cent. of nickel and which, when suitably heat treated, has a higher magnetic permeability then either pure iron or silicon iron. This alloy is used for loading submarine telegraph cables. The term "loading" designates a system of adding inductance to a transmission circuit for the purpose of overcoming the effects caused by the capacity of the circuit. Loading submarine cables with nickel-iron strip has enabled their carrying capacity to be increased five times. The same principle is used in telephone transmission circuits, but in this case, finely divided nickel-iron cores are used in the loading coils.

There are also nickel-iron alloys, containing much lower proportions of nickel, which are non-magnetic and these are used extensively for constructional parts, often in the form of castings.

By varying the nickel content variations may be made in flux density, electrical resistance and hysteresis loss so that alloys of widely different properties can be obtained. If high resistivity combined with high permeability is required an alloy containing between 40 and 50 per cent. nickel may be used. If high resistivity and low magnetic permeability are needed the 30 per cent. nickel alloy is employed.

Nickel-Iron for Wireless.

Low frequency transformers used in wireless receiving sets are made with cores of nickel-iron of varying compositions, the object being to reduce the size of the transformer without loss of efficiency and to minimise the risk of saturation of the core. This is one of the most common causes of distortion in wireless receiving. Similar transformers are used in moving-coil loud speakers, and in certain special types of navigational equipment, including gyro-compasses and depth-sounding machines. The armatures of the generators used in gyro-compasses are also made from nickel-iron alloys.

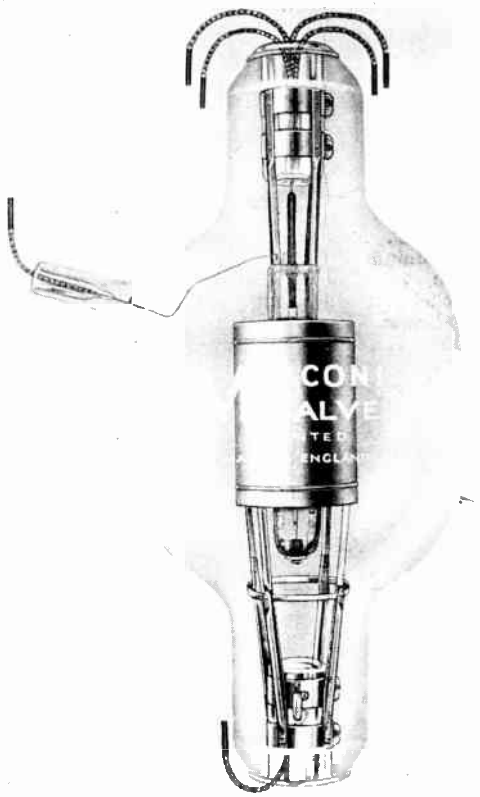

Fig. 4.—A Wireless Valve in which Pure Nickel is Used for the Grid, Grid Supports, Plate, etc. (*The Marconi Co., Ltd.*)

Copper-Nickel Alloys.

The chief copper-nickel alloy used in the electrical industry is the 45 per cent. nickel alloy which has a practically zero temperature coefficient and is used in very large quantities as a resistance material. Its resistance is unalterable, it will not rust, become brittle or perish with heat, age or exposure, it is not attacked by sea-water and is resistant to the majority of dilute acids. This alloy is used for instrument shunts of all kinds, field-regulator resistances, cinematograph resistances, motor starters, arc lamp resistances and fan starters. It is sometimes used with an oxide coating, the insulating qualities of which enable the wire to be close wound on sliding contact resistances.

Nickel-Chromium Alloys.

The use of nickel-chromium and nickel-

COMPARATIVE ELECTRICAL DATA—WIRES AND TAPES.

TABLE I.—METALS.

	Specific Resistance Microhms per cm.³	Resistance Compared with Copper.	Temperature Coefficient per 1° C.	Melting Point.
Copper	1.72	1	.0043	1084
Gold	2.42	1.41	.004	1062
Aluminium	3.17	1.85	.0038	657
Zinc	6.06	3.53	.0037	418
Nickel	9.0	5.25	.005	1452
Platinum	10.92	6.37	.0038	1756
Tin	11.2	6.43	.0045	232
Iron	11.85	6.9	.0062	1530
Lead	20.6	12.0	.0043	327

TABLE II.—ALLOYS.

Alloy.	Composition.	Specific Resistance in Microhms per cm. cube at 0° C.
Brightray	Nickel 80, Chromium 20	103
Glowray	Nickel 65, Chromium 15, Iron 20	106
Dullray	Nickel 30, Iron 70	91
Ferry	Copper 55, Nickel 45	48
Mangonic	Nickel 97, Manganese 3	14.5
Monel Metal	Nickel 67, Copper 33	42.5
Nickel Silver	Nickel 25, Copper 55, Zinc 20	36
Nickel Silver	Nickel 20, Copper 64, Zinc 16	31
Platinoid	Copper 62, Nickel 15, Zinc 22	34

chromium-iron alloys for the elements of electrical heating, cooking and domestic appliances is very well known. The nickel-chromium alloy containing 80 per cent. nickel is used where high temperatures are encountered, as in electric fires and furnaces, and also in electric irons, toasters, percolators and similar apparatus. The heat-resisting qualities of nickel-chromium alloys ensure that such elements will have a very long life. Practically all good quality electrically heated appliances to-day employ this type of wire. The nickel-chromium-iron alloys are used where lower temperatures are encountered, as in soldering irons and for resistances.

Nickel Alloy Steels.

Although nickel alloy steels, which are so widely used on account of their great strength and toughness, are not primarily electrical materials, they are used in power-producing equipment where heavy stresses are involved. Generator shafts and heavy moving parts are examples of this type of service.

Nickel-Copper Alloys.

The use of nickel-copper alloys, notably those containing approximately 68 per cent. of nickel, for transmission system equipment is old established. They are employed for bolts and pole line hardware, particularly in places where corrosive atmospheres are encountered.

Miscellaneous.

Numerous uses of nickel-bearing materials appear in the electrical industry where the reason for such use is not strictly due to electrical properties. The employment of nickel-silver and copper-nickel alloys in the manufacture of electrical appliances, and the widespread use of nickel-plated components in apparatus generally, may be mentioned.

CONDENSERS FOR WIRELESS PURPOSES

PRACTICAL NOTES ON FIXED, VARIABLE AND ELECTROLYTIC CONDENSERS

By A. E. WATKINS

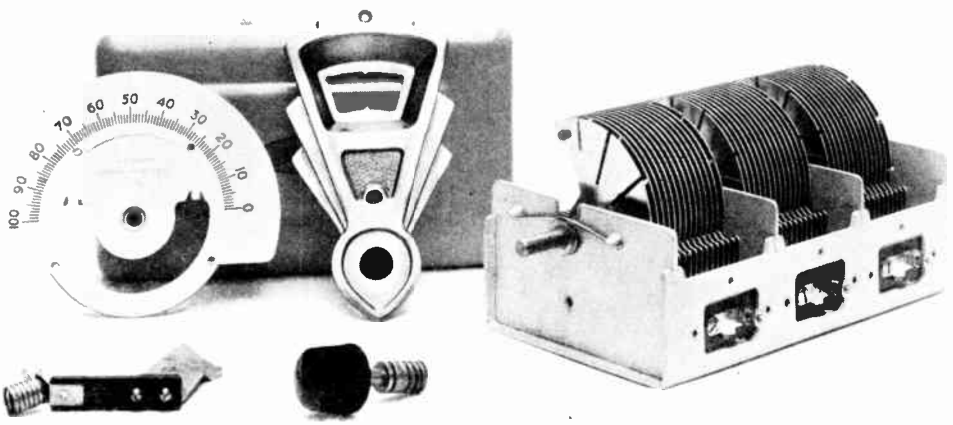

Fig. 1.—COMPONENTS OF A MODERN SCREENED TRIPLE GANGED CONDENSER. (*The British Radiophone, Ltd.*)
The slotted end vanes are for correctly balancing the condensers.

THERE are many different types and designs of condensers, but they are all the same elementally, irrespective of their outward appearance. Likewise, in a sense, they all serve the same purpose; namely, to accumulate (" condense ") and release electrical energy, but the ends to which they serve differ greatly. In any standard receiving set there are fixed and variable condensers. Some are used for tuning, some to by-pass electrical energy and others to block electrical energy or for smoothing the high tension supply. There are many other purposes which they can serve in a receiving set and its attendant devices.

The importance of condensers is not fully appreciated by the average radio engineer. Without them radio would be a hopeless affair.

In order to gain a satisfactory conception of the value of condensers and the ways in which they can be used, one must have some understanding as to how they function.

FUNDAMENTAL PRINCIPLES.

Basically a condenser consists of nothing more than two electrical conductors insulated from each other. If we take two metal plates and bring them close to each other, we have formed an electrical condenser. If we move the two plates towards or away from each other, the capacity of the unit is altered. The nearer the plates are to each other, the greater is the capacity, and vice versa.

The unit of capacity is the farad. Since this value is too large for practical purposes we employ the more convenient terms microfarad (abbreviated as mf. or mfd.) and micro-microfarad (abbreviated as mmf. or mmfd.). The first is one-thousandth of a farad, and the second the thousandth part of a microfarad. All condensers employed in radio have capacities which can be stated conveniently in one or the other of the above units.

Capacity of a Condenser.

The capacity of a condenser is determined by a number of factors, namely: the total surface area of the two conductors, the distance between the two conductors and the nature of the insulation between the conductors, which is called the dielectric.

The capacity can be further increased if the nature of the dielectric or insulation is changed. If instead of air as the dielectric we use, say, mica, the capacity of the condenser will have increased five times. The amount of increase in capacity in this instance is dependent on the dielectric constant of the medium employed, which is expressed on a comparative basis. Air is the standard, and is considered to have a dielectric constant of 1. The constant of good mica is 5.7. Thus, if mica were used in place of air the capacity would be multiplied by 5.7.

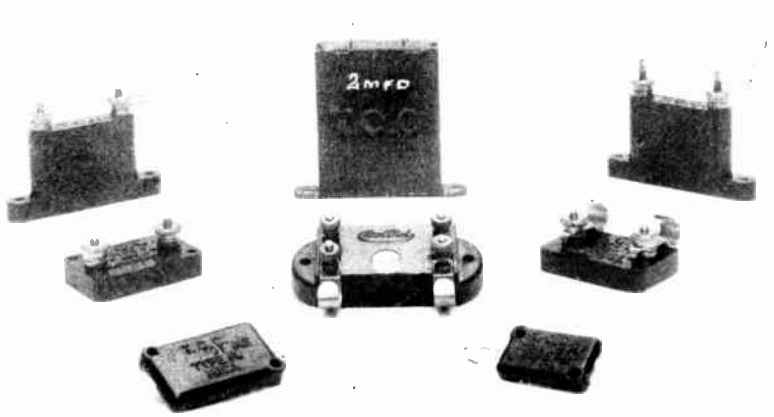

Fig. 2.—A Group of Small Fixed Condensers.
Showing also a 2 mfd. smoothing or blocking condenser.

Capacities for Radio Work.

In order to produce the necessary capacities for radio work, series of small metal plates or sheets, spaced one above the other, are used so that the size of the condenser will not be too large. In other words, instead of using two very large plates to get the required surface, we pile up a batch of small ones, the alternative plates being connected together. Thus, a fixed condenser might consist of six small sheets of foil with mica between the sheets. The first, third and fifth sheets, connected together, would constitute one conductor; and the second, fourth and sixth sheets, also connected together, the other, the five sections of mica being the dielectric.

Dry air is the most satisfactory dielectric as it introduces no serious losses. Other forms of dielectric, such as mica, paper, etc., present higher leakage paths than air and also introduce "hysteresis" losses. It is for this reason that air is employed as the dielectric in most variable condensers. Fixed condensers employ either mica or paraffin paper.

WHAT CAPACITY IS.

A condenser can be likened to a water tank. We can charge a condenser with electricity, just as we can pour water into a tank. The amount of electricity a condenser can hold is dependent on its capacity. The amount of water a tank can hold depends on its size. When a condenser is connected in a working circuit and becomes fully charged, that is, filled to capacity, it will automatically discharge its entire contents through an attached circuit. When it is empty it will start charging again. The number of times a condenser will charge and discharge each second depends on its capacity and on the frequency of the current flowing in the circuit containing it. It is obvious that it takes a condenser of large capacity longer to charge than one of small capacity. Consequently it will discharge at a slower rate than a small one. The capacity of a condenser has a great deal to do with its reactance, or resistance to currents. A condenser of small capacity offers high resistance or reactance to alternating currents of low frequency, but as the frequency of the current increases, the reactance of the condenser decreases.

Reactance of a Condenser.

It will be noted that the reactance of any condenser increases as the frequency of the alternating current is lowered. If we continue to lower the frequency, until it alternates only once every minute or so, the reactance of the condenser to it is practically infinite. When the current ceases to alternate, or becomes direct current, the reactance of the condenser is infinite and no current can flow through it. It becomes a blocking device. The answer is, then, that a direct current cannot pass through a condenser, but an alternating current can. The amount of alternating current that can pass depends on its own frequency and the capacity of the condenser. These characteristics of a condenser are important.

CAPACITY AND INDUCTANCE.

It might be well to explain here just how important variable condensers are in a radio circuit. The chief property of a coil used in a receiver is inductance, and it is this property, together with the capacity of the condensers, that makes it possible for us to vary the frequency of our receiving circuits and so "tune-in" one station after another.

In order to change the point of resonance of a circuit (at which it responds to a station's carrier wave) from one frequency to another, if the inductance is fixed, then the capacity must be capable of being varied.

LEAKAGE EFFECTS.

The losses in condensers do not amount to a great deal at low frequencies; but they can be extremely high at radio frequencies if the instruments are not well designed. It is very important to keep down the losses in variable condensers, for instance, as these are connected directly in the tuned circuits, through which the radio-frequency currents flow. There will be (1) leakage and "hysteresis" losses, through the dielectric; (2) hysteresis losses in the insulation of the condenser itself; (3) leakage through the insulation and leakage into adjacent apparatus through stray electrostatic fields. The dielectric losses may not amount to much, but great losses can take place in the insulation of the condenser if the insulating material is poor, or if it is not kept out of the strongest part of the electrostatic field. The electrostatic field produced by a condenser is somewhat like the electromagnetic field around a coil; only it is less pronounced and does not extend any great distance from the plates.

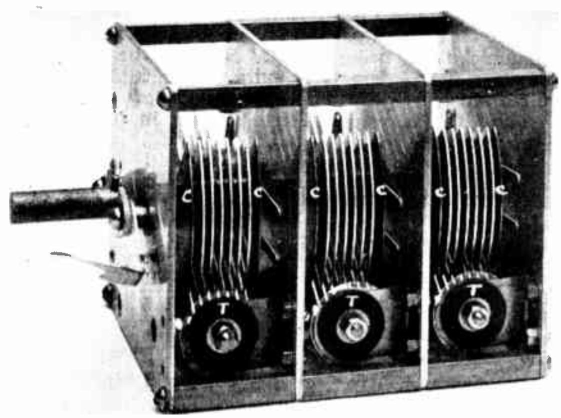

Fig. 3.—CYLDON TRIPLE GANGED TUNING CONDENSER. The copper end vanes C can be accurately adjusted so that all condensers read correctly together from zero to maximum. The trimmers T are to compensate for stray capacities in the circuits.

Modern variable condensers are enclosed in metal screens so that coils, transformers and other apparatus may be mounted close to them without being affected.

TYPES OF CONDENSERS.

There is a condenser for every purpose, such as grid-condensers, by-pass condensers, blocking condensers, fixed balancing condensers, various trimming condensers, etc. They are made in many different capacity values to suit different parts of the circuit.

Fixed condensers from 0.1 mfd. to about

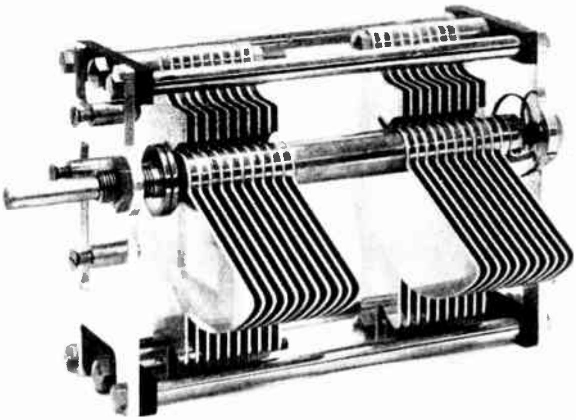

Fig. 4.—THE CYLDON UNIVERSAL CONDENSER.
By connecting the fixed vanes in series this condenser is suitable for short wave and low power transmitting, the maximum capacity being .00025. By using the two halves of the two condensers it is suitable for tuning double circuits which require two condensers of .0005. By connecting the two sets of fixed vanes in parallel the maximum capacity is increased to .001 mfd.

2 mfd. are employed primarily as by-pass condensers in radio- and audio-frequency circuits, as blocking condensers in resistance- and impedance-coupled audio-frequency amplifiers, and sometimes as filter condensers in tone filter circuits.

Larger fixed condensers which have capacity values ranging from 2 mfd. to 8 mfd. are used as filter condensers in H.T. eliminators. They must be capable of withstanding much higher voltages than the smaller type of condensers; that is to say, their breakdown voltage is much higher.

Adjustable Condensers.

Special adjustable condensers are used to stabilise, balance or neutralise radio-frequency receiving circuits. They are, of course, variable condensers, but cover a limited capacity range and are so made that certain capacity values may be obtained and the adjustments then locked.

"Vernier" Condensers.

"Vernier" condensers are nothing more than very small variable condensers and are valuable in any receiving circuit requiring very fine tuning. They are often employed in connection with tandem or gang variable condensers as a means for making up for any discrepancy in capacity between two of the sections. Like the adjustable condensers, they may also be employed for the purpose of balancing radio-frequency or regenerative circuits.

Variable Tuning Condensers.

There are four types of variable tuning condensers; the straight-line capacity, the straight-line wavelength, the straight-line-frequency and the straight-line-tuning, the latter being an evolution from the other forms. The straight-line-capacity variable condenser gives a comparatively uniform increase in capacity as the rotor plates are turned and intermesh with the stator plates. A condenser of this type, used for tuning purposes in a receiving circuit, does not give a uniform increase in wavelength as the dial is turned from zero to maximum. The straight-line-

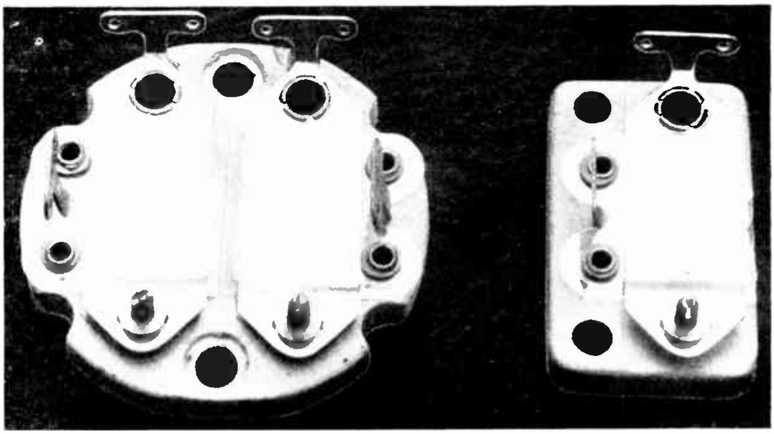

Fig. 5.—A SINGLE AND DOUBLE CYLDON TRIMMING CONDENSER.
The dielectric is mica and the base porcelain.

wavelength condenser does not give a uniform increase in capacity when varied, but does give a uniform increase in wavelength. In other words, the wavelength to which the set is tuned will increase so much for a definite number of degrees on the condenser dial, throughout the entire scale. With a straight-line-capacity condenser it may take only one degree on the lower part of the dial to make a 10-metre change, but five or ten degrees on the upper part of the dial for the same change.

The straight-line-frequency condenser, as the name applies, gives a uniform increase or decrease in frequency, so that every degree on the dial will represent a definite change, of 10 kilocycles. The straight-line-tuning condenser has several advantages of both the S.L.W. and S.L.F. condensers. It provides for a more evenly spaced distribution of stations throughout the dial readings, and does not tend to bunch them at any one band of wavelengths or frequencies.

Short Wave or Transmitting Condensers.

Variable condensers for use in short wave receiving sets must necessarily have comparatively low capacities and still be able to cover a fairly wide wavelength band without crowding stations. A good many condensers of this type employ double spacing between the plates, or are changed slightly in design from the regular type. Most of these short-wave condensers are also adaptable to short wave transmitting circuits of low and medium power.

Gang or Tandem Condensers.

Ganged condensers are designed for use in receiving circits where it is desirable to group two or more stages of tuned-radio-frequency amplification under a single control. Manufacturing developments have made possible producing accurately graded condensers of this type. The discrepancy in capacity between the units, from zero to maximum, is usually small, but so that they may be accurate, manufacturers fit slotted end vanes to the rotors. In the case of the Cyldon soft copper end vanes are used, which can be adjusted so that each condenser reads correctly from zero to maximum. In addition to this adjustment it is necessary to have small trimmings on each condenser to balance each circuit.

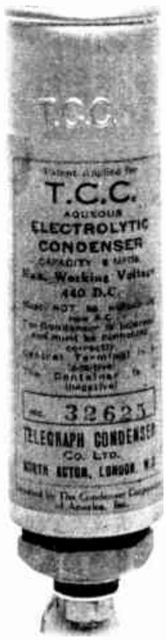

Fig. 6.—A Wet Electrolytic Condenser of Tubular Form Suitable for Use on Voltages up to 440.

ELECTROLYTIC CONDENSERS.

1. The Principle of the Electrolytic Condenser.

Three-quarters of a century ago, Wheatstone discovered that if a piece of metallic aluminium is placed in a certain aqueous solution, and then connected to the positive pole of a battery, while the negative pole is connected to a strip of any conductor which also dips into the liquid (see Fig. 8), then the current, which at first may be quite large, steadily diminishes to a very low value, as represented in Fig. 9. That is to say, the resistance of the cell increases to a relatively high value. This resistance is known to be due to the formation on the surface of the aluminium of a film of aluminium oxide, or of oxygen gas, or of both.

Even after the applied potential is withdrawn, the film remains on the aluminium, and subsequent application of potential, provided it does not exceed the original or "forming" voltage, causes only a small current to pass.

Aluminium can be "formed" at about 500 volts and then pass only one micro-ampere per square centimetre of surface at a voltage only slightly below the forming voltage. If the voltage is increased above this value, the current increases very rapidly indeed; the cell behaves as a short circuit at a potential

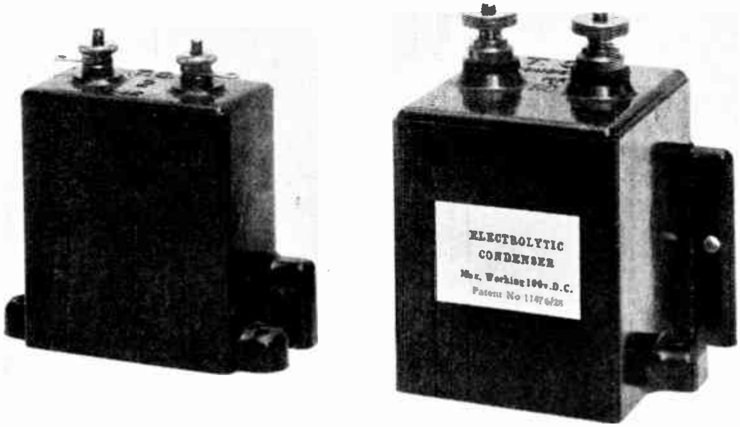

Fig. 7.—Two Useful Types of Condensers.
On the left is a 2 mfd. non-inductive condenser to be used in circuits for coupling inductances such as in band pass tuning. On the right, an 80-mfd. dry electrolytic condenser. It is interesting to note that it is only about twice the size of the ordinary 2-mfd. type.

only a few volts in excess of the voltage at which it is quite stable and safe. On reducing the voltage the current drops again to its very low value—the cell is quite unharmed by temporary excess voltage. If, however, the voltage is reversed, the cell will behave as a short circuit, even with only a few volts applied.

How the Film-forming Property of Aluminium is Applied.

The film-forming property of aluminium described above finds application in at least three forms of electric apparatus. The uni-directional conductivity of an aluminium electrode can be made use of to construct a rectifier ; the short circuiting when a critical voltage is exceeded allows the electrode to be used as a voltage-limiting device ; the insulating properties of the film, together with its extreme thinness, are employed to make a condenser in which the electrolyte and the metallic aluminium are the conductors and the film is the dielectric. Another metal plate must, of course, be used to make contact with the electrolyte.

Such an arrangement will only work satisfactorily as a condenser provided the voltage is never reversed ; aluminium must always be more positive than the liquid ; it cannot, therefore, be used on unrectified alternating current, but is ideal to smooth out the pulsations in rectified alternating current. We are only concerned here with the application of the aluminium electrode to the constructions of condensers, and we will now describe a condenser which will withstand voltages up to 500.

Wet Electrolytic Condenser.

This consists of a drawn cylindrical aluminium container to which the negative connection is made. It is not essential to use aluminium, but for mechanical reasons it is preferred. At one end it is provided with a stout boss enclosing a watertight insulating bushing, through which passes an aluminium rod. This rod carries a coiled spiral of aluminium foil, suitably formed and covered amply by a liquid electrolyte. The opening at the other end is sealed by a metal closure which carries a rubber valve to release the small quantities of oxygen and hydrogen which are evolved while the condenser is working. During actual operation this valve must be uppermost.

Electrical Properties.

Condenser 440 *volts working.* 8 *mfd.*

When this condenser is connected to a 440-volt D.C. supply, the current taken

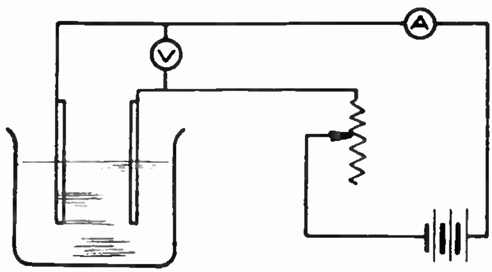

Fig. 8.—Principle of an Electrolytic Condenser.

falls almost at once to about 1 milliampere. This represents a production of heat in the condenser at a rate of less than half a watt and results in a temperature rise of about 5° F. in the liquid. At lower voltages the leakage is much less; at higher voltages it increases rapidly and the condenser will be heard sparking. (See Table I.) Occasional application of extra voltage will not harm the condenser; perfect insulation is restored as soon as the voltage is reduced.

The condenser must not be operated for long periods at voltages at or above the

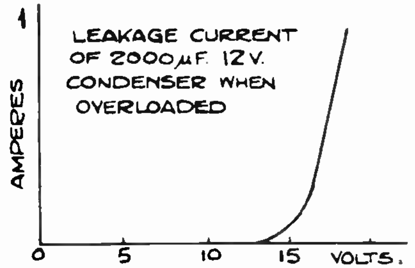

Fig. 10.—Diagram Showing Leakage Current of Condenser when Overloaded.

sparking voltage, or it will become overheated. It is particularly useful for smoothing the rectified alternating current fed to the valves of modern radio receivers and radio gramophones which frequently work at 350 volts or more. It may, however, be used on any D.C. circuit up to 440 volts.

TABLE I.—Showing Variation of Leakage Current with Voltage.

Condenser 8 mfd. 440-volt working.

Volts.		Milliamperes.	
350		.2	
400		.4	
420		.5	Temperature 60° F. At higher temperatures leakage is greater—approximately double at 110°F.
440		.7	
460	Sparking	1.5	
465	Sparking	2.5	
468	Sparking	3.5	
469		10	

Further slight increase of voltage leads to passage of very large current.

Condenser 460-volt normal working voltage, 500-volt peak. 7 mfd.

To meet cases where the voltage is likely to exceed 440 peak, there is a condenser, capacity 7 mfds., which will operate continuously up to 460-volt peak,

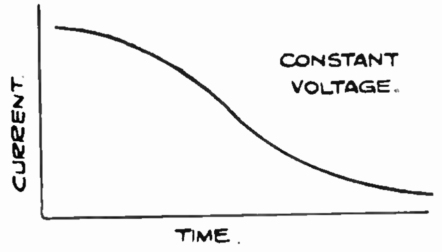

Fig. 9.—Diagram Showing How the Current Steadily Diminishes to a Very Low Value.

and in addition will work for short periods up to 2 minutes at 500-volt peak. The current voltage relations are shown in Table II. It will be noticed that the leakage at 500 volts is 4 milliamperes; for that reason, the time during which 500 volts may be applied is limited, the figure given, however, may be exceeded so long as the condenser does not become unduly hot.

TABLE II.—Showing Variation of Leakage Current with Voltage.

Condenser 7 mfd. 460-volt working, 500-volt peak.

Volts.	Milliamperes.	
350	.2	
400	.4	Temperature 60° F.
420	.6	
440	.8	
460	1.0	
480	1.3	
490	2.0	
500	4.0	

Dry Electrolytic Condensers.

It is only recently that there has been a demand for a condenser to work at such high voltages as the wet electrolytic condensers described. The Telegraph Condenser Company produced a condenser having a capacity of about 2,000 microfarads to smooth the output from rectifiers to the filaments of valves in wireless sets.

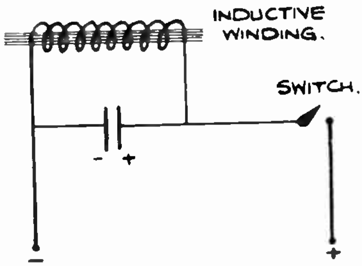

Fig. 11.—Diagram Showing Use of Electrolytic Condenser as a Voltage Limiter.

Such a condenser would only be required to work at about 12 volts. It was found possible to replace the liquid electrolyte with a semi-liquid paste. The positive electrode could then be a thin aluminium foil, separated from another negative foil by a layer of fibrous material impregnated in the pasty electrolyte, the whole being rolled up together, giving a large capacity in a very small space. This method has since been developed to produce condensers working up to 200 volts.

The general electrical properties of the dry condenser are similar to those of the wet. As before, leakage current increases gradually, with applied voltage until the rated conditions are exceeded, and then the current goes up rapidly. As soon as voltage is reduced the condenser behaves normally again, and is quite unharmed by the excess voltage, unless it has been allowed to last long enough to cause overheating.

Further Characteristics of Electrolytic Condensers.

The electrolytic condenser is not a pure capacity. Liquids which are most suitable to maintain the film on the surface of the aluminium are rather poor conductors, so that an electrolytic condenser behaves as a pure condenser in series, with a resistance. This is allowed for in manufacture, extra capacity being provided to compensate for the resistance. By saying the capacity of the condenser is 8 mfds. we refer to its effective capacity; that is, we mean that it will smooth as well as a perfect condenser whose capacity is 8 mfds. The electrolytic condensers are particularly designed for low frequency smoothing from 25 to 100 c.p.s. (cycles per sec.). At these frequencies the resistance is not of great consequence; at higher frequencies, however, the effect becomes greater, and at 1,000 cycles outweighs the effect of the capacity.

Electrolytic Condensers as Voltage Limiters.

When a highly inductive circuit, such as the field windings of a moving coil loud speaker, carrying a current, is interrupted, the voltage rises instantaneously to a dangerously high value, and may lead to arcing at switch contacts, and possibly to breakdown of any paper condenser which is connected across the apparatus. It has been found, however, that if an electrolytic condenser is used as Fig. 11, no surge can occur, for any tendency towards a rise in voltage only leads to a slightly increased leakage current in the condenser. The condenser thus fulfils two purposes. It smooths the supply and protects the windings from breakdown of insulation when switching off.

QUESTIONS AND ANSWERS

What would be the effect of substituting mica instead of air as the dielectric?

The capacity of the condenser would be increased nearly six times as the capacity is dependent on the dielectric constant of the medium employed. Air is considered to have a dielectric constant of 1, while the constant of good mica is 5.7.

For what purposes are fixed condensers of from 0.1 mfd. to 2 mfd. generally used?

As by-pass condensers in radio- and audio-frequency circuits, as blocking condensers in resistance and impedance-coupled audio-frequency amplifiers and sometimes as filter condensers in tone filter circuits.

Why is dry air the most satisfactory dielectric?

Because it introduces no serious losses. Other forms of dielectric such as mica, paper, etc., present higher leakage paths.

What are the four main types of tuning condensers?

(1) Straight-line capacity, giving a comparatively uniform increase in capacity over the whole scale.

(2) Straight-line wavelength, giving a uniform increase in wavelength.

(3) Straight-line frequency, giving a uniform increase in frequency.

(4) Straight-line tuning, which combines the advantages of types (2) and (3).

HOSPITAL LIGHTING

By E. H. Freeman, M.I.E.E.

The problems involved in designing the lighting installation for a hospital include very few that need close calculation of illumination details. The solution required is, in almost all areas, the method of utilizing the light sources to meet the special condition of the building, and in finding this solution for each area of the building very little accurate calculation is required in deciding the arrangement of the lighting units. As for other buildings, the requirements for each section must be considered in detail as different areas need different treatment.

WARDS.

General Lighting.

In an ordinary ward such as that shown in Fig. 1, with accommodation for twelve patients, a couple of general lighting units will be ample with 100-watt or 150-watt lamps in each. These fittings must be of an enclosed unit type. The tops must be enclosed to facilitate cleaning and the lamps must be shielded from below so that there is no possibility of direct glare on the patients' eyes when lying in bed. The enclosing globes should be of ample size —14 in. or 16 in. in diameter—so that the intensity of illumination on the surface of the fitting is reduced to a minimum consistent with good lighting.

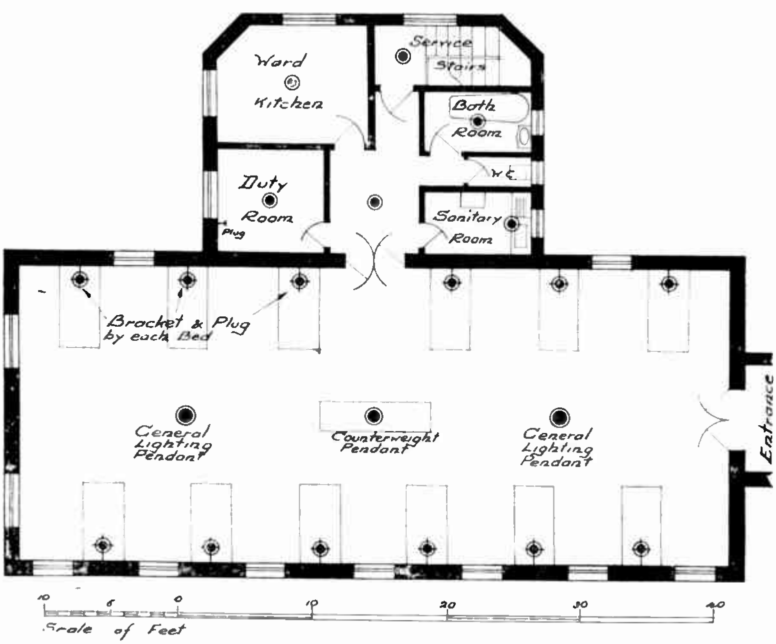

Fig. 1.—General Arrangement and Lighting Scheme for Typical Ward for 12 Patients.

Switch Control.

The lighting units must be sufficient for reasonably good general lighting—say 3 to 4 candle feet—but provision must also be made for reducing this illumination at night, and the desired result can be obtained in several ways.

(1) Series Parallel Control.

The lights can be connected in pairs by a series parallel switch, as made by Lundbergs or other firms, the connections being as shown in Figs. 2A and 2B. With the switch in one position the lamps are in parallel, giving full illumination, whilst in the other position the switch puts the lamps in series, giving a reduced light sufficient for night use. This system can

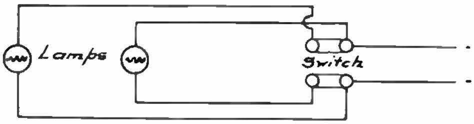

Fig. 2A.—Wiring Connections for Series-parallel Control of Two Fittings.
Lamps in parallel for full light.

only be used if there are exact pairs of fittings.

(2) Dimming Switches.

A second solution is to use a dimming switch which has a resistance which can be put in series with the lamp filament, as in Fig. 3. This provides more opportunity of varying the amount of light, as the resistance can be adjusted and the light increased or decreased as desired. Such switches should be fixed outside the wards, as they must be of a surface type to allow opportunities for ventilation. The proportion of current absorbed in the resistance must be dissipated as heat and if enclosed the heat would damage the wires.

(3) Duplicate Wiring.

A third solution is to provide two circuits to each unit, the main circuit supplying the large lamps for normal lighting and the other circuit supplying small lamps—25 to 40 watts—of sufficient size to provide the night lighting required. The method of wiring is shown in Fig. 4.

(4) Second Supply.

If it is possible to obtain two separate services at different voltages for lighting the hospital, further reference to which is made later, this secondary supply for the small lamps can with advantage be connected up to a different source from that supplying the main lighting, i.e., the

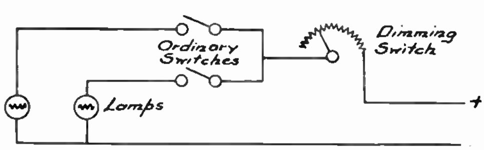

Fig. 3.—Wiring Diagram of Control of Lamps by Dimming Switch.
The handle of the dimming switch can be moved to dim the lights as required.

larger lamps. The method of wiring is the same as in Fig. 4.

(5) Low Voltage Supply.

If a second supply is available at a lower voltage than the main supply, dimming can be effected by a change-over switch which will transfer the whole range of lamps to be dimmed from the main (high voltage) supply to the secondary (low voltage) supply. This method is illustrated in Fig. 5A.

(6) Transformers.

If the supply to the hospital is on an alternating current system, another solution can consist of taking a night supply through a transformer and a change-over switch. This is really the same in effect

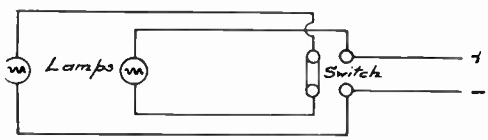

Fig. 2B.—Wiring Connections for Series-parallel Control of Two Fittings.
Lamps in series for dimmed light.

as scheme 2, but it is less wasteful in that no current is lost in heating the dimming switch resistance. On the other hand, there is not the opportunity for adjustment of illumination by putting more or less resistance in series with the lamp filament, but this is not very important, however, as the alternative voltage can easily be arranged to give the intensity of lighting required. The wiring diagram is shown in Fig. 5B.

All these methods are in regular use in various hospitals and the selection of the one to adopt depends on local conditions. Scheme 1 cannot be used if the ward needs 3 or 5 pendants; scheme 6 cannot be used unless the supply is alternating; schemes 3 and 4 are more expensive than the others, but better in that two entirely separate circuits are used, so that the ward need not be in darkness if a fuse blows for longer than is necessary to switch on the second supply. The opinions of the matron or resident medical officer and considerations of cost will decide which of the different schemes is to be adopted.

Local Lighting.

In addition to the general lights, local lights must be provided at each bed and the most satisfactory form is a bracket over each bed with a local switch within reach of the patient. The brackets must be high enough to avoid risk of damage and a height of about 7 ft. 6 in. is usually suitable.

The brackets and shades to be used should be carefully selected. The shades should be such as to screen the lamp completely from patients in adjacent or opposite beds.

Ward brackets should have a smoothly tapering back for fixing to the wall and a coned cover to enclose the lamp holder, fitting closely to the shade. The bracket and shade should provide a smooth surface, free of corners that might collect dust—an essential feature of all hospital fittings.

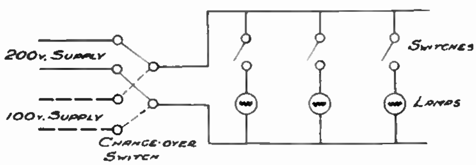

Fig. 5A.—Wiring Diagram with High and Low Voltage Supplies, with Change-over Switch for Dimming Lights.

Switch Control.

Obviously, each bedside bracket must have its own local switch and as a rule nothing more is required, as if the shades are of suitable type adjacent patients will not be disturbed if a bedside bracket is switched on.

Occasionally, dimming of these lights after a fixed hour is considered necessary, but this is not so easily arranged as with the general lights. Each light must be separately switched so that series parallel control is not suitable. Dimming switches are unsuitable in the wards, so that this solution is also unsatisfactory, except at the considerable expense of providing dimming switches outside the ward to control the small groups of bracket lights.

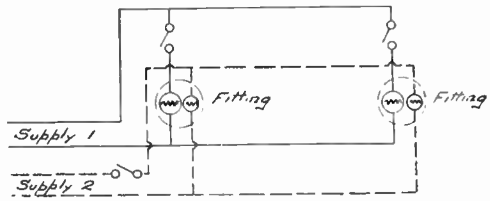

Fig. 4.—Wiring Diagram with Duplicate Supply to Each Fitting.

The main lighting lamps are each controlled by a separate switch, whilst the auxiliary (dim) lights are all controlled by one switch.

Duplicate wiring for each fitting is also unsuitable as the brackets cannot well be arranged for two lamps.

The best solution is therefore to use a transformer or a separate supply and to change the entire circuit over from one system to another at a lower voltage. This involves no particular difficulty if (*a*) the supply is alternating current, or (*b*) if the secondary supply is at a substantially lower voltage than the main supply. If neither condition holds it will be necessary to provide a battery for an auxiliary supply, which, if it is to be large enough for the entire building, is also an expensive method.

The methods suggested are indicated diagrammatically in Figs. 5A and 5B.

Other Local Lights.

Apart from the general lighting and bedside lights, various other lights must be provided. If finance allows, a plug for each bed should be arranged—mainly for the use of the medical and nursing staff. Extra lighting is frequently required for the medical examinations and, long trailing flexible cords being undesirable, a plug for each bed is indicated. These plugs may be used with standard lamps, in place of the bedside brackets, but this

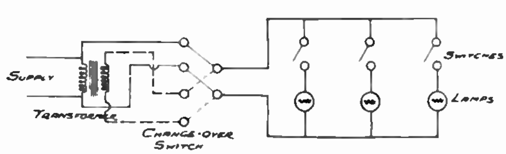

Fig. 5B.—Wiring Diagram with Transformer for Changing Over from High to Low Voltage for Dimming Lights.

This can also be applied to the general lighting or to the bedside brackets.

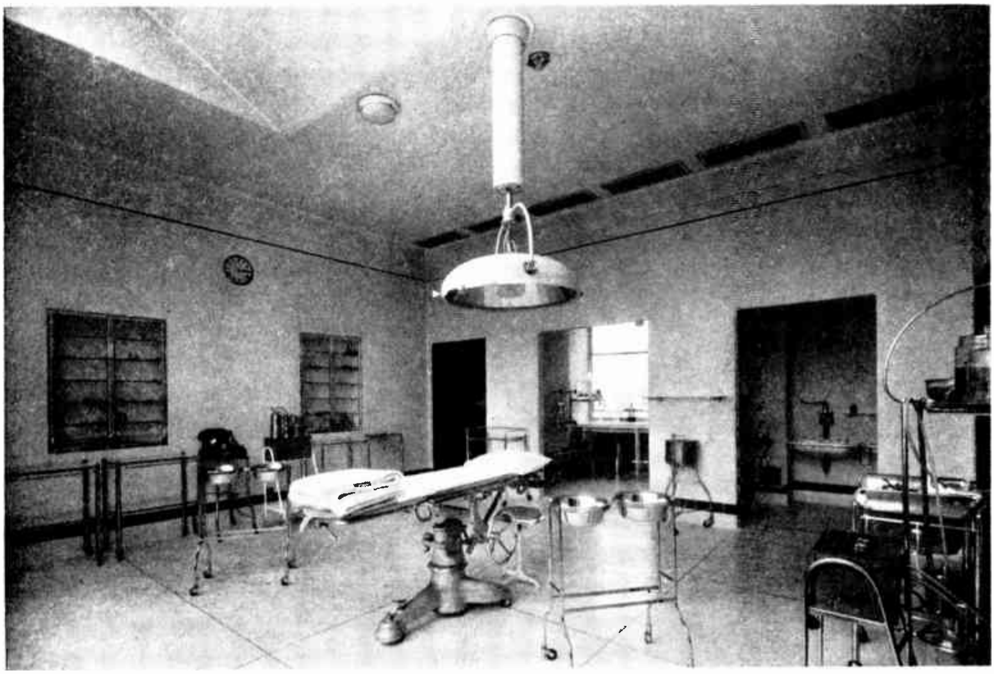

Fig. 6.—OPERATING THEATRE WITH SCIALYTIC FITTING OVER TABLE.
Note the general lighting unit on ceiling to left of central fitting and small auxiliary lighting unit to right on ceiling.

is not advisable as the portable lamp and flexible cord is a nuisance in a ward. It is difficult to keep clean and is apt to get in the way and be knocked over.

If finance does not allow a plug for every bed, then the number must be reduced, but certainly one to every 3 or 4 beds is essential.

Nurse's Lamp.

Another local light that must be provided is that for the night nurse's table. This also must have a shade to screen the lamp from the patients, but it must also provide ample light for the nurse. A low bracket for a wall table or a counterweight pendant for a centre table should be provided with a separate switch.

Medicine Cupboards.

The medicine cupboard should also have its own local light, so that there can be no need to find the right medicine in semi-darkness. This is most important, though often omitted.

ANNEXE.

Attached to each ward there is usually an annexe containing the bathroom, lavatory, ward kitchen and so forth. Such rooms do not require any special lighting, apart from the use of fittings of a type that can be easily cleaned. A single lamp in each room is usually ample, though a plug in the nurses' room, if this is provided, is a desirable addition. A typical annexe is shown in Fig. 1, with the lighting details.

PRIVATE WARDS.

If there are private wards in the hospital these must be treated as the general wards, full provision for lighting being arranged. · Each private ward should have a general lighting pendant in the centre, with an enclosed type unit and lamp to give 3 to 4 candle feet. This light should be controlled by a dimming switch, which will be best fixed outside the ward. The nurse can then leave the centre light out or dimmed, as necessary, leaving the patient to control the bed light as desired.

The bedside bracket and switch should also be provided and a bedside plug, but it is sometimes possible to omit the bracket in private wards. It is not so inconvenient in such a ward to use a portable lamp as in a general ward, as there is more space and less consequent trouble from loose flexible cords. If possible however, both should be provided—the bracket for the regular use of the patient in bed and the plug for the use of the doctor or for the patient, if well enough to be out of bed.

OPERATING THEATRES.

After the ward the operating theatre needs most consideration but the lighting problems connected with this department have been largely solved by the development of various special fittings. The most difficult problem is to provide adequate light on the operating table in such a way as to avoid risk of shadow. In past years fittings were used with a series of lamps arranged over a comparatively large area, so that shadows from one lamp were eliminated by the light from others.

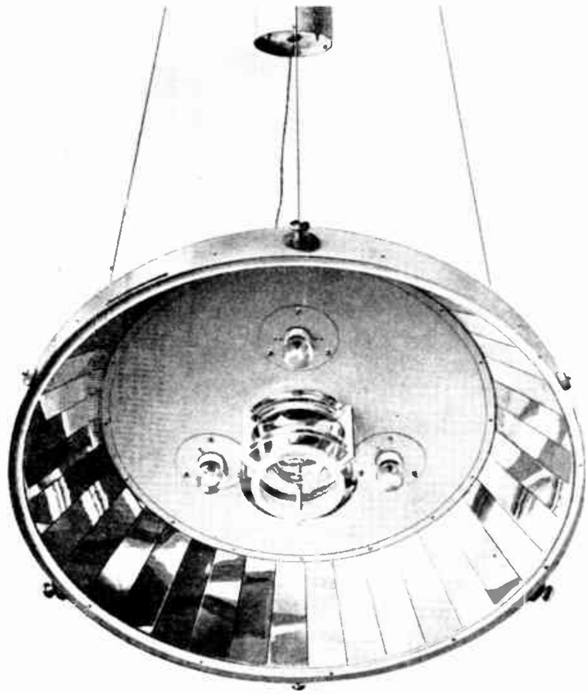

Fig. 7.—Interior of Scialytic Operating Table Reflector.

Note the three small lamps, arranged for connection to a secondary supply.

More modern fittings are of the types shown in Figs. 6 and 9, these being respectively the Scialytic and Zeiss fittings—the two most widely used of this type—both of which have been designed to meet the special difficulties involved in operating theatre lighting.

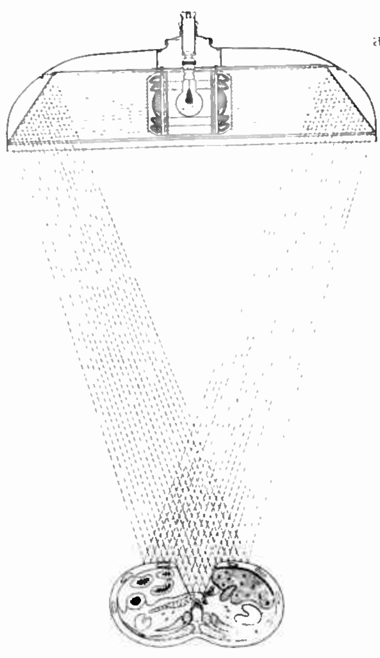

Fig. 8.—Diagram Showing Method of Reflecting the Light Rays in the Scialytic Fitting.

Scialytic Fitting.

This fitting is shown in Fig. 6, which shows the interior of the operating theatre at the Eastman Dental Clinic. It will be seen that the fitting is suspended on a stirrup which allows tilting in any direction as the fitting can be twisted in the central suspension, which also contains the counter weights to allow of vertical movement.

The construction of the fitting is shown more clearly in Fig. 7. This shows the

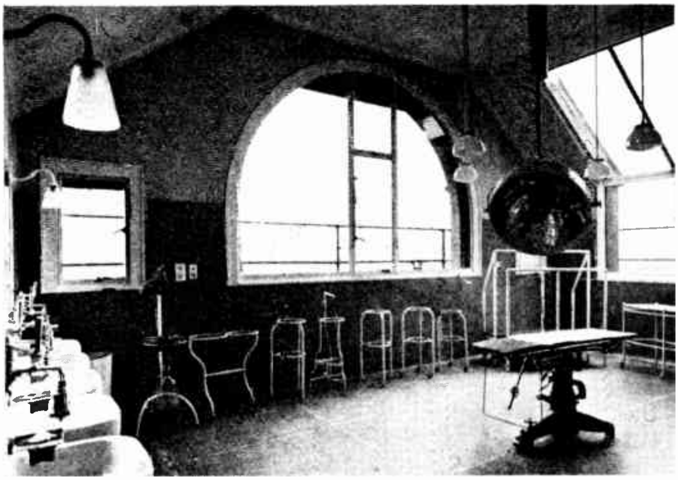

Fig. 9.—OPERATING THEATRE WITH ZEISS FITTING OVER TABLE. Note the alternative lighting provided by four pendants spaced round the central pendant.

special lens that is fixed to surround the lamp and which projects all the light rays on to the mirrors that form the interior of the reflector and which concentrate the light when reflected on to the operating table. This is further indicated diagrammatically in Fig. 8.

Fig. 7 also shows a variation of the fitting with pilot lighting connected to a secondary supply, whilst a further variation consists in the addition of a centre mirror fixed below the lamp, which enables students to observe the details of the operation.

Zeiss Fitting.

This type of fitting is illustrated in Fig. 9, which shows one of the operating theatres at University College Hospital. The suspension is very similar to that of the Scialytic fitting, all necessary movements being provided. The principle of construction is in many ways similar to the Scialytic, but the special lens round the lamp is omitted, a reflector below the lamp being substituted, which reflects the light on to the mirrored interior of the fitting, whence it is reflected on to the operating table. This is shown diagrammatically in Fig. 10.

Small Operations.

Both the types of fitting described above can be adapted for such local operations as dental work, throat and eye operations and so forth, and in such cases it is often convenient to have the fittings mounted as brackets, which can be pivoted for moving out of the way when not required.

Secondary Lighting for Operating Theatres.

Some secondary supply of light for the operating theatre may be regarded as essential—at any rate, in any important hospital.

If a second company's service can be arranged, this is decidedly the best scheme to adopt. If this is not possible, an independent battery of the "Keepalite" type is an excellent substitute. Such batteries are usually arranged for control by an automatic switch operated by the main supply, so that the auxiliary battery is automatically switched on if the main supply fails. The battery can supply only emergency lighting for the operating theatre or it can supply additional light in wards, corridors, etc. This, of course, is a matter of cost and availability of funds to meet the expense of the larger plant.

In either case the automatic switch should be actuated from the

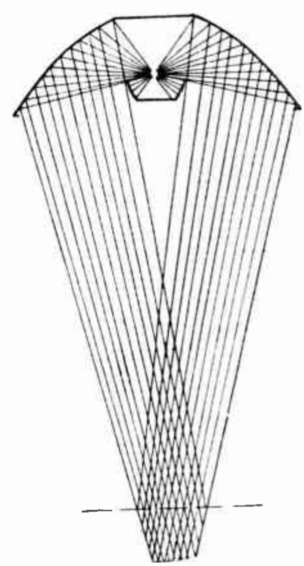

Fig. 10.—DIAGRAM SHOWING THE METHOD OF REFLECTING THE LIGHT RAYS IN THE ZEISS FITTING.

circuit that the battery supply will replace, i.e., by the local operating theatre circuit if the battery is only to supply light for that room or by the main supply if it is to provide subsidiary lighting all over the hospital.

In the illustrations of operating theatres the secondary lighting fittings are shown. In Fig. 6 of the Eastman Dental Clinic theatre two stand-by supplies are provided. The first, with ceiling bulkhead fittings, of which one appears in the illustration, is taken from the main lighting system, but on an entirely independent main cable to that supplying the operating table fitting. The second supply is from a battery and the lamp can be seen to the right of the main fitting. This supply is operated by an automatic switch controlled by the circuit supplying the table fitting and plugs for small portable lamps are connected to the same circuit.

In Fig. 9 the secondary lighting is on a more extensive scale, with four lighting units spaced round the central table fitting. These units are designed so that in case of need they will provide light sufficient for carrying on the operation. At University College Hospital these are hand controlled, but on a special circuit run back to the supply independently of the other lighting, no alternative supply being available.

The secondary lights provided in some Scialytic fittings, as shown in Fig. 7, can be connected up to any other supply—either a separate service or a battery or special circuit and can be arranged for control by a hand or automatic switch.

Head Lamps.

In some operations the surgeon finds a local lamp of value that can be attached to his head by suitable straps. This ensures the light being directed exactly at the point which he is examining. Such lamps, if used, should always be supplied from a low voltage battery, as the possibilities of accident in the event of leakage of current from the supply are too serious for a high voltage supply to be used. If suitable apparatus for such lamps is provided, a small hand lamp that can be held by the nurse is a valuable addition to the other lighting.

Local Lights for Operating Theatre.

Various local lights may also be advantageous in the operating theatre, such as those shown in Fig. 10, over the sinks or hand basins, or over sterilizing apparatus. In modern hospitals it is usual to find such apparatus in special rooms outside the actual theatre, and if so, no local lights may be required, and it is, in fact, best if all such lights can be omitted. They mean so much extra cleaning and may be a source of annoyance or worse to the surgeon if the light is in a position where it may distract his attention from the operation.

Subsidiary Rooms to Operating Theatre.

There is usually a series of rooms attached to the operating theatre for various purposes connected with the operation. These may include anæsthetic room, sterilizing rooms, waiting room, doctors' changing or dressing room, nurses' room and so on. None of these calls for any special lighting. The anæsthetic room and the sterilizing room need very good general lighting up to 10 ft. candles, and may need some local lighting according to the planning of the rooms, but the other rooms only need a single pendant in each with a 40 or 60-watt lamp. The fittings must, of course, all be of an enclosed type to facilitate the cleaning so essential in all hospital fixtures.

Remaining Areas.

The remaining areas of the hospital, such as casualty department, waiting hall, dispensary, domestic areas, nurses' bedrooms, etc., do not call for such special treatments as the wards and operating theatre and can be planned in accordance with the usual requirements for ordinary rooms. All must be well lit in accordance with the principle described in earlier articles, but the arrangement of the lights must be schemed to suit the rooms.

MOTOR CAR IGNITION SYSTEMS

PRACTICAL NOTES ON COIL AND MAGNETO IGNITION

By E. Hill

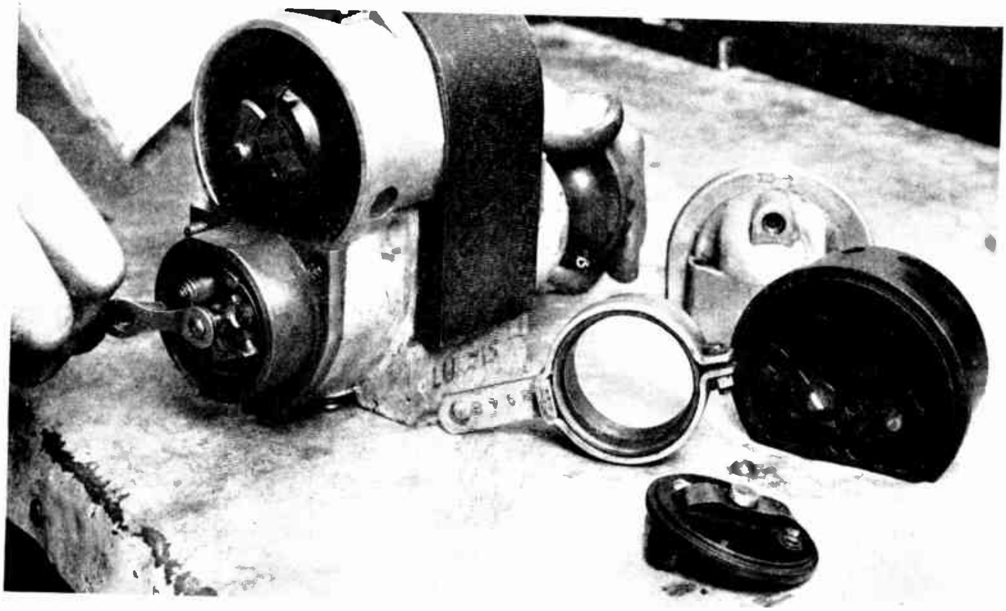

Fig. 1.—Dismantling a Motor Car Magneto.
Showing the method of removing the contact breaker. The cam ring, distributor, contact breaker cover and drive end cover have already been removed.
(*Euston Ignition Co.*)

In recent years the coil or battery ignition system has come into general favour and is used on a large percentage of all the motor vehicles built in this country.

THE COIL IGNITION SYSTEM.

Two circuits are involved, the primary, or low tension—consisting of battery, ignition switch, contact breaker and the primary winding of the coil; and the secondary, or high tension—consisting of the secondary winding of the coil, the high tension distributor and the spark plugs. The ignition switch is a simple single-pole switch of the tumbler, pull-and-push or rotary type.

Distributor and Contact Breaker Unit.

The contact breaker is combined with the distributor head for multi-cylinder engines, and the unit as a whole is standardised in regard to the mounting.

Setting of the Contact Breaker.

The relation of the cam to the contact breaker is set so that the contacts are opened at the top of each compression stroke with the timing lever in a fully retarded position. On distributors which have a timing lever clamped to the body or shank, this lever is given a limited radial movement to alter the relation between the contact breaker and the cam, thus advancing or retarding the firing spark.

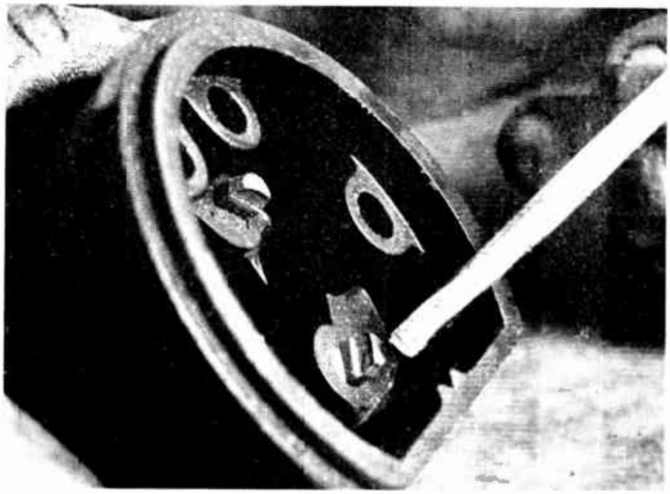

Fig. 2.—A LIKELY FAULT TO LOOK FOR IN A DISTRIBUTOR.
Showing a badly worn distributor segment (jump spark type).
(*Euston Ignition Co.*)

How the Windings are Connected Up.

It is general practice to connect one end of the secondary coil to the core and also to connect the core to the H.T. terminal. With this arrangement the core must be insulated from the case. The other end of the secondary coil is connected to one end of the primary windings, this end also being connected to the battery terminal. The other end of the primary coil is attached to the contact breaker terminal.

Insulated Return System.

For coils used on an insulated return system, it is necessary to insulate the primary winding, and this is connected across the battery and contact breaker terminals. The secondary winding in this case is connected to the H.T. terminal and the other end sweated to the container, and the H.T. circuit completed by earthing the casing.

The two windings are close coupled and so proportioned that a current of

Timing the Ignition.

When timing the ignition, the timing lever is loosened from the distributor shank, and the contact breaker set so that the contacts are just beginning to break and the electrode on the rotor is opposite the terminal contact for No. 1 cylinder, with No. 1 piston at the top of the compression stroke. The timing lever is then tightened up (in the retarded position) so that the full movement is available to advance the spark to the best running position.

How an Ignition Coil is Constructed.

The ignition coil consists of a soft iron core built up of laminated strip or wire on which is wound the secondary winding, and over this the primary winding, enclosed in a metal case. The container has a metal base cover and the head is filled in with a bakelite cap on which are mounted the H.T. terminal and the terminals for battery and contact breaker connections.

Fig. 3.—WHAT TO DO WHEN THE CONTACT BREAKER HAS BEEN REMOVED.

Showing the rocker arm being removed to examine contacts after taking off the spring. (*Euston Ignition Co.*)

one ampere through the primary turns will induce an open circuit voltage of 7,000/10,000 across the secondary winding.

Enamelled copper wire is used for the coils and when wound these are impregnated with a mixture of resin and wax. The windings are insulated with waxed paper, and in some instances an insulated tube is interposed between the secondary turns and the core and also between the primary turns and the secondary winding. Varnished paper and cloth may be used in place of the wax impregnation. The container is filled in and sealed with pitch after the coil assembly is fitted in position.

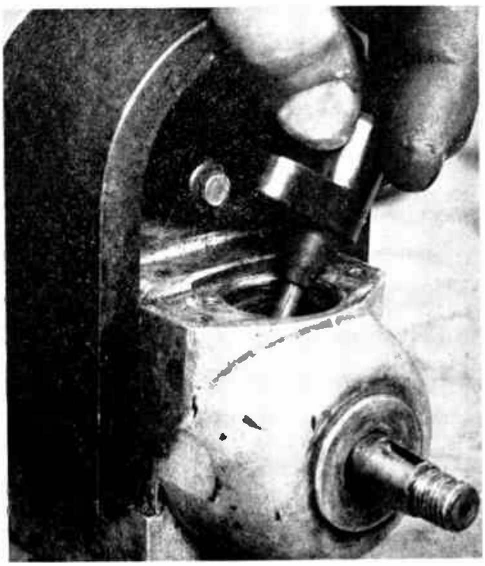

Fig. 4.—Another Step in Dismantling a Motor Car Magneto.

Showing removal of carbon brush holder, care being taken not to break brushes. (*Euston Ignition Co.*)

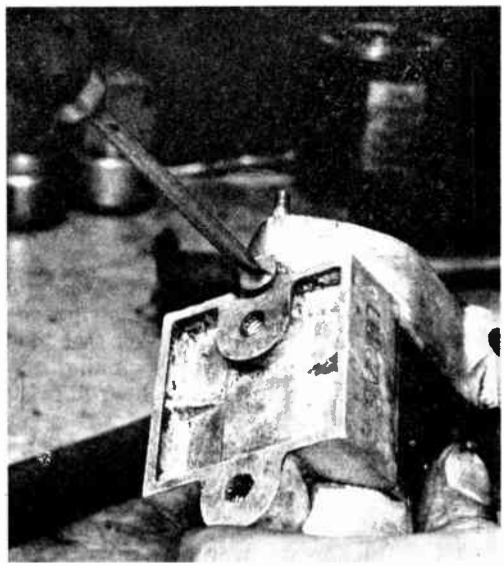

Fig. 5.—The Next Step in Dismantling a Motor Car Magneto.

Removing the earthing screw before withdrawing the armature. (See Fig. 9.) (*Euston Ignition Co.*)

Using a Ballast Resistance.

A ballast resistance is sometimes connected in series with the primary coil (usually when the secondary turns are wound over the primary), with the object of reducing the heat generated in the primary circuit. This resistance is fixed external to the coil, is circular in form and has a high temperature coefficient.

The Spark Plugs.

The spark plugs form the final link in the ignition system, and as these have to withstand the high temperatures of the explosion chamber and the high voltage required to produce the firing spark, a great deal depends on the design, manufacture and quality of materials used. A central electrode is encased by a porcelain or mica shrouding, the outer end of the electrode forming a terminal to which the H.T. lead is attached. The inner end projects into the cylinder head adjacent to prong electrodes fixed in the metal body of the plug enclosing the insulated electrode. The body is made from hexagon bar and is screwed to fit into the cylinder head, a gas-tight joint being formed by a gasket ring.

Cable to Use for Connecting Up the Various Units.

Interconnections between the various units of the ignition system are made with cables. The L.T. connections can be suitably made by means of 14/.012 in. copper conductors covered with pure and vulcanised rubber to a diameter of 5mm., or standard 14/.012 in. V.I.R. and braided

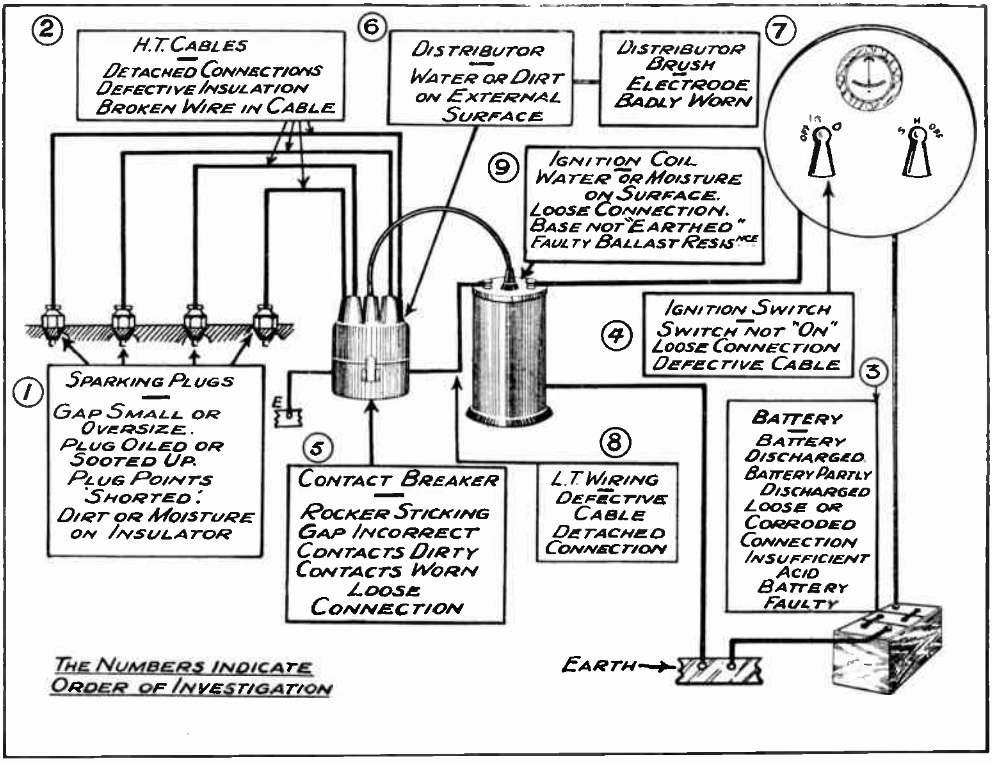

Fig. 6.—WHERE TO LOOK FOR TROUBLE IN A COIL IGNITION SYSTEM. (Pictorial diagram.) See also Fig. 7.

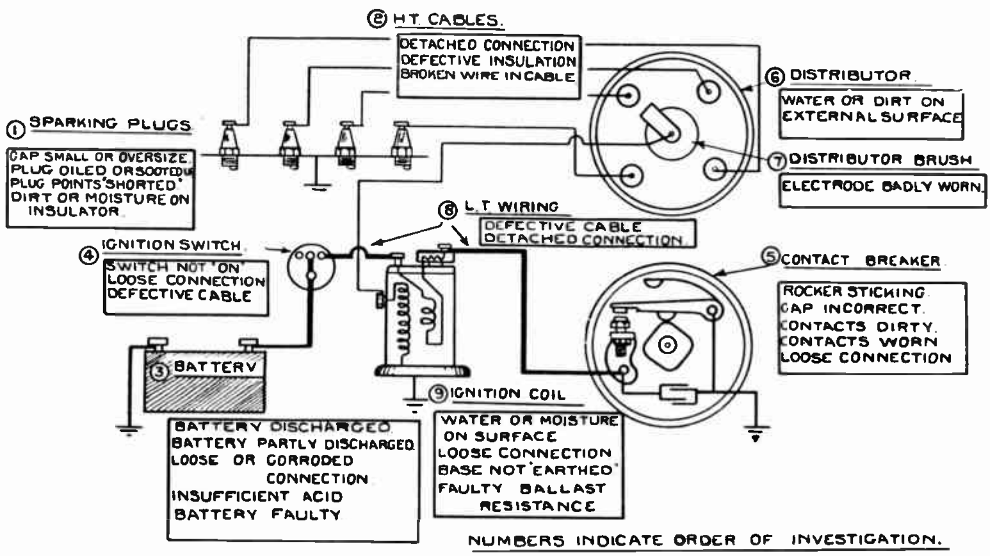

Fig. 7.—WHERE TO LOOK FOR TROUBLE IN A COIL IGNITION SYSTEM. (Technical diagram.) To be studied in conjunction with Fig. 6.

cable may be used, in which case it should be covered with sistoflex. The H.T. cable should consist of 40/.010 in. copper wire covered with pure and vulcanised rubber to a diameter of 7 mm., and should be capable of withstanding a puncture test between the core and outer covering of 40,000 volts.

Current Required for Coil Ignition.

The current required for the primary circuit of the ignition system is normally between 3 and 4 amperes when standing; this decreases during running periods to $1\frac{1}{4}$-$1\frac{3}{4}$ amperes, but varies with the state of charge of the battery, and will be rather higher in daylight running than when running with lights on. It will be seen that the current discharge will run down the battery if the ignition switch is left on for long periods with the engine stalled. A warning lamp is usually incorporated in the switch panel to indicate this current wastage.

Magneto Replacement Units.

Magneto replacement units are made to facilitate the substitution of a coil ignition equipment for a magneto. These units have a horizontal driving shaft with taper end suitable in size and centre height for coupling up with the drive of the replaced machine. A skew gear on this shaft drives a pinion on the vertical distributor spindle, and the shank of the distributor is housed by a boss on the frame casting. Timing is adjusted by the coupling as for a magneto. The coil may be mounted on the unit or separately, as most convenient.

MAINTENANCE OF COIL IGNITION SYSTEM.

Coil ignition maintenance is very simple, and the only points needing attention are the distributor and plugs, apart from cleaning the head of the coil occasionally and testing the connections and leads. The lubricator on the distributor shank should be given a turn every 500 miles or so, if of the greaser type, or a few drops of oil if an oiler is provided. Pack the greaser with high melting point grease when necessary.

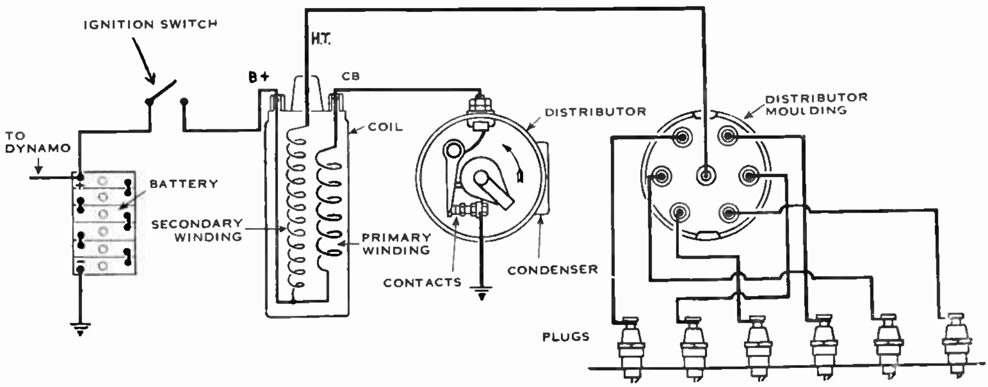

Fig. 8.—Diagram Showing Essentials of a Modern Coil-Ignition System.
This shows an earth-return set for a 6-cylinder car.

The cam should be greased with a slight film of vaseline every 2,500 miles. On the type of distributor fitted with automatic timing control it is necessary to lubricate this mechanism about every 2,500 miles, and this may be done by removing the rotor arm from the head of the spindle and dropping a little machine oil round the screw head exposed on the top of the spindle. A channel is provided under the screw head to permit the oil to pass through to the timing control.

The contact breaker pivot also requires a drop of oil occasionally if the contact arm has a metal bushing. Skew gear drives for distributors run most satisfactorily when packed with grease, but care must be taken to prevent this

This article on Motor Car Ignition Systems is continued in Part 31. Ready May 13th. Order your copy to-day.

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