THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

VOL. 33 JULY, 1940 PART 2

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0- 50 ,,	500 ,,
0- 100 ,,	1 Volt
0- 200 ,,	2 ,,
0- 400 ,,	4 ,,
0- 500 ,,	5 ,,
0-1,000 ,,	10 ,,

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A.C.

Range.	Value per division
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0- 50 ,,	500 ,,
0-100 ,,	1 mA
0-500 ,,	5 ,,
0- 1 Amp.	10 ,,
0- 5 ,,	50 ,,
0- 10 ,,	100 ,,

D.C.

Range.	Value per division
0- 1 mA	10 μA
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0- 5 ,,	50 ,,
0- 10 ,,	100 ,,
0- 50 ,,	500 ,,
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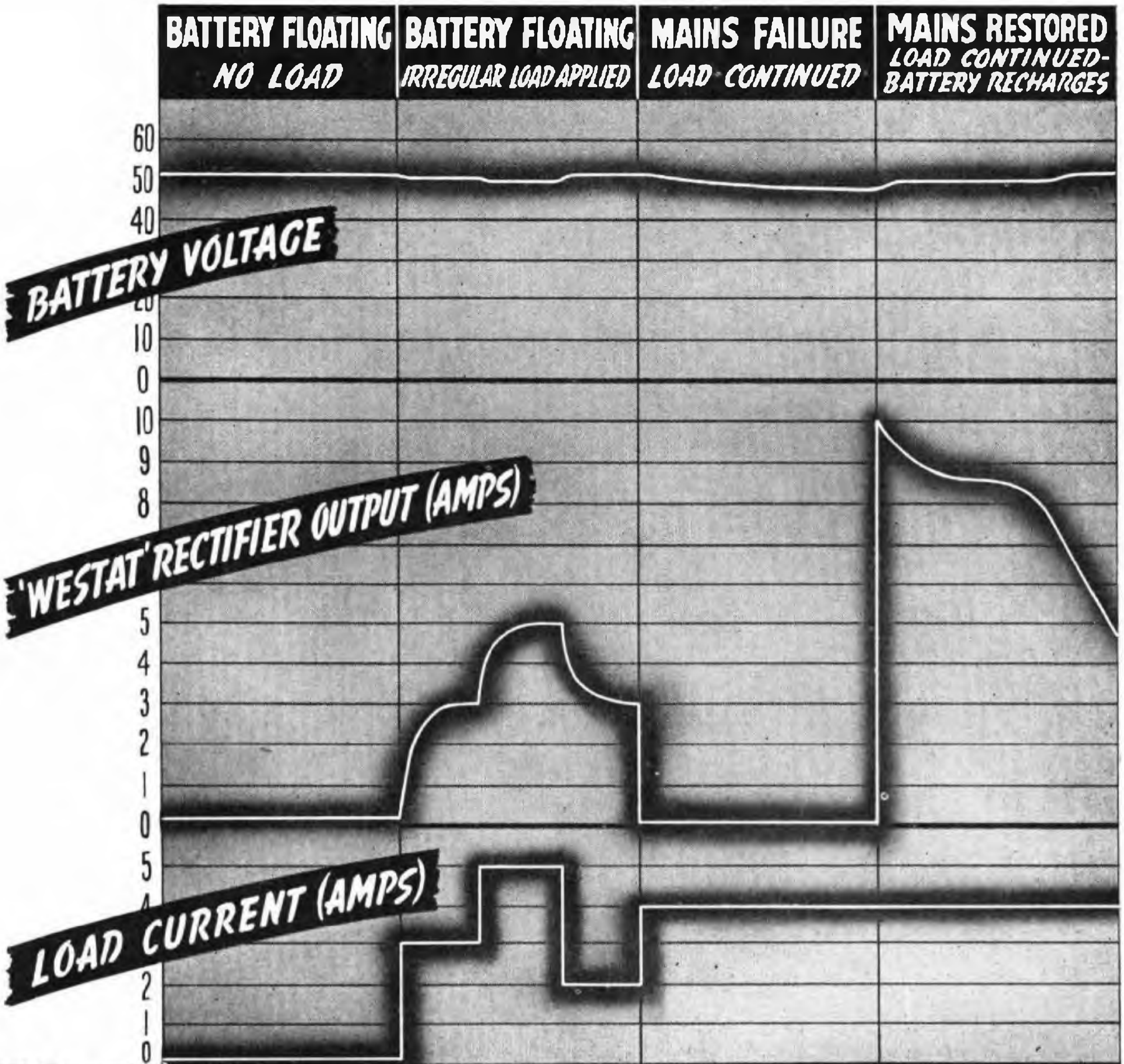

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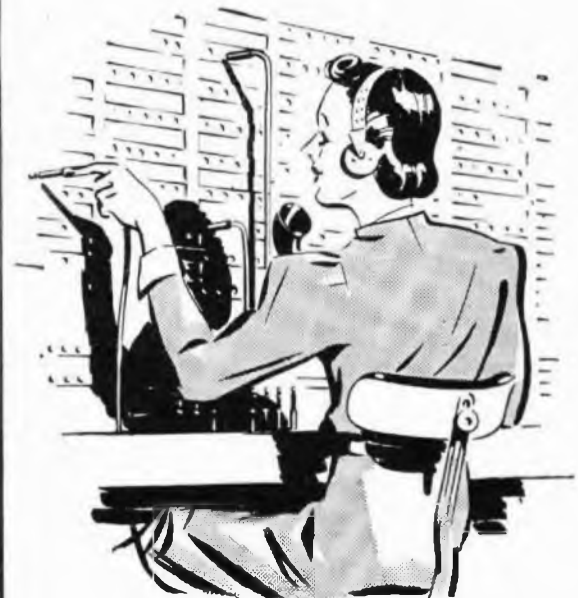

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THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

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Modern Materials in Telecommunications

U.D.C. 539

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Part I.—The Growth of Knowledge concerning the Internal Structure of Matter

This article is the first of a projected series which will deal with the properties of some of the materials now available for building into telecommunication equipment. Many of these materials are of comparatively recent introduction and the present article shows in a general way how the development of new ones has been aided by increasing knowledge of their internal structure. Later articles will discuss in greater detail mechanical, dielectric and magnetic properties of some of these materials and show how these are related to the arrangement of molecules and atoms.

Introduction.

IT is on record that twenty-three centuries ago there was much speculation among philosophers as to the constitution of materials. All interest in this connection was lost during the period of confusion which followed the fall of the Roman Empire, but the Middle Ages introduce us to the alchemist's laboratory and to countless undirected experiments the object of which was to transmute the baser metals into gold. The seventeenth, eighteenth and nineteenth centuries witnessed the decline of alchemy, but provided a gradually accumulating mass of experimental data relating to all kinds of chemical substances. These data might have had little effect on everyday life had it not been for the men who sought to explain them in a few simple laws, which were of very general application and gave direction to further experiments. Speculation and experiment were at last united, and one result has been that new materials are now at the disposal of the engineer.

Transmutation of the elements—the alchemist's dream—is taking place in a score or more of laboratories at the present time. This involves a change in the inconceivably minute central nucleus of the atom and was first observed by men patiently seeking for new light on the nature of our physical world. The discovery that such changes took place—and in particular the discovery by M. and Mme. Curie of radium in which the change takes place spontaneously—has given much more to human welfare than the ability to transform base metals into gold. These changes give rise to the emission of radiation (gamma rays) which has been of inestimable use in the treatment of disease.

More apparent in everyday life, however, have been the results of the disclosure of the secrets of material structures on a grosser scale—of the way in which atoms are linked together to form molecules, and molecules in turn are built into crystal structures. As more of this architecture in which atoms and molecules are the bricks has been learned, so has it been seen how the plan of building might be varied, or bricks of a different kind introduced in a way to give materials more nearly possessing those properties or combination of properties required.

It is impossible to say how much the rapid industrial progress of the present time owes to the introduction of new materials. The telecommunications engineer has been given two new series of magnetic alloys having properties of entirely different orders from those of the materials available at the beginning of the century. The alloys in one of these series are so easily magnetised and demagnetised (they have high initial permeability and low hysteresis) that they make easy the task of adding inductance to a telephone circuit without materially increasing its losses. The alloys in the other class are so difficult to magnetise, but so retentive of their magnetism once they have been magnetised, that a permanent magnet necessary to store a given amount of energy can now be made one-fifth the size it was twenty years ago. Such advances have not been without their effect on the design of telephone instruments.

Of equal importance has been the development of two new types of dielectric, one having very high permittivity and the other very low dielectric loss. The latter type, comprising a whole range of materials, has been particularly valuable in a period when the use of radio-frequency currents as carriers is being adopted for wire transmission. It is true, however, to say that neither of these has had such an effect on outward designs as the introduction of synthetic resin plastic materials lending themselves readily to the fabrication of piece-parts by moulding. It is doubtful whether the pleasing design of the modern hand microtelephone could have been achieved had such materials not been available. The availability of plastics has solved problems in every department of modern life. A synthetic resin plastic which is as transparent as ordinary glass, lighter in weight and will not splinter on impact, is used for roofing in the observation turrets of aeroplanes; and gear wheels made of another may be actually more durable than the steel pinions with which they are engaged. In the domestic field, articles which are in daily use such as all kinds of fancy goods, ash trays, door handles and even doors, make one aware of the existence of plastics. For so many purposes have these materials replaced metals that it has sometimes been said that, following the stone, bronze and iron ages, the world is now entering into a new era—the plastic age.

In the subsequent articles of this series, it is proposed to describe the properties of some new materials and to attempt to show how some of these properties are related to the structure of the particular material. Before this is done it will be useful to review the present state of knowledge concerning the minute structure of material things and to recall how this knowledge has been, and is still being, accumulated.

Atoms and Molecules.

In such a review it is perhaps as well to start by recalling that the hypothesis that gross matter is composed of tiny indivisible entities was recorded in the works of Greek and Roman writers. For example, Democritus wrote in 400 B.C.:—

> "Atoms are infinite in number and infinitely varied in form. They strike together and the lateral motions and whirlings are the beginnings of worlds. The varieties of all things depend upon the varieties of their atoms in number, size and aggregation."

Such statements have much in common with twentieth-century ideas. They had, however, no experimental justification, nor did Greek and Roman philosophers make any attempt to devise the experiments which would test their speculations. The atomic theory remained a speculation until the beginning of modern chemistry began to reveal facts which gave to it a shape approximating to its present form. One of the outstanding figures of this period was Dalton (1766-1844) who again put forward the view that matter was constituted of a vast number of extremely small particles or atoms bound together by attractive forces. They were not, however, like the atoms conceived by Democritus, "infinitely varied in form," but "belonged to a limited number of species." Such were the elements. Innumerable different materials of natural occurrence were explained by the fact that most of these were composed of atoms of two or more different species joined together, as we know now, to form chemical compounds. The development of these ideas stimulated experiments which, in the early years of the nineteenth century, gave rise to the formulation of the laws of conservation of mass and of chemical combination summarising the rigid principles governing all types of chemical change. We learned that there was nothing haphazard about these changes or about the composition of compounds which resulted from them.

It is scarcely possible to imagine the amount of work that was undertaken about this period. Multitudes of substances were analysed to ascertain whether they were elements or compounds or mixtures. After each element had been separated there was the task of measuring its properties, such as melting and boiling temperatures, its density as solid, liquid and gas, its conductivity and magnetic susceptibility and a host of others. The ways in which the various elements combined or failed to combine with one another were studied. This led to various systems of classification of the elements one of which, Mendeleef's Periodic Table (1869), has stood the test of all later work. As originally set down in this table, the elements fell into 7 groups, each of which contained elements showing distinct family resemblances. The subsequent discovery of the rare gases added another group of strikingly similar elements. The reason for these resemblances and their periodic recurrence was not apparent until atomic physics began to give us a mental picture of the atom.

Towards the end of the nineteenth century we had reached the stage of having a conception of the molecule as the smallest part of any substance capable of free existence. It contained, for any specific chemical compound, a definite number of atoms of each element entering into the make-up of the compound. But, although the relative masses of molecules and the number of atoms which they contained were known with accuracy, only the roughest approximations were available for their absolute masses and nothing was known at all of the structure of atoms and of the mechanism which holds them together to form a molecule.

Electronic Theory of Matter.

The year 1897 with the discovery by Thomson of the electron in an electric discharge through a gas, and its isolation and measurement as a negative electric charge a few years later, gave the first real proof that the atom had any parts. A decade later there followed the conception of the atom as a comparatively massive central nucleus bearing a positive electric charge and surrounded by a number of electrons arranged on successive concentric shells. But the most important clue to the secrets of atomic structure came in 1913 when Moseley, examining the X-ray spectra from a number of neighbouring elements in the periodic table, observed a beautiful regularity as he passed from one element to the next. This led him to the conclusion that "there is in the atom a fundamental quantity which increases by regular steps as we pass from one element to the next. This quantity can only be the charge on the positive nucleus." At once it was possible to visualise a distinctive model for the atom of each element.

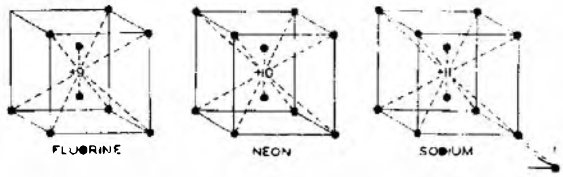


Fig. 1.—Static Atom Models.

Conceptions of the Structure of Atoms and Molecules.

Static atom models are very old-fashioned in 1940, but they do help us to understand chemical behaviour, and the models once suggested by Lewis and Langmuir for atoms of fluorine, neon and sodium are sketched in Fig. **1**. The central nuclei carry, respectively, positive charges equivalent to 9, 10 and 11 units, and, normally, this charge is neutralised by a corresponding number of surrounding electrons. The configuration of neon is mechanically as well as electrically stable, hence the gas is inert and does not readily enter into chemical combination. The fluorine atom on the other hand has one electron too few and the sodium atom one too many to be really stable. Hence if a stray electron is available it will readily be captured by the fluorine atom, which will thus acquire a negative charge, whereas the sodium atom will easily lose its odd electron and become positively charged. A realisitic mechanical picture of the formation of molecules is provided as the positively and negatively charged atoms come together to form sodium fluoride whose stability is explained by the electrostatic attraction between the two charges. Other types of molecule are formed, for example, where two atoms of fluorine join together in such a way that the deficiency in the outer shells of electrons is shared between the two of them (Fig. **2**). It is not difficult to see that, as the charge on the nucleus is increased and successive shells of electrons completed, structures will again be formed which have electrons short, or in excess, of a stable configuration. Hence the occurrence of the family resemblance between groups of atoms in the periodic table.

Such models do not satisfy the physicist. For a time his needs were met by the Bohr-Rutherford model with its "restless girdles of electrons" following a complicated system of orbits of differing energy values. This model had the amazing power of predicting the wavelengths of the lines in some of the simpler spectra by a system which was subject only to the ordinary Newtonian laws of mechanics. It has now disappeared in favour of a less easily visualised conception in terms of wave mechanics. All these models are of importance only as they help in understanding physical and chemical phenomena and, especially, as they suggest the properties which are to be expected from atoms in the aggregate—that is, from bulk material. It is of importance to note that the grouping of electrons on a series of concentric shells persists in every picture of the atom and that, although a molecule is inherently neutral as regards its total electric charge, the arrangement of the component nuclei and electron shells may be such that the complete structure is left with an electric moment. It will be seen in a later article that this leads to an explanation of the behaviour of certain types of dielectric.

The Structure of Solids.

At this point it is, perhaps, as well to recall that some of the properties possessed by materials are also those of individual atoms or molecules whereas others are not. For example, the power of combining violently with oxygen, each atom of which requires two additional electrons to complete the outer shell, is as much that of two atoms of hydrogen, each with an odd electron, as it is of the gas in bulk. Similarly certain properties of the water which is formed as a result of this combination are properties of the individual molecule consisting of three atoms. There are other properties, however, which do not become apparent until a number of molecules are joined together and become the beginnings of a solid body.

That some sort of ordered arrangement of the molecules existed within solids had long been inferred from the fact that many of these occurred naturally as crystals. The regularity of the surface exhibited by such crystals, and the observation that these surfaces were not haphazard but at definite angles to one another, betokened some degree of order of the structure within. All attempts to use the microscope as a means for seeing the arrangement of the atoms within a crystal structure failed, no matter how great the magnification. It is known now that no microscope can ever distinguish details smaller than half a wavelength of light, that is, about 2×10^{-5} cm, but the diameter of an atom and its spacing in a solid body is about 1,000 times smaller than this. Information as to the structural patterns was therefore lacking until von Laue suggested in 1912

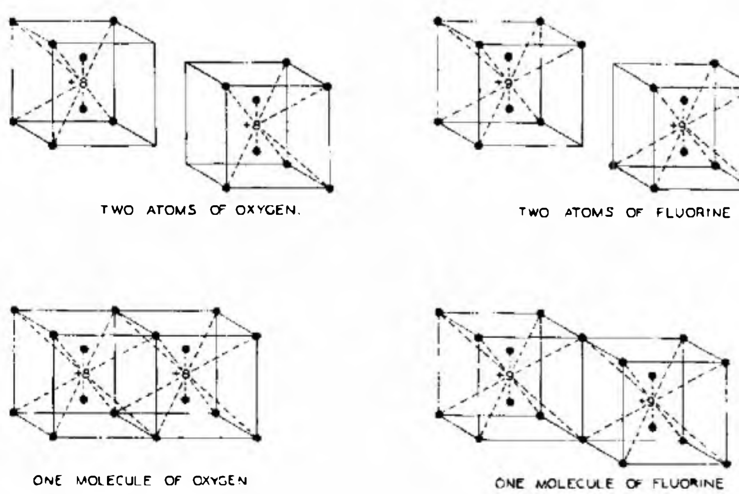


Fig. 2.—Illustrating the Formation of Molecules by Electron Sharing Atoms.

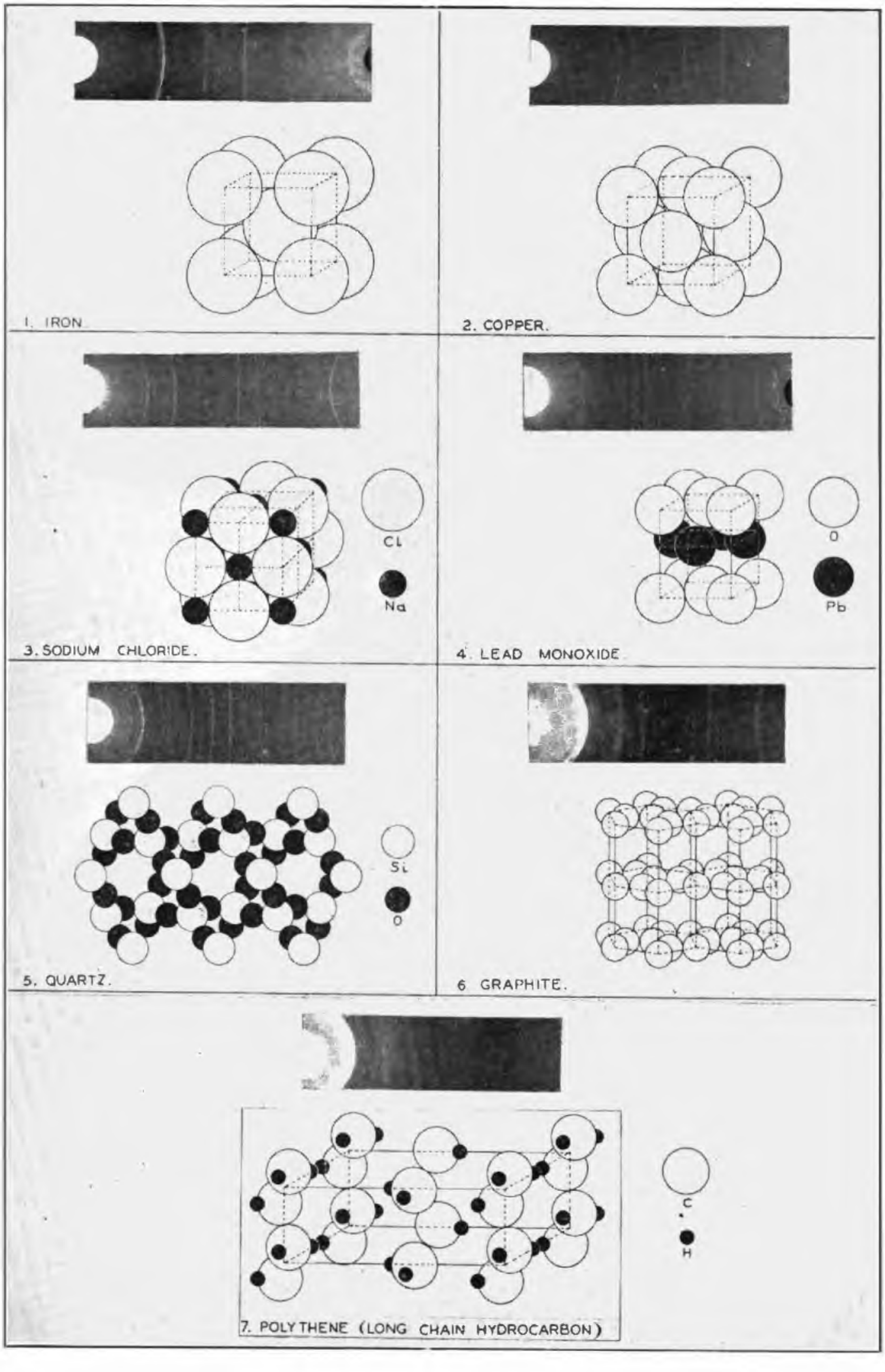
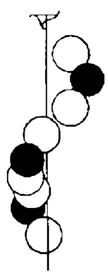


FIG. 3.—TYPICAL X-RAY DIFFRACTION PATTERNS AND THEIR SOLUTIONS.

that if the atomic or molecular units were regularly arranged, and X-rays which have a wavelength of the same order as the diameter of an atom were directed on to the structure, a diffraction pattern would be formed in much the same way as a pattern is formed when light waves are diffracted by a regularly ruled optical grating. The experiment was tried and a pattern was obtained which could be interpreted to give information relating to the spacing of atoms within a crystal. Immediately a method was available for investigation of the minutely planned structure of crystalline materials. The pioneer investigators were the Braggs, father and son. Interpretation of many of the diffraction patterns was not easy ; indeed, the determination of a crystalline structure by X-ray methods has been likened to " the solution of a crossword puzzle in that there is no direct method of arriving at the answer. Progress is made by guesswork and when the right guess has been made the evidence for its correctness is that everything fits into place and the observations are completely explained." Typical puzzles and their solutions are shown in Fig. **3**.

Structures such as shown in Fig. **3** introduce the idea of the crystal unit, that is, a small assemblage of atoms or molecules rigidly fixed in a definite spatial relationship one to another which is regnlarly repeated throughout the structure. This crystal unit may have a volume of only 10^{-24}c.c., but it displays all the properties of the solid in tangible form. It possesses elasticity, thermal and electrical conductivities, dielectric constants and optical activities, and in the crystal unit these are vector and not scalar functions. As an example of the importance of the directional nature of the properties disclosed by the crystal unit, the crystal unit of quartz (SiO_2) consists of nine atoms packed together in a cork-screw fashion (Fig. **4**). Hidden in this arrangement



REPRESENTS A SILICON ATOM.

REPRESENTS AN OXYGEN ATOM.

FIG. **4**.—THE CRYSTAL UNIT OF QUARTZ.

of nine atoms is the secret of the rotation of the plane of polarisation of light by a quartz plate. The discussion in later articles of other properties which make their first appearance in the crystal unit will show the importance of this unit.

Next, when a large number of such crystal units is fitted together to form a crystal of visible size—and the scale of things under discussion is such that it takes roughly 10^{20} crystal units of quartz or 10^{21} atoms to form a crystal the size of a pin's head—there will be found to exist in the structure certain planes in the direction of which slip, or fracture, takes place more readily than in others. From the X-ray diffraction patterns produced by some metals and their alloys it is possible to see how comparatively few atoms of a " foreign " element can enter into what we might term the " framework " of the atomic arrangement proper to another in such a way that movement of one part of the framework relative to another is made more difficult. The whole structure is stiffened. The hardening of copper by the addition of zinc, producing the alloy brass, and many other familiar changes in the mechanical properties of metals have acquired a physical explanation in this way.

The investigation of the alloys of iron, copper, nickel, cobalt and aluminium by X-rays has yielded most interesting results. Many of these alloys, such as Fe_2NiAl and closely related compositions produce extremely strong permanent magnets. It has been found that the state of the alloy in which this desirable property is present is not a state of equilibrium but one in which the transition from one form of structure to another has been arrested before it is complete and " frozen " in the half-way stage by cooling. It appears that the valuable magnetic property is due to an intense type of local strain in the atomic structures when in this condition. This has given a clue to the regions of alloy composition which should be explored in the search for new permanent-magnet materials.

The task of unravelling the structure of many materials is being carried on in a number of laboratories. Research workers are tantalised by not being able to interpret outstanding diffraction patterns. Solution of the " crossword puzzle " still lacks a clue. This is true, for instance, of the patterns resulting from the diffraction of a beam of X-rays by crystalline proteins. The pattern is complete and perfect. When it is solved, it may throw a flood of light on the structure of living matter.

In the meantime industry is making use of X-ray diffraction patterns for controlling the processing of metals and alloys. The six photographs in Fig. **5** were all taken from a modern aluminium alloy. To the skilled reader they give valuable information concerning what is sometimes known as the " texture" of the material. They tell, in effect, of the large-scale disturbances to the regularity of the atomic structure which result from mechanical and thermal processes like rolling and annealing.

Materials composed of Large Molecules.

Very little attention has, as yet, been given to the arrangement of atoms within the highly complex chemical structures which result from a process of polymerisation. The process is a most important one to the modern plastics industry. In broad outline it signifies the linking together of many comparatively simple molecules of one kind to form a gigantic molecular aggregate. Within the aggregate the bonds between atoms are far stronger than the inter-molecular forces existing between a number of

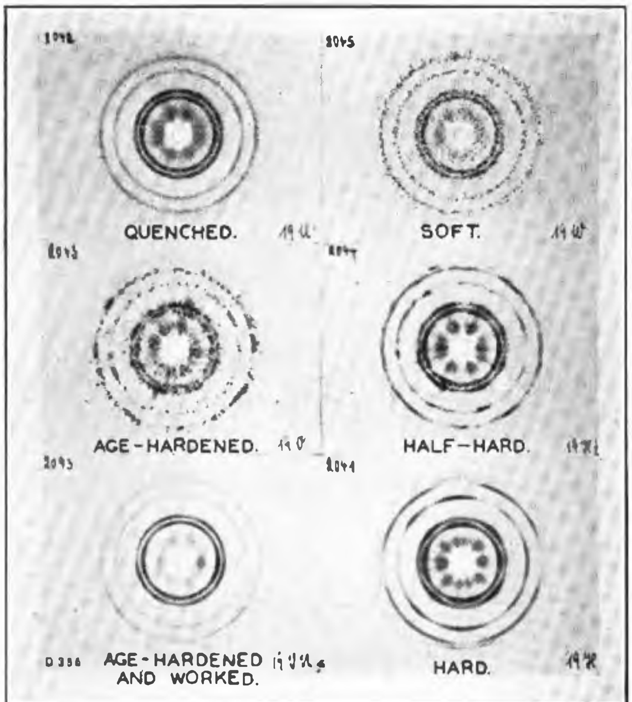


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FIG. 5.—EFFECT OF TEXTURE OF AN ALLOY ON X-RAY DIFFRACTION PATTERN

molecules forming part of an ordered array in a crystal structure. The aggregate is, in fact, itself a molecule but, whereas those from which it was made may have comprised at the most a score of atoms, the giant may contain many thousand. The effect on the chemical and physical properties of the material may be very marked. As an example, the ethylene molecule contains two carbon and four hydrogen atoms arranged as shown in Fig. **6** (*a*). A somewhat similar arrangement containing in all 50 or more atoms as shown by Fig. **6** (*b*), represents a molecule of a paraffin wax. In many respects this structure is extremely strong ; for example, the forces uniting its component atoms are thousands of times greater than those existing between iron atoms in a steel. On the other hand the cohesion between molecules when the latter are packed together is small, and this accounts for the mechanical weakness of a block of paraffin wax. During the past few years, however, it has been found possible to lengthen further the chains shown in Fig. **6** (*a*) and (*b*) so that the molecule contains up to 3,000 atoms. The polymerised material " Polythene " retains the advantage of good electrical properties, but has in addition considerable mechanical strength. The new material can be used as a wire or cable covering.

Generally the polymerisation process is aided by the application of extreme heat and pressure. The way in which the original molecules join together is not clearly known, but it appears that sometimes they are linked together in long chains, whereas at others they produce a mesh-like structure more resembling chain-mail. The suggestion has been made, although it is not yet proven, that the difference in properties between the so-called " thermo-plastic " and " thermo-hardening " plastics is accounted for by the first possessing a chain and the second the chain-mail type of structure. The first of these can be softened by the application of heat, whereas the second is permanently infusible once polymerisation has taken place.

Surface Films.

The discussion so far has been confined to the structure of the interior of a material. Surface films are of particular interest to the telecommunications engineer. Microphonicity is a surface effect. The contribution made by a multiplicity of switch contacts to general circuit noise is becoming one of the outstanding difficulties limiting design. Now the layer that is of particular interest when surface phenomena are concerned is only a few atoms thick. X-ray methods failed when applied to the investigation of such layers, as any information which might be obtained from markings on a diffraction pattern was masked by the much more pronounced markings giving a wealth of detail concerning the interior structure of the material. Investigation of surface films had therefore to await the development of a probe which would penetrate only to the depth of a few atoms. That probe was found in **1927**.

About **1925** the idea had been put forward that the electron itself might under certain circumstances behave not as a flying bullet but as a short train of waves. If so, a stream of electrons should exhibit, in appropriate circumstances, all the properties of a beam of light. Under certain conditions the beam should be diffracted by an ordered array of atoms in a metal surface. The experiment was first tried in the Bell Telephone Laboratory by Davisson and Germer, and the diffraction patterns which they obtained proved that the assumptions were true. More than that, the exceedingly low penetrating power (10^{-6} cm.) of even high-speed electrons provided the experimental physicist with the appropriate tool for the investigation of surface phenomena.

The information that has been gathered as a result of the use of this tool has already been of interest to the motor industry. Electron-diffraction patterns taken from the walls of pistons made of certain aluminium alloys have shown that under working conditions the surface becomes converted into

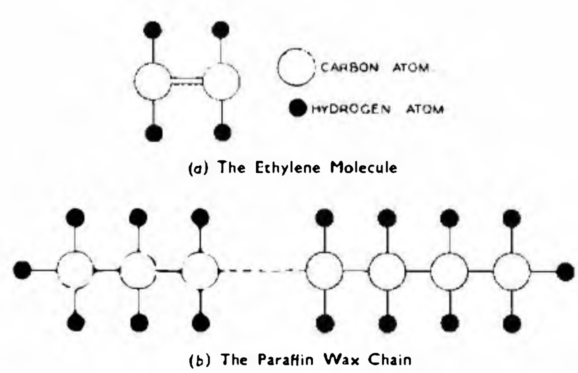

FIG. 6.—EXAMPLE OF THE FORMATION OF LARGE MOLECULES.

minute crystals of corundum. These are abrasive. On the other hand, use of certain magnesium-aluminium alloys results in a surface formation of spinel, and this polishes to a permanently amorphous surface.

Future Developments.

The end of the story is not yet in sight, and it is possible that by the time this is published new light will be thrown on the structure of some common material. Despite the preoccupations of war for many physicists, an intensive attack on the nucleus of the atom is being carried on in laboratories all over the world. Papers which are unintelligible except to the expert, discuss this minute structure at length. There is still very much to be cleared up, but it appears that the nucleus contains two kinds of particles—protons carrying a positive electric charge and neutrons which are uncharged. There may be others, but their existence is not certain. What is important, however, is that it has proved possible to shoot an additional one of these particles into the nucleus or to knock one out. If the charge on the nucleus is altered the result is a transmutation of the atom. On the other hand, when a fast neutron is shot into the nucleus, the charge is unaltered, but the nucleus becomes unstable and liable to disintegration. When it disintegrates it may emit gamma rays as do the naturally occurring radioactive elements. Joliot and Curie, son-in-law and daughter of the discoverers of radium, made the first successful experiments, but the nuclear physicist can now induce radioactivity in practically all of the elements. To generate his bombarding stream of fast-moving particles, however, he may require a cyclotron weighing over 200 tons and taking its power supplies from what is beginning to approach a small generating station.

The results of all this have been of tremendous value; radio-sodium is being increasingly used as a substitute for radium in the treatment of disease, and radio-phosphorus has found a wide field of use for biological investigations. It is not true to say that these materials have been discovered: neither have they been compounded in an alchemist's furnace. They are logical end products of a long series of experiments designed to throw increasing light on the structure of materials.

TELEGRAPH AND TELEPHONE PLANT IN THE UNITED KINGDOM

TELEPHONES AND WIRE MILEAGES. THE PROPERTY OF, AND MAINTAINED BY, THE POST OFFICE IN EACH REGION AND ENGINEERING DISTRICT AS AT 31st MARCH, 1940.

NO. OF TELEPHONES	OVERHEAD WIRE MILEAGES			REGION OR DISTRICT	UNDERGROUND WIRE MILEAGES		
	Trunks and Telegraphs	Junctions	Subscribers*		Trunks and Telegraphs†	Junctions‡	Subscribers¶
1,148,184	826	1,465	64,603	London Region	501,817	1,329,360	3,397,826
151,140	2,139	9,388	73,232	South Eastern	233,318	54,121	413,538
191,702	9,023	24,804	148,091	South Western	261,818	47,880	408,970
136,592	8,597	18,615	119,850	Eastern	342,688	68,145	295,662
156,615	8,660	17,530	115,604	North Midland	365,284	67,343	331,342
178,903	5,085	15,173	109,135	South Midland	327,693	87,430	451,473
93,240	4,628	15,638	76,798	South Wales	206,950	50,071	177,655
79,969	7,057	16,168	81,465	North Wales	240,595	23,299	140,904
147,501	2,056	5,251	37,592	Birmingham	198,319	142,891	346,642
371,141	2,914	7,968	100,283	N. Western Region	467,381	209,459	1,026,784
44,421	8,804	7,092	23,578	Northern Ireland	41,928	13,656	98,336
319,679	13,875	21,015	141,015	N. Eastern Region	521,288	154,101	792,497
298,143	24,258	32,368	148,626	Scottish Region	440,498	134,615	597,395
3,317,230	97,922	192,475	1,239,872	Totals	4,149,577	2,382,371	8,479,024
‖3,364,294	98,820	192,910	1,231,438	Totals as at 31st December, 1939	‖4,070,994	‖2,335,642	8,380,425

* Includes all spare wires. † All wires (including spares) in MU cables. ‡ All wires (including spares) in wholly Junction cables.
¶ All wires (including spares) in Subscribers' and mixed Junction and Subscribers' cables. ‖ Figure amended since issue of December return.

Multiphone Working

U.D.C. 621.395.331.3

E. W. AYERS, B.Sc.(Eng.), and
H. E. STEVENS

The authors describe equipment which enables a central station to speak simultaneously to a number of others. The system permits the out-stations to speak to the central office but not to one another.

Introduction.

IN the last few years there has been a growing demand for facilities for more than two people to take part simultaneously in a telephone conversation. In the attempt to meet this demand three main types of service have been developed, known as: multiphone, conference and broadcast.

It is the object of this article to distinguish between these three and then to give a brief description of multiphone facilities offered by the G.P.O. and of the apparatus and circuits employed.

Definitions.

Multiphone provides for two-way conversations between a central station and a number of outstations. The central station can call and speak to one outstation or to any number of outstations simultaneously, but the latter cannot speak to one another. This can be illustrated very simply by reference to Fig. 1:

A can talk to b, c and d individually or simultaneously: b, c and d can talk to A but cannot talk to one another.

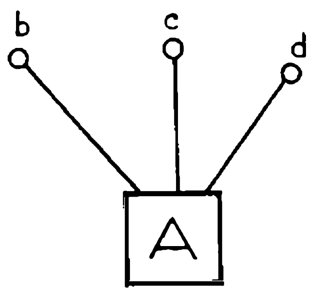

FIG. 1.—MAIN AND THREE OUTSTATIONS.

Conference facilities provide for connecting a number of lines together to allow both-way conversation between all the stations concerned. Again referring to Fig. 1:

A can talk to b, c and d.
b can talk to A, c and d.
c can talk to A, b and d.
d can talk to A, b and c.

Broadcast facilities provide for a central station to speak to a number of outstations, which are, however, unable to reply, i.e., speech is one way only. In Fig. 1: A can talk to b, c and d, but b, c and d are unable to talk to A or to one another.

Scope and Applications of Multiphone.

Multiphone facilities can be provided over all types of circuits, private wires, exchange lines or extensions from P.B.X.'s, but private wires must not be mixed with exchange lines on the same multiphone board, owing to the ban on the extension of exchange calls over private wires. Although multiphone facilities can be provided over exchange lines, there has been a relatively small demand for this service, and the principal applications have been to private wires.

As an example, a subscriber may have a private wire network devoted entirely to one purpose such as the distribution or collection of news. In such a case the lines would be terminated at the head office on a multiphone board from which the distribution of news can be handled.

On the other hand, a number of private wires, linking together various branches of an organisation, may be terminated on a P.B.X. and be available to any extension. As a supplementary service the lines could be intercepted on a multiphone board to allow general instructions or information to be sent out from the head office to all branches simultaneously.

So far the greatest demand for multiphone facilities has arisen in conjunction with:

(1) Organisations interested in the rapid transmission of racing and press news to subscribers and agencies throughout the country.

(2) County police telephone networks, where a multiphone switchboard is installed at the divisional headquarters, and is used for quickly disseminating police news over the system.

The ability to issue information or instructions from a central point to a number of outstations simultaneously has obvious applications in other directions under present conditions as well as in peace-time.

Facilities.

The lines from outstations are terminated at the head office on a multiphone switchboard which comprises calling indicators and keys to connect selected lines to the operator's telephone. On some boards provision is made for two or three operators. One point that should be emphasised is that a multiphone switchboard does not provide intercommunication between one outstation and another, and if this facility is wanted the multiphone board must be associated with a P.B.X. switchboard.

When a large number of lines is bunched or the transmission loss over the worst circuit exceeds 20 db., an amplifier is used, details of which are given later. This equipment enables an operator to broadcast to a maximum of 80 lines without loss in sending efficiency. Any outstation may reply to the operator, but conversations between outstations are prevented by joining the lines in parallel across a low resistance.

A ringing key is provided for each line, and on some boards a single "group" key is fitted for simultaneously ringing the whole of a previously selected group of lines. Ringing power may be taken from A.C. mains via a step down transformer, since it is rarely practicable to obtain a large enough current from a ringing lead from the public exchange. Hand generators are not favoured where speed of signalling is of paramount importance as in the distribution of news. A disadvantage resulting from the use of A.C. mains is that it is necessary to adjust outstation bells specially to respond to both 17 and 50 c/s ringing.

A line may be terminated at an outstation on a single instrument or on a P.B.X. switchboard. At the central station the lines may be taken to a P.B.X., in which event they are wired via the keys on the multiphone board so that they may be intercepted when a message is to be broadcast. It is occasionally desired to broadcast messages or information from a point remote from the actual switchboard. If an amplifier is used, this necessitates a special 4-wire extension wired from the normal operator's circuit.

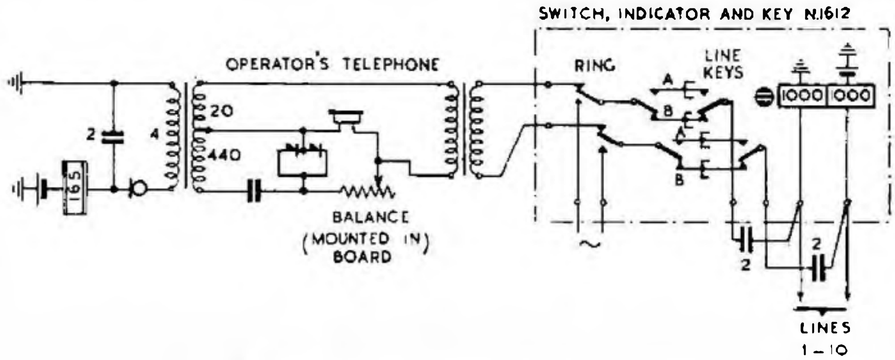

Fig. 3.—Multiphone Working without Amplifier.

The operator's instrument consists of a breastplate transmitter and a single or double headgear receiver, connected to a standard anti-side-tone induction coil, fed from a power lead when possible. A copper oxide limiter is joined across the receiver to reduce switching clicks. At the outstations, standard types of telephone instrument are fitted, but where room noise is troublesome, e.g., in press rooms, grand stands, etc., a hand or foot-operated switch is provided to cut out the transmitter when listening.

Apparatus.

Three types of switchboard have been designed. The first, illustrated in Fig. 2, is a 10-line C.B.S. private wire switchboard (Switch, Indicator and Key N 1612 10/10) specially designed for press work to allow rapid manipulation of a previously selected group of lines. The incoming circuits terminate on disk signal indicators which operate when the distant end of the circuit is looped, and remain operated while the circuit is in use, giving negative clearing. Calling, clearing and supervisory signals are all received on one indicator.

A schematic diagram of the circuit conditions is given in Fig. 3. The speech and ringing path is via the 2 μF blocking condensers inserted to give individual D.C. supervision on each line. Ten line keys offer the choice of either of two speaking commons, A and B, and a third position marked " Line out of use " disconnects the circuit from both speech commons but leaves the indicator across the line. The indicator coil resistance is 2,000 ohms, and it is sufficiently sensitive to work over a 2,000 ohm line with a 20 V supply at the central station.

When an amplifier is used with this board, the top positions of the line keys are arranged to substitute a 600 ohms resistance for the line to maintain the balance of the hybrid transformer in the amplifier.

The two speaking commons are connected via ringing keys and a changeover key to the operator's circuit. It is thus possible to set up a broadcast on one common while still dealing with individual circuits on the other. When the time for a broadcast comes (e.g., when the result of a race is received) the operator has merely to throw over the speaking keys and ring all the lines simultaneously. As each station answers, the corresponding indicator operates, any lines not participating in the broadcast being switched to the " Out of use " position. Alternatively, terminals are provided so that the two commons may be brought out to two separate operators if desired.

Fig. 2.—10-line C.B.S. Switchboard.

The second type of switchboard (Switch, Indicator and Key N1617 10/10) is a 10-line universal switchboard suitable for any type of line — private wire, P.B.X. extension, manual or automatic exchange line. Disk signal indicators are used which may be arranged to operate to either generator ringing current or a D.C. loop according

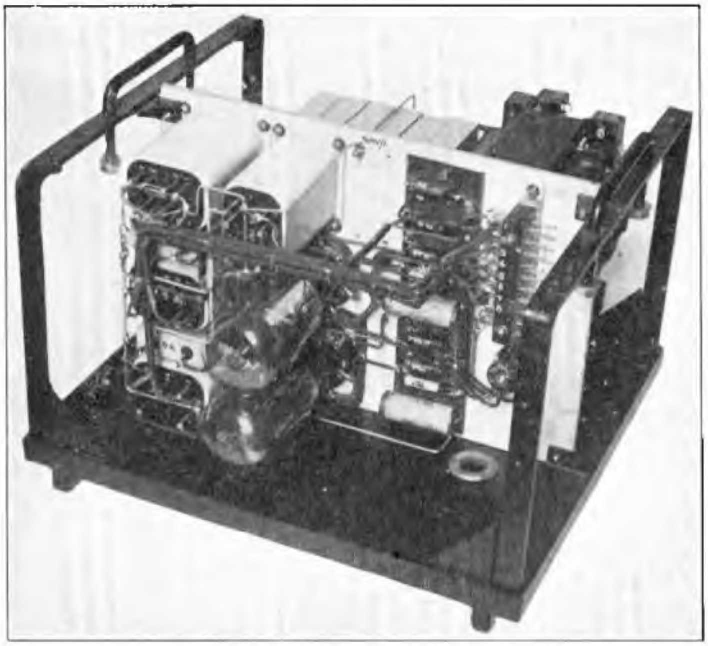

Fig. 4.—Unit Amplifying No. 23A.

to the type of line connected. One, two or three operators may work at the board at the same time, each having access to a small group of lines. This is useful where each group is reserved for a special purpose, and coupling keys are provided so that one operator can control all three groups during slack periods.

The third type (Switchboard T.L.1806 10/10) is a 10-line magneto signalling board with drop indicators and keys to allow any line to be connected to either of two operators' circuits. This board has been used for private wires where, owing to the length of a circuit it has been necessary to use generator signalling in both directions.

Each of the above switchboards is contained in a wooden case 13$\frac{5}{8}$ in. by 7$\frac{3}{8}$ in. by 6$\frac{7}{8}$ in. deep, adapted so that if more than 10 lines are to be accommodated the boards may be stacked together or mounted side by side.

Multiphone Working Without Amplifier.

Fig. **3** shows the principles adopted and is almost self-explanatory. The operator's instrument is coupled to the mnltiphone board via a matching transformer so that the maximum possible output is obtained from the transmitter. A consistently high sending efficiency is ensured by feeding the transmitter from a power lead or secondary battery. The line balance on the operator's induction coil is made variable by a potentiometer mounted on the switchboard so that optimum conditions may be secured when the number of lines at the bunching point is varied.

Amplifier.

The amplifying unit (No. 23a) (Fig. **4**), consists of a pair of single-stage amplifiers employing pentode valves, with an output sufficient to cater for a maximum of 80 lines. The unit is designed for operation from A.C. mains (100-250 V, 50 c/s), and a rotary transformer is used if D.C. mains only are available. Separate go and return paths are provided from the operator's instrument as far as the line hybrid transformer. When several lines are connected a separate balance is dispensed with by dividing the lines into two complementary groups and connecting one group to each side of the hybrid. When only a few lines are connected it has been the practice to connect all lines to one side of the hybrid and provide an adjustable resistance balance across the other side (Fig. **5**). Consideration is being given, however, to the design of an amplifier fitted with a simple side-tone suppressor circuit. With this it should be possible to tolerate a less exact balance and thus avoid the need for an adjustment under the control of the operator.

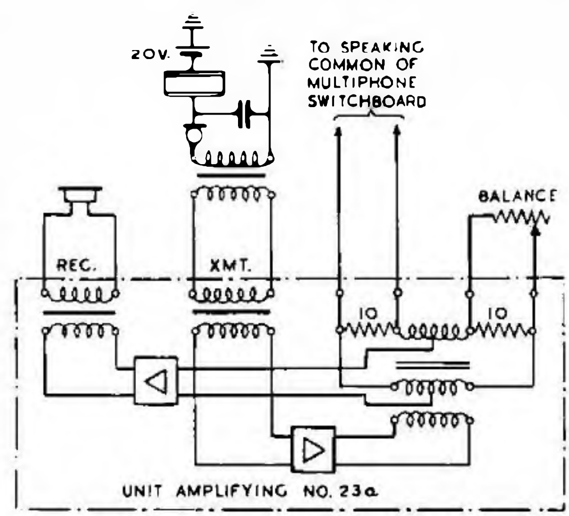

Fig. 5.—Multiphone Working with Amplifier.

Conclusion and Acknowledgments.

The subject of simultaneous transmission to a number of stations on a telephone network is one which is still largely in the development stage. Certain items of equipment have been standardised, but so many different problems arise that each new request has to be considered on its merits. There is not doubt however that the facility has a wide field of application, much of which has still to be explored.

Finally the authors wish to thank Messrs. W. Bryan Savage, Ltd., for the photograph of the Unit Amplifying No. 23a.

Pole Routes in Tropical Countries

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U.D.C. 621.315.17 621.315.66

A survey is given of the types of poles, arms and fittings used in tropical and sub-tropical countries for telephone and telegraph purposes

Introduction.

THE characteristic of pole routes in the tropics and sub-tropics is the use of iron and steel poles and arms. The advantages of the steel pole in tropical and low latitudes are its immunity from attacks by termites (" white ants ") and its portability, as it can be obtained in sections small enough to be carried over paths or through bush where no vehicle can go. The latter advantage is of lessening importance as roads are extended, but the former ensures its continued use.

The steel pole, however, has one disadvantage. The cost prohibits the use of poles which possess the same stiffness as wooden poles. This lack of stiffness necessitates more frequent staying and the accurate placing of the stays. In many places a route has to be selected, not because it is the best but because it is the only one where angle poles can be adequately stayed.

Expenditure on poles is a serious item in the budget of a colonial Posts and Telegraphs Department. Rail and sea freight may amount to as much as the price of the pole at the foundry. Local timber, if it were available and had a reasonable life, might cut down pole costs to a tenth or even a twentieth. It is not surprising that the search for a reasonably ant-proof timber (with an immunity either natural or acquired) should have occupied the time and thought of forestry workers and others for many years ; the results, however, have not been commensurate with the labour expended. Timbers which are naturally termite proof are obtainable, but are excessively hard and heavy and, apart from arsenate derivatives, no new treatments have been discovered. Impregnation with arsenious oxide or sodium arsenate is useful where creosote is not readily obtainable, but the immunity given by them is not so long lasting; creosote remains the supreme preservative against white ants as well as against other insects and fungi.

Many tropical countries are without suitable indigenous or planted timber, and will be dependent on steel poles for many years to come. It would be uneconomical to import wooden poles, and the practice of using green poles of a suitable species, cut from the surrounding bush, is adopted only for single wire telegraph lines of no great importance.

Standard Types of Steel Poles.

The British Standard Specification for steel poles provides four main types (Fig. 1), which are :—

A. Tapered upper section with 7 ft. cast-iron base with buckled plate (except smallest size). This is the most commonly used type.

B. Riveted seam tapered pole in multiple sections with cast-iron base with circular sole plate or buckled plate.

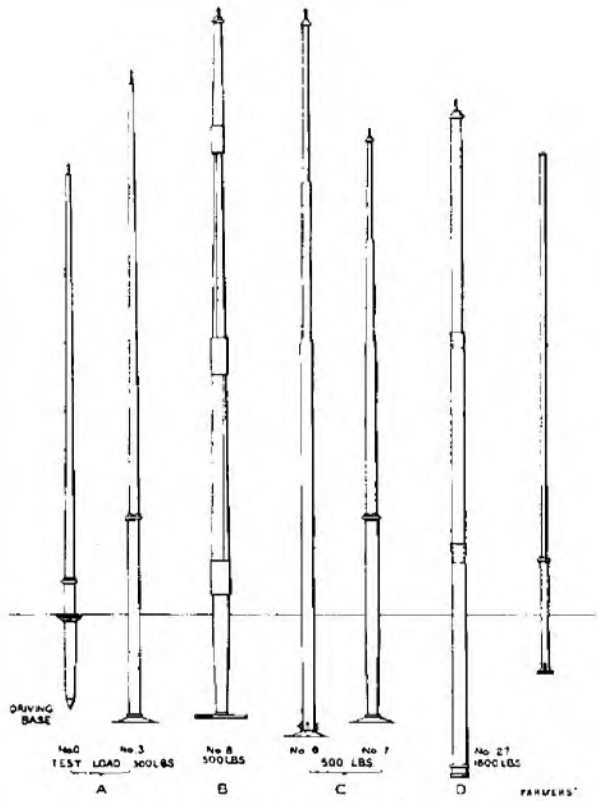

FIG. 1.—TYPES OF STEEL POLES.

C. Upper section in reduced parallel steps :
  (*a*) Tubular throughout, i.e., the upper section is bolted directly to the buckled plate.
  (*b*) With 7 ft. cast-iron base.

D. Multiple section pole in parallel steps :
  (*a*) Tubular throughout, the bottom tubular section being fitted into a cast-iron shoe (except smallest size).
  (*b*) With 7 ft. cast-iron base and buckled plate.

A separate specification deals with the " Farmers' Pole," which is an extra light pole in two sizes, 18 ft. and 20 ft.

The normal material for the tubes is low-tensile mild steel, but type D is specified also in high-tensile steel, effecting a reduction in weight of from a third to a sixth. Types A and D may also be supplied in wrought iron having the same strength as low-tensile steel.

The specification provides for a range of strengths corresponding to test loads of 300, 500, 750, 1,100, 1,600 and 2,200 lb., though the full range is not available in all types or in all sizes. Type A is not standardised for loads over 750 lb., and poles for the maximum load of 2,200 lb. are made only in two lengths, 22 ft. and 29 ft. The test loads mentioned above are the equivalent test loads for the pole as a whole, the actual performance tests being carried out on the component sections. Contrary to usual practice it is the permanent set after removal of the test load that is measured, not the deflection under load. It should be noted that poles of the same length and test load, but of different types, are not necessarily equally strong. Thus for a pole with a test load of 300 lb., the maximum permissible set is, for type A ¾ in., but for type C, tubular throughout, 1 in.

The type B pole has the peculiar virtue that the sections comprising a standard pole can be nested inside each other, thus reducing the pole for transport to a package 8 ft. long by the diameter of the largest section. Type D, though likewise in sections, cannot be so nested.

The driving base is now confined to poles 16 ft. or less in length of types A and D. This base is, as its name implies, designed to be driven into the ground by a simple form of pile driver ; it is, however, frequently excavated for like any other pole.

In type A the top of the pole is plugged to form a solid end 1½ in. deep. This can be tapped to take an insulator spindle instead of the usual lightning spike. This cannot be done with the other types of pole which have the top closed with a loose-fitting cap.

The " Farmers' Pole " is light and cheap and useful for farmers' party lines, minor telegraph routes, etc. Its capacity is four 200 lb. wires or the equivalent. It is a very simple pole consisting of a 2 in. diameter tube in a cast-iron base. A wedge holds the tube firmly in the base and a cap, with or without lightning spike, fits in the top of the tube.

Arms.

The arm universally used is the tubular iron type with two shaped flanges (Fig. 2) at the centre to allow the arm to seat itself on the pole. These flanges are welded or riveted to the tube and take the place of the clumsy, loose malleable iron seat which was a necessary fitment till about 1926. Prior to the last war, the usual practice was to space all wires at equal distances, usually 6 in. for subscribers' lines and 12 in. for trunks. To allow access to the top of the pole the centre wires were 15 in. apart on both trunk and subscribers' lines. It is now common practice to space subscribers' wires 4 in. apart between the wires of a pair, with 8 in. between wires of adjacent pairs, i.e., pairs are spaced 12 in. centre to centre. This principle is being extended to trunk circuits. In the Union of South Africa the standard spacing for wires carrying V.F. circuits is 15 in. between wires of adjacent pairs and 8 in. between wires of the same pair. Routes carrying these circuits have the arms spaced 2 ft. apart. An arm that is common in some administrations is one with a 9 in. spacing for all wires. The usual 16 in. between the inside positions do not leave the lineman any spare room, but with this 9 in. spacing it is quite impossible for him to climb up through the bed of wires to attend to circuits on the inside positions.

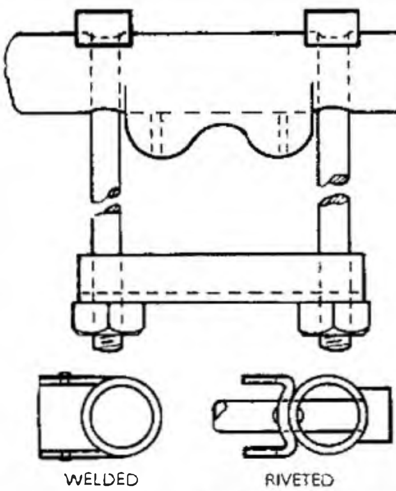

FIG. 2.—FIXED SEAT ARM FITTING.

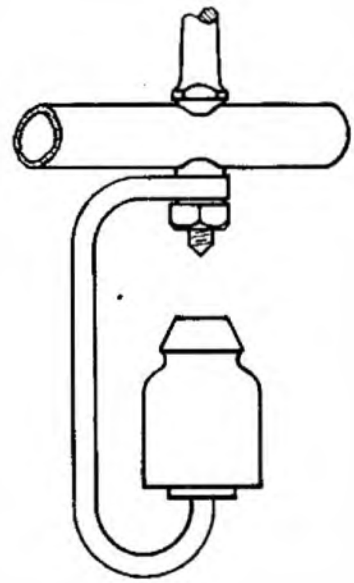

FIG. 3.—HANGING SPINDLE.

It might be thought that economies could be effected by the use of wooden arms but, in practice, it is found that the cost of the special malleable iron seat, necessary for fixing a flat arm to a round pole, raises the price to more than that of an iron arm. It is true that minor electric light lines are sometimes run on wooden arms directly bolted to the poles, without any special fittings, but on these lines regulation, as the Post Office engineer understands it, is non-existent. The great difficulty, often impossibility, of getting seasoned local timber in sufficient quantity is another factor that militates against the use of wooden arms.

Spindles.

The spindles used are identical with those used in the home service except for the slight modifications necessary to fit them to tubular arms. There is a hanging spindle (Fig. 3) which is very useful for providing an extra wire without going to the expense of erecting another arm, but it often leads to a row of these spindles between the arms.

Line Wire.

Galvanised steel or iron wire continues to be largely used for telegraph routes and for farmers' party lines, the general tendency toward the use of copper for all circuits being overborne to a large extent by local conditions.

Frequently, however, it is found cheaper to use copper than iron, the freight charges, which are always heavy and much the same for either kind of wire, weighting the scale in favour of the higher conductivity metal. The question is somewhat academic, as most long-distance telegraph circuits are nowadays either V.F. or by-products of telephone trunks for which copper will be selected for technical reasons.

Line Wire Joints.

It is advisable to use jointing sleeves for all sizes of copper wire. A twisted sleeve joint may not be always as satisfactory as a properly soldered Britannia joint, but experience shows that " dry " joints are much less likely to occur with the former than with the latter. Iron wire has, of course, to be soldered, but if the circuit is a telegraph, a few dry joints can be borne.

Stays.

Stays are usually made off on to a thimble which is bolted to a clip at the required point on the pole. Where there is only one arm, or a bracket, a loop on the end of the wire, slipped over the end of the pole, is quite satisfactory. A steel or wrought iron plate 9, 12 or 18 in. square takes the place of the buried baulk of timber. Rusting is a slow process in most tropical soils, and galvanising of the plate is an unnecessary refinement ; tarring is quite sufficient. On light routes a 400 lb. G.I. wire made off on to a piece of angle iron, driven at an angle like a tent peg, is found cheap and efficient.

Lightning Protectors.

Lightning is severe in the tropics and serious damage to pole routes is not infrequent. Damage to telegraph instruments and exchange apparatus is sometimes inevitable. In one district vacuum arrestors in series with protectors H.C. and F. were insufficient to keep repeating coils from being burnt out. It is fortunate that thunderstorms occur only for a few months in the year, the maximum intensity being usually at the end of the hot season as the rains break. Pole-mounted protectors will be found useful. The type shown in Fig. 4 consists of two carbon blocks on either side of a third from which they are separated by a tapering gap. The outer blocks are connected to line and the inner is earthed through the metalwork. If considered desirable, an earth wire can be connected to the centre terminal. The projecting pins of the terminals serve to locate the carbon block assembly, which is removable, and a loose domed iron cover protects it from rain.

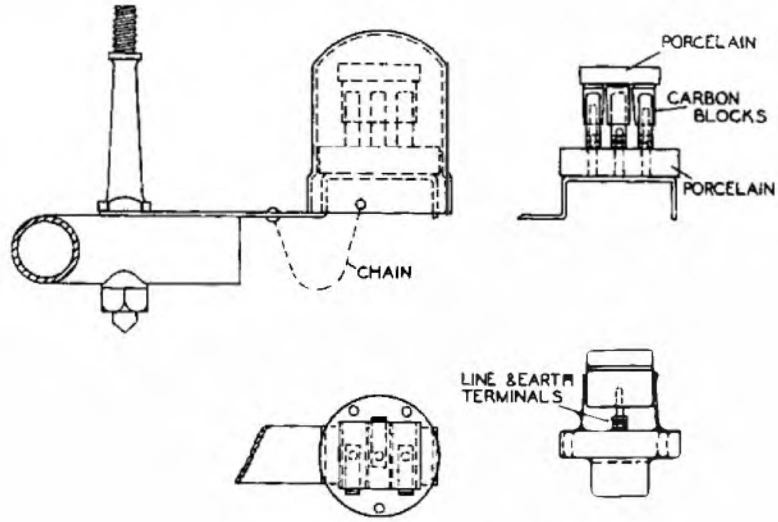

Fig. 4.—Outdoor Protector with Carbon Blocks.

In Fig. 5 is shown a vacuum tube mounted in an extra large composition insulator. The line is connected through the screw-down conical cover to the top of the tube. The bottom of the tube is earthed through a helical spring to the insulator spindle. This type should have frequent inspection as the vacuum tubes are often shattered by discharges.

An elevated earth wire may be found a useful protection for the pole route itself. An interesting instance is that of a short junction route with light gauge conductors which the writer unknowingly sited so as to cross a severe lightning area. The route was struck twice in the first two years at approximately the same spot. The second time all circuits were put out of commission, and on both occasions wires were fused, insulators shattered and even arms bent. A 200 lb. iron wire was run in the saddle position over a distance of two miles, bound in intermediately to bare spindles and earthed at each end and at every fifth pole to buried plates. It is now the third subsequent lightning season, but in spite of storms, said to have been the worst for twenty years, there has been no damage to the route and no indication of a direct stroke on any of the circuits.

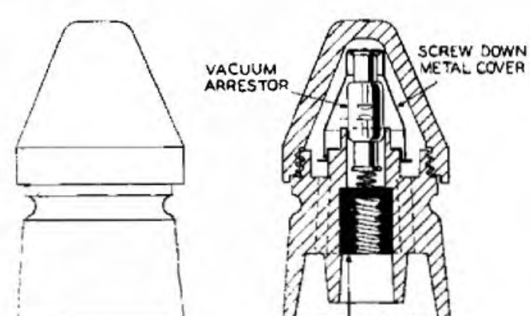

Fig. 5.—Vacuum Tube Protector.

A Voice-operated Relay for Use on Long Distance Private Wires

ALAN FAIRWEATHER, M.Sc., Grad.I.E.E

U.D.C. 621.395.22 : 621.395.648

A description is given of a unit now in service, by which the difficulties frequently encountered in providing calling facilities over emergency long distance private wires have been overcome. Two valves are employed, and operation is possible from all the usual types of A.C. and D.C. supplies having voltages from 50-250.

Introduction.

WHEN long distance private wires are required at short notice, difficulty is frequently experienced in providing calling facilities. It was suggested that, in certain circumstances, calling facilities could be provided by furnishing the subscribers concerned with a voice-operated calling device suitable for operation from all the usual types of A.C. and D.C. supplies having voltages from 50–250.

Two main applications were envisaged, in which the unit would be associated with either an ordinary subscriber's instrument or a P.B.X.

In the first of these, the general operating procedure envisaged was as follows: a subscriber X wishes to call another subscriber Y at a given instant, each being equipped with a voice-operated relay. X lifts his handset and speaks, preferably a prolonged " Hello." On the reception of the signal by the voice-operated relay of Y, a local circuit providing a calling signal is closed.

In the second, the method would depend upon the type of P.B.X. With a cord type P.B.X. the unit would be associated with the termination of a long-distance private wire in such a manner that the equivalent of generator signalling would be provided as far as incoming calls are concerned: the unit would be interposed between the line jack and the calling indicator. A similar method of employing the unit would be adopted with a lamp-signalling P.B.X. In a cordless type, however, the exchange line key does not disconnect the drop indicator; thus, to prevent subsequent re-operation of the unit during conversation, it would be necessary for the operator to disconnect the unit by means of its own key.

Performance Requirements.

Consideration of the field of application of such a device suggested that a unit satisfying the following conditions would be suitable for most purposes. It should be:

(1) Such as to give reliable operation with an input voltage of 0·05 R.M.S. (i.e., an input level of approximately -24 db. with respect to 1 mW in 600 ohms) throughout, and confined to a frequency range of 300-3,000 c/s; means to be provided for adjusting the voltage sensitivity in steps of 6 db.

The frequency range was selected so as to provide some measure of immunity from false operation due to interference. The lower limit of 300 c/s serves to reduce the likelihood of false operation resulting from leaks from power systems, and the upper one of 3,000 c/s serves a similar purpose with respect to carrier telephone systems.

(2) Provided with a time delay of approximately 500 mS, so as to ensure immunity from operation by miscellaneous noises of short duration.

(3) Such that its insertion loss does not exceed 0·5 db.

(4) Furnished with means for closing a local calling circuit on the operation of the unit: this to take the form of a " make " contact brought out to two terminals.

(5) Fitted with a lamp for the purpose of identifying which of several units is operated, the lamp to be an ordinary mains type obtained and inserted on site.

(6) Provided with means for looping a line in order that two such units, situated one at each end of a circuit, may be capable of holding a connection set up via an automatic exchange indefinitely.

(7) Incapable of putting any noise, e.g., mains hum, on a line to which it may be connected.

(8) Suitable for operation from both A.C. and D.C. mains of voltage between 50 and 250.

(9) Simple and cheap: this precludes the use of expensive filter circuits, either to secure the required frequency response or to provide smoothing when A.C. or D.C. mains are employed.

(10) Capable of ready connection to a subscriber's instrument.

(11) Designed for operation in such a manner that no alteration is required to the subscriber's instrument: in particular, the gravity switch must not be called upon to perform any additional switching operations.

General Principles of Design.

Previous experience, together with some preliminary experiments, suggested that the requirements could most conveniently be met by development along the following general lines. The basic circuit of the unit should be a two-valve arrangement, comprising a single stage amplifier driving a relay-operating stage of the positive rectified reaction type.[1] The required frequency response should be produced by a resistance-capacitance filter between the two stages. Operation on A.C. mains should be arranged for by the provision of the simplest possible type of conversion circuit, consisting of a half-wave rectifier and a reservoir condenser, with no further smoothing devices. Since the range of D.C. voltages to be employed greatly exceeds that capable of automatic compensation by any of the usual voltage-stabilising devices, a series voltage-dropping resistance becomes necessary. For simplicity, the same means

[1] *P.O.E.E.J.* Vol. 30, p. 294.

of adjusting the voltage applied to the set in the A.C. case should be used. The valves employed in the unit should preferably be standard types, for which specifications already exist. In view of the experience obtained in the design of the 2 V.F. receivers,[2,3] it was decided to utilise the same pair of valves, namely, VT 100 (Mazda HL 1320) and VT 103 (Mazda Pen 3520).

The circuit of the unit developed in this way is shown in Fig. 1 and will be described in detail in

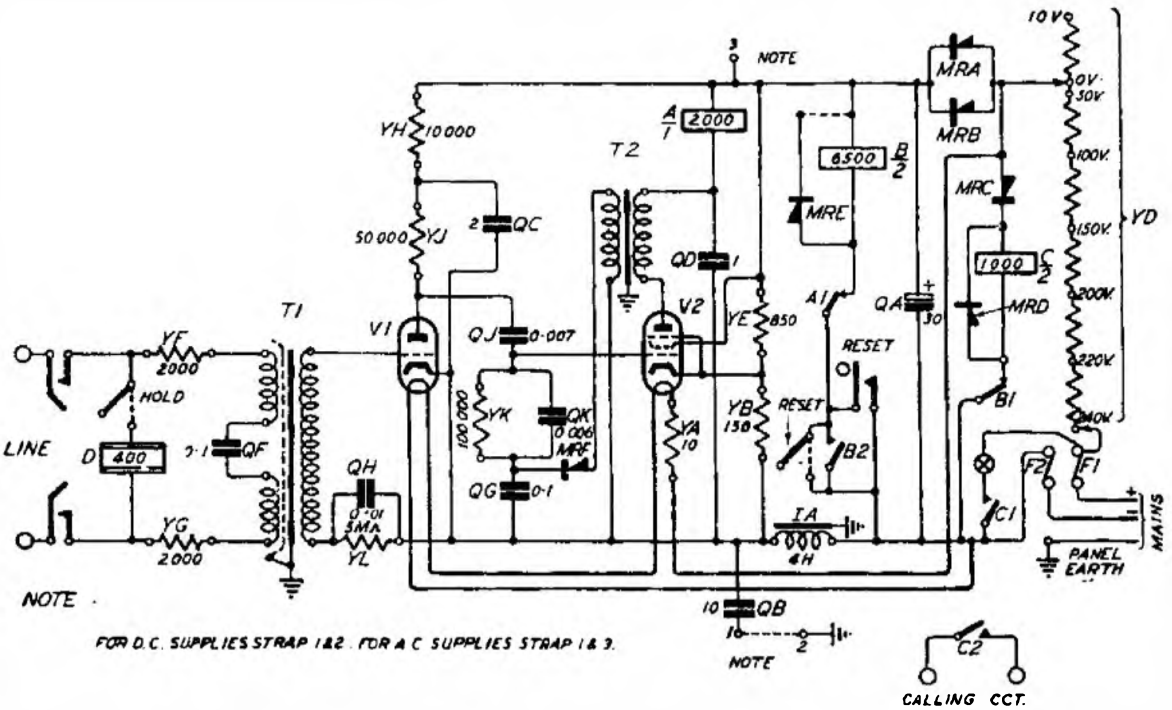

FIG. 1.—CIRCUIT DIAGRAM.

the following section. The unit is known in the Post Office as Unit Signalling No. 5.

Circuit Details.

On the reception of a signal of adequate level, relay A operates and, provided that the call is of long enough duration, releases relay B, which is normally operated via a contact of its own, B2, and a break contact on A, A1. B1 makes, and operates relay C; C1 and C2 make, and operate the indicator lamp and the calling circuit respectively. Under normal circumstances, i.e., when the local calling circuit is of the "non-locking" type, relay B is not self-restoring, and the calling signal continues while B remains released. Means are required, therefore, by which B may be reset; this is achieved by the use of a "reset key," the operation of which short-circuits B2. If the local calling circuit is of the "locking" type, then continued release of B is not required, and it may be made self-restoring by the application of a continued short-circuit to B2; a strap is provided for this purpose. If emergency conditions demand that the private wire be set up via an automatic exchange, provision must be made for looping the line when necessary. Retard D is furnished for this purpose, and may be brought into circuit by a strap.

Relay B is made slow to release, when necessary, by the rectifier MRE; a high resistance relay with rectifier shunt was used in preference to a slugged relay for economy in rectified current. Since the closure of C1 completes the circuit for a mains lamp, it is necessary that relay C should be specially designed, both as regards insulation and contacts: the relay employed is of "3,000" type construction, except that the coil and spring sets are specially insulated, and the contacts are of a heavy duty pattern and made of tungsten.

The first stage is arranged as a grid current limiter-amplifier for two reasons. With such an amplifier the negative bias resulting from an input signal reduces the flow of grid current considerably. Thus, any distortion of sending end speech may be avoided, and performance variations, which would result from the employment of different valves in a high impedance input circuit to a linear amplifier, are reduced.

The signal voltage is applied to the grid of the first valve via an input transformer T1. Series resistances YF and YG are placed in each lead to the primary winding to keep the input impedance as high as possible consistent with adequate sensitivity. The primary winding is split by a condenser QF to prevent the flow of D.C. and to avoid looping the line. The size of this condenser is selected with due regard to sensitivity, input impedance and frequency response. The secondary winding is connected between grid and cathode of the first valve via the parallel combination of resistance and capacitance YL and

[2] *P.O.E.E.J.* Vol. 29, p. 43.

[3] *I.P.O.E.E.* Printed Paper, No. 162.

QH which provides the limiting characteristic. No steady bias is used.

Since no mains transformer is employed, the input transformer forms the sole means of insulating the line from apparatus at mains potential. The insulation and screening of a transformer performing such a function need special attention ; the requirements are laid down in the Department's Engineering Instructions. Otherwise, the transformer is of normal construction : it has a maximum step-up ratio of 1 : 12 with secondary taps to provide a means of adjusting the voltage sensitivity in steps of about 6 db. should this be necessary for noisy lines.

As any loss of sensitivity is to be avoided, the grid circuit of the first valve is necessarily of high impedance ; the input transformer has a high step-up ratio and the resistance component of the limiting condenser and resistance is of large value[4]. Without adequate precautions, the use of such a high impedance input circuit would render the unit unstable and susceptible to false operation resulting from various types of interference—in particular those in which alternating potential differences exist, either between the windings, or between either winding and earth, and cause the flow of circulating currents through the windings, which are of high impedance. If units having much greater sensitivity were required, then it would be found that, even when all reasonable care had been taken to eliminate interference, the combined effect of a small residual disturbance and a high input impedance would be still sufficient to cause false operation. In such circumstances, it would be necessary to reduce the input impedance ; as a first step, the magnitude of the leak resistance might be reduced (and that of the condenser correspondingly increased, so as to retain a suitable value of time constant). If this were found to be not completely effective, then the impedance of the transformer would have to be made smaller.

The input transformer is provided with an earthed screen between primary and secondary windings for several reasons :

(*a*) In the event of the unit being connected to a circuit subject to induced longitudinal voltages then, in the absence of the screen, a circulating current would flow through the interwinding capacitance and leakance to earth. This would result in the injection of a spurious input signal, and so render the unit susceptible to false operation. The screen by-passes such a circulating current from the secondary winding, and so reduces the effect.

(*b*) Under certain conditions, depending upon the type of mains supply employed, an appreciable difference of potential, alternating at ripple frequency, may exist between the primary and secondary windings. This may be caused, for example, by a difference of potential between the set and the mains earths when the common cathode lead is connected to the earthed side of the supply mains. Alternatively, the common cathode lead may not be connected to the earthed side of the supply mains. Such a state of affairs may exist when the set is operated from A.C. mains and connected in such a way that the " positive " of the set is wired to the " neutral " of the mains ; or again, when the set is operated from the positively earthed side of a 3-wire D.C. system. In any of these conditions, in the absence of a screen, a circulating current would flow as before, and would result in noise being fed to the line. The screen again by-passes this current—this time from the primary winding. But the current still traverses the secondary winding, and produces a spurious input signal. The reduction of this effect will be dealt with later.

(*c*) In the unlikely event of insulation breakdown, the mains are earthed, and the failure makes itself apparent by the blowing of a fuse instead of possible personal injury.

The first stage is coupled to the rectified-reaction stage via the resistance-capacitance network comprising resistances YJ and YK and condensers QJ and QK. The size of YJ was selected to be the optimum value for a supply voltage of 50 ; the series condenser QJ controls the low frequency response, and the shunt condenser QK the high frequency response. Condenser QG serves the twofold purpose of completing the output circuit of the coupling network, and behaving as a feedback condenser for the rectified-reaction stage. Resistance YH and condenser QC decouple the first stage and its associated coupling network from the considerable ripple voltage which is present when A.C. or D.C. mains are used. In the absence of these components, there would be sufficient ripple voltage applied to the rectified-reaction stage to trigger it without any additional input signal. Transformer T2 and rectifier MRF provide positive rectified-reaction in the usual manner. Relay A and condenser QD afford some measure of decoupling and smoothing of the supply to valve V2. The steady bias to V2, the nominal cut-off of about 7V, is provided by resistance YB which, together with YE, forms a potential divider across the supply.

Resistance YA is a voltage-dropping resistance, and ensures that the heaters are supplied with their nominal voltage of 48 for the two in series.

Condenser QA is the reservoir condenser for the rectified voltage produced by the voltage dropping resistance YD and the rectifiers MRA and MRB. Two rectifiers are used, instead of one, in the interests of reliability, the nominal rating of rectifiers of this type being only 50 mA. This current is drawn by the potential divider alone, and relays A or B, which operate alternately, need providing for. The mean value of the supply voltage depends on the magnitude of QA ; the smaller the value of QA the further the mean value of the supply voltage falls below its peak value. The size selected ensures that the mean voltage is approximately 50 and permits the one set of taps on YD to be used for both A.C. and D.C. supplies.

It has been pointed out that, under certain cir-

[4] *The Wireless Engineer.* Vol. 16, p. 330.

cumstances, the full mains voltage appears between the secondary winding and the earthed screen of the input transformer, and a circulating current of ripple frequency flows, via the common cathode lead and the screen-to-secondary winding capacitance and leakance, to earth. If this circulating current traverses any impedance present in the grid-cathode loop of the first valve, then an alternating voltage is injected into this loop, and this is equivalent to the application of a constant spurious signal to the valve. If the supply is A.C., then the frequency of the signal is 50 c/s. Fortunately, this frequency is well outside the normal operating range of the unit, but it may still be possible for the limiter condenser to acquire a large steady negative bias which will reduce the sensitivity of the unit considerably. If the supply is D.C., derived from A.C. by the usual form of converter, the fundamental frequency of this spurious signal will be 300 c/s and serious trouble is to be expected. Thus every effort must be made to reduce the magnitude of any injecting impedance present in the grid circuit of the first valve to negligible proportions.

Accordingly, the secondary of the input transformer is wound in such a way that the cathode end is nearest to the screen so that the circulating current to the screen does not traverse the impedance of most of the secondary winding. Similarly, the condenser and resistance required for limiting purposes should be placed in the grid side in preference to the cathode side of the secondary winding. Experiment showed that the observation of this latter precaution made very little difference; these components were, therefore, left in the cathode lead since this was the most convenient position from a wiring point of view.

Consideration of methods for the reduction of the interference suggests that the insertion of the usual type of mains filter (consisting of series inductance and shunt capacitance between the rectified supply and the set) would afford only a partial remedy as a result of the presence of the power rectifier and the mains dropping resistance. The most effective cure is the decoupling of the common cathode lead to earth by means of a suitable series inductance and shunt capacitance; choke IA and condenser QB are provided for this purpose. It is not desirable to leave the condenser permanently connected to earth on account of the large current which would flow if the unit were connected to the A.C. mains "live to negative." Thus, adequate interference suppression is not readily obtainable under such conditions, and appropriate "poling" of the supply is required. As an additional precaution when A.C. mains are employed, the earth lead to the condenser should be either disconnected or, preferably, transferred to the common anode supply lead. A strap is furnished to enable this to be done.

Construction.

The general appearance of the unit may be ascertained from Fig. **2**. It is accommodated in a metal box 14¼ in. × 9⅜ in. × 4¼ in. The alarm lamp and the handles of the "Line" and "Reset" keys project through the top of the detachable cover. The base is furnished with rubber feet, the fixing screws of which may be otherwise employed for attaching the units in pairs to mounting bars on a repeater type rack.

Performance.

Frequency Response and Corresponding Specification Limits.—The behaviour of a typical unit, when connected in parallel with a resistance of 600 ohms and fed by a generator of internal resistance 600 ohms, is shown in Fig. **3**. The testing conditions were

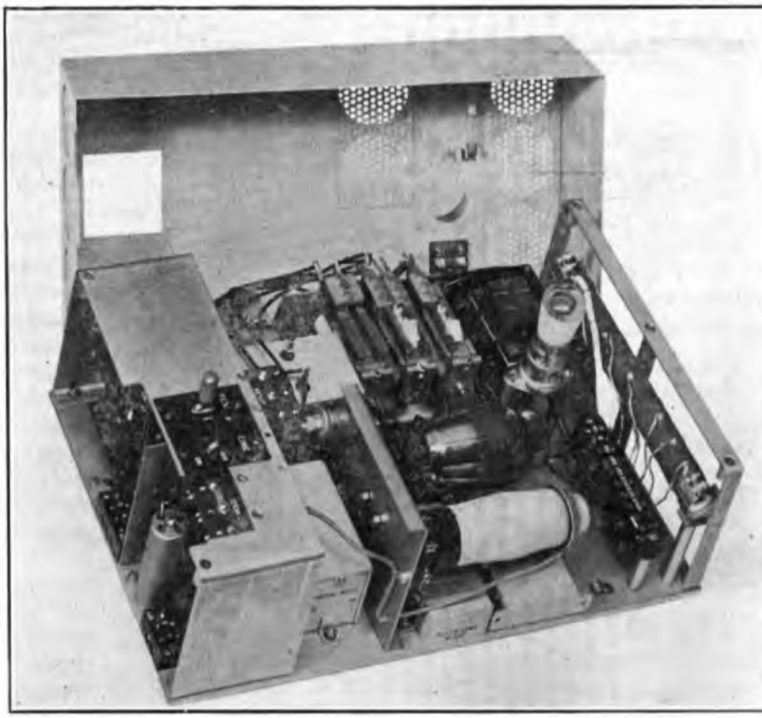

FIG. **2**.—UNIT SIGNALLING NO. 5.

such that the input signal at any given level was applied as nearly instantaneously as possible, i.e., by the operation of a switch and not by the gradual removal of loss in an attenuator; the results obtained depend, to a small extent, upon the testing method adopted. It may be seen that, over the required operating range of 300–3,000 c/s, the sensitivity is of the order of 30 db. below 1 mW in 600 ohms. Under practical conditions, however, the unit would be connected to an open-circuited line, and the sensitivity would be increased by a further 6 db., i.e., to 36 db. below 1 mW in 600 ohms.

It was considered that the most satisfactory method of describing the behaviour of the unit would be to fix limiting positions for the location of three characteristic points on the response curve.

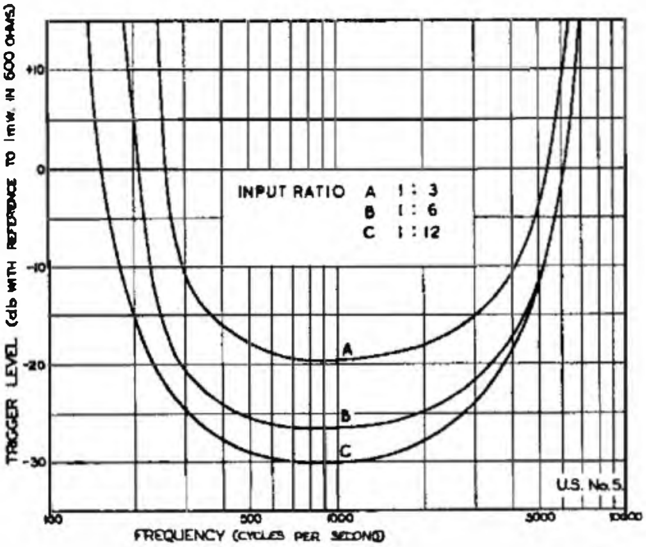

FIG. 3.—VARIATION OF TRIGGER LEVEL WITH FREQUENCY AND INPUT TRANSFORMER TAP FOR INSTANTANEOUSLY APPLIED SIGNALS.

Those selected were the two points of intersection with the " zero level " axis, and another situated somewhere within a frequency range throughout which the trigger level remains sensibly constant—say 800 c/s.

Accordingly, the above three points were determined in this way for each of a number of laboratory and manufacturer's units, and the following limits decided upon :

Lower " zero level " trigger frequency (c/s) .. .. :	250 $\mp$ 100
Upper " zero level " trigger frequency (c/s) .. .. :	5500 $\mp$ 1000
800 c/s trigger level (db. below 1mW in 600 ohms) .. .. .. :	28 $\mp$ 3

Insertion Loss.—Over the required operating frequency range the insertion loss varies between approximately 0·25 and 0·33 db.

Surge Immunity and Time Delay.—In laying down the original requirements for the unit, it was assumed that a time delay was essential to secure immunity from false operation due to surges. In the normal mode of use, such surges may result from flicking the subscriber's gravity switch ; or again, when the unit is employed on a P.B.X. in the position usually occupied by the calling indicator (i.e., across the inner springs of the answering jack), a surge may occur on the insertion of the operator's plug, since the effect of this operation is a complete disconnection of the unit.

In general, such voltage surges consist of an initial peak followed by a highly damped oscillation. The frequency of this oscillation depends on all the associated apparatus, and may, possibly, lie within the normal operating frequency range of the unit. In such circumstances, in the absence of a time delay, false operation would be quite likely.

The provision of such a delay, however, reduces the apparent sensitivity of the unit to a subscriber, on account of the greater vocal energy which has to be expended. Thus, it is desirable to ascertain to what extent the unit is immune from false operation by surges, if most of the time delay is removed by disconnecting the rectifier across relay B. Accordingly, tests were carried out in which the unit was subjected to surges of a type corresponding to those produced by the opening and closing of a called subscriber's loop. No false operations of relay A could be obtained, and it was concluded, therefore, that the unit was reasonably surge immune, even without a time delay. Therefore, it was decided to make the provision of a time delay on relay B optional by a strap in series with the shunt rectifier. The operate lag of the unit with the rectifier in circuit is of the order of 360 mS : with the rectifier disconnected, it is of the order of 100 mS.

Effect Upon 17 *c/s Ringing.*—Experiment showed that the unit has no appreciable shunting effect on 17 c/s ringing.

Behaviour with Low Supply Voltages.—Certain applications of the unit rendered it desirable to obtain some idea of that minimum supply voltage at which the unit first fails to satisfy specification requirements. The significant variables are the valves, and variations in their behaviour arise from two main sources : first, from differences in the electrode structure, in particular the emitting quality of the cathode ; and, secondly, from the heater element. The voltage required to produce the rated heater current for a given type of valve varies with the sample used. Thus a set might be encountered employing two valves which possess not only cathodes such that the anode current figures are the poorest allowable, but also heaters requiring the maximum permissible voltage. For experimental purposes a pair of valves was used which simulated a worse than average case : the anode current figures were poor, but the heater voltages average. Using these, it was found that, as the supply voltage was lowered, the upper and lower " zero level " trigger frequencies approach one another, and the band-width decreases, whereas the 800 c/s trigger level increases. Since the tolerances on the former are comparatively wide, failure to satisfy specification requirements occurs as soon as the 800 c/s trigger level exceeds − 25 db. In the unit tested, this took place at about 38 V, i.e., a permissible drop of 12 V. This was considered more than adequate for all practical purposes.

Effect of Overheating resulting from Prolonged Operation with Inadequate Ventilation.—Experiment showed that, provided the paper wrappings are removed from the rectifiers—in particular the power rectifier (MRA and MRB)—then prolonged running with the main grille closed may result in an increase of trigger level of about 1·5 db. Under normal circumstances, with the grille open, no appreciable change is to be expected.

Distribution of Power in 2,000-Type Exchanges

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U.D.C. 621.395.64 621.311.8 : 621.395.722

Particulars are given of the new standardised bus-bar system of distributing power to the apparatus racks in 2000-type telephone exchanges.

General.

THE supply of power to the apparatus employed in automatic telephone exchanges requires a distribution system which must be carefully designed in every detail if it is to be safe and economical. There are, in addition, certain over-riding requirements of the Post Office which must be met. These are :—

(*a*) The potential drop in the feed and return combined must not, under full load conditions, exceed 1 volt.

(*b*) The system must be fully protected, and

(*c*) Alarm arrangements which fit in with the general alarm system of the exchange must be provided.

In general, the various systems which have been employed consist of a main feed from the power board to the apparatus rooms (the cross sectional area of this feeder, of course, depends upon the load to be carried and varies from exchange to exchange) ; in the apparatus rooms the feeder takes the most convenient route for branches to be made from it to feed suites of racks (Fig. 1) ; from these there are further branches which feed the bus-bars of the rack fuse panels to which the apparatus is wired. At convenient points as the load decreases the cross sectional area of the feed is reduced, the reduction being made at each branch.

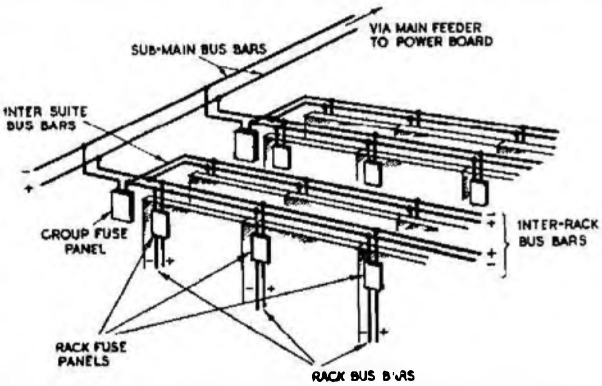


FIG. 1.—GENERAL SCHEME OF POWER DISTRIBUTION.

In exchanges of the pre-2,000 type, contractors were permitted to install distribution plant to their own design provided this plant conformed with the over-riding requirements quoted above. As a consequence it will be found that a variety of designs has been used. In some exchanges the distribution system consists entirely of cable, in others bus-bars are used throughout, whereas others have a combination of bus-bars and cable.

With the development of the 2,000-type selector and the concurrent standardisation of apparatus racks and the layout of equipment on these racks, it was decided that the design of the power distribution system should also be standardised. This has now been accomplished as far as the apparatus rooms are concerned, bus-bars being adopted as the standard means of distributing the power. These are classified as follows :—

(*a*) *Sub-main bus-bars.* These are connected by main feeder to the power board and are situated in main aisles of the apparatus room in such a position as to enable branches which feed suites of racks to be conveniently connected.

(*b*) *Inter-rack and inter-suite bus-bars.* These respectively feed the racks in a suite and connect the inter-rack bus-bars when more than one suite of racks is served from a single tee off the sub-main bus-bars.

(*c*) *Rack bus-bars.* These form part of the apparatus racks and it is to these that the rack fuse panels are directly connected.

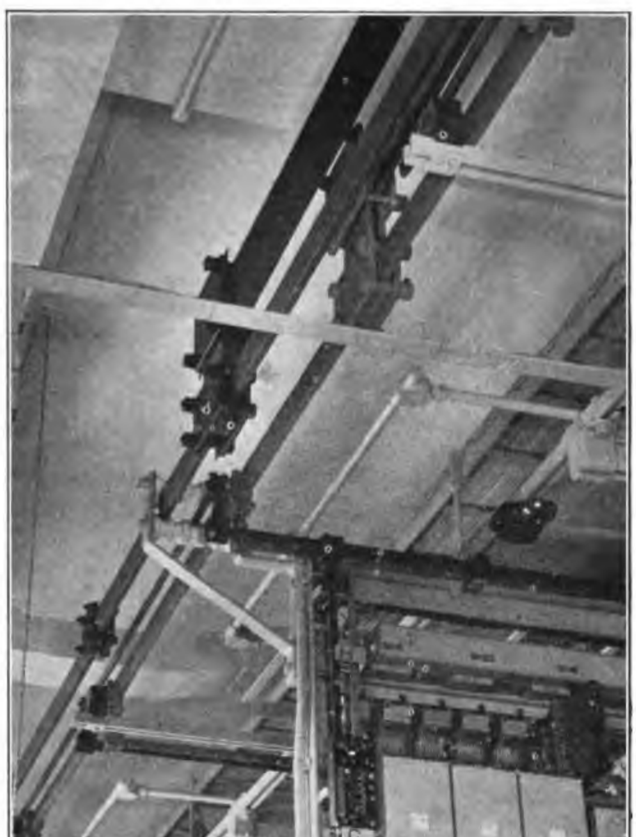


FIG. 2.—CONNECTION OF MAIN FEEDERS TO SUB-MAIN BUS-BARS.

Detailed piece part and assembly drawings have been prepared and the methods to be adopted by the contractors are specified in such a way that all 2,000-type installations will have the same type of equipment, method of assembly and general lay-out, no matter which contractor is responsible for the work. The scheme adopted is that one standard size of rack and one of inter-rack bus-bar are used, and one of three standard sizes of sub-main bus-bar. The size of the main feeder is varied so that the overall voltage drop at full load does not exceed the limit of 1 V. A brief description of the parts employed in this standard system is given in the following paragraphs.

Sub-Main Bus-bars.

The sub-main bus-bars which form the first links in the apparatus room distribution system are connected by feeder (Fig. **2**) to the power board and from there to the 50 V supply and earth. These bus-bars are made of copper and have a rectangular cross section. They are installed in the apparatus room in such a position as to allow the smaller gauge bus-bars which feed the racks in a suite of racks to branch off at the ends of the suites. Owing to the varying sizes of exchanges, there are three standard sizes of cross section for these bus-bars viz., 2 in. by $\frac{1}{4}$ in., 2 in. by $\frac{3}{8}$ in. and 2 in. by $\frac{1}{2}$ in.

The bus-bars are supported on the end of each of the suites of racks which they serve. An assembly which consists of a porcelain insulator and bracket, as shown in Fig. **3**, is used for this purpose. In this

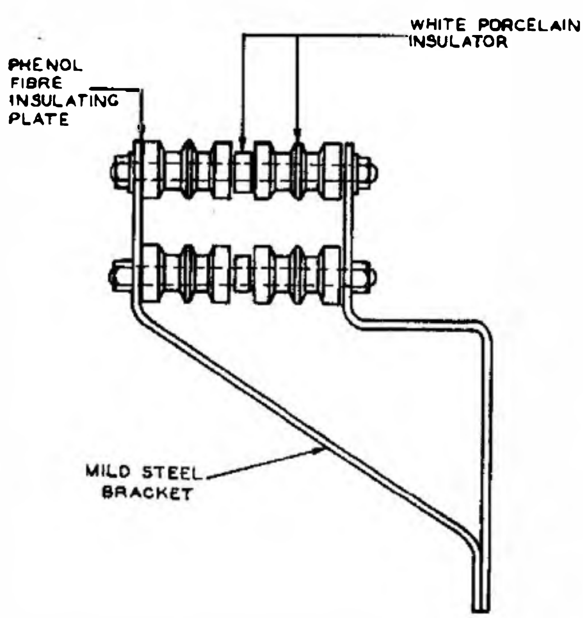


Fig. **3**.—Supporting Bracket for Sub-Main Bus-bars.

way a rigid structure is ensured. When a suite is not installed in the early part of the life of an exchange, floor supports may be required to support the bus-bars between the equipped suites. If the distance is not too great, however, these supports may be dispensed with but bus-bar spacers must be fitted at the points at which the bars would normally be supported.

Inter-Suite and Inter-Rack Bus-bars.

The smaller gauge bus-bars which branch off the sub-main bus-bars are also made of copper. They have a rectangular cross section, $\frac{3}{4}$ in. by $\frac{1}{4}$ in., and are supported by an assembly of insulator and bracket (Fig. **4**) which is fitted to the underside of the rack overhead ironwork or superstructure.

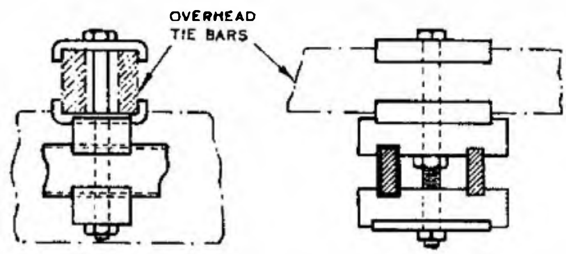


Fig. **4**.—Inter-Rack Bus-bar Supports.

Details of the support and the method of attachment to the overhead ironwork may be seen from Fig. **5**. The members of the overhead ironwork to which the supporting brackets are attached are spaced at intervals not exceeding 2 ft. 6 in.

When more than one suite of racks is served from one branch off the sub-main bus-bar, the inter-rack bus-bars project at the supply ends of the suites served, and these are connected by inter-suite bus-bars. The inter-suite bus-bars are short lengths of copper of the same cross sectional area as the inter-rack bus-bars.

Rack Bus-bars.

The inter-rack bus-bars pass over and slightly in front of the apparatus side of the racks in a suite and so enable the rack bus-bars which are fitted to the left-hand vertical of each rack to be easily connected. The rack bus-bars are made of copper and have a matt nickel finish. They are rectangular in cross section, the dimensions of the cross section being $\frac{1}{2}$ in. by $\frac{3}{4}$ in.

A feature of the rack bus-bars is the provision of holes which are drilled and tapped at half-inch centres over the whole of the length of the bars. The studs which secure the fuses in the rack fuse panels are screwed into these holes. The fuses, therefore, make direct contact with the bus-bars and the fuse panels can be mounted at any point over the length of the bars. It is thus very convenient to mount a fuse panel opposite the shelf of apparatus to which the associated fuses are connected.

Bus-bar Joints.

With the exception of those made by the inter-rack bus-bars to sub-main bus-bars, all connections whether for the purpose of extending or branching are made by directly clamping together the bars to be joined. For this purpose zinc-plated steel clamps

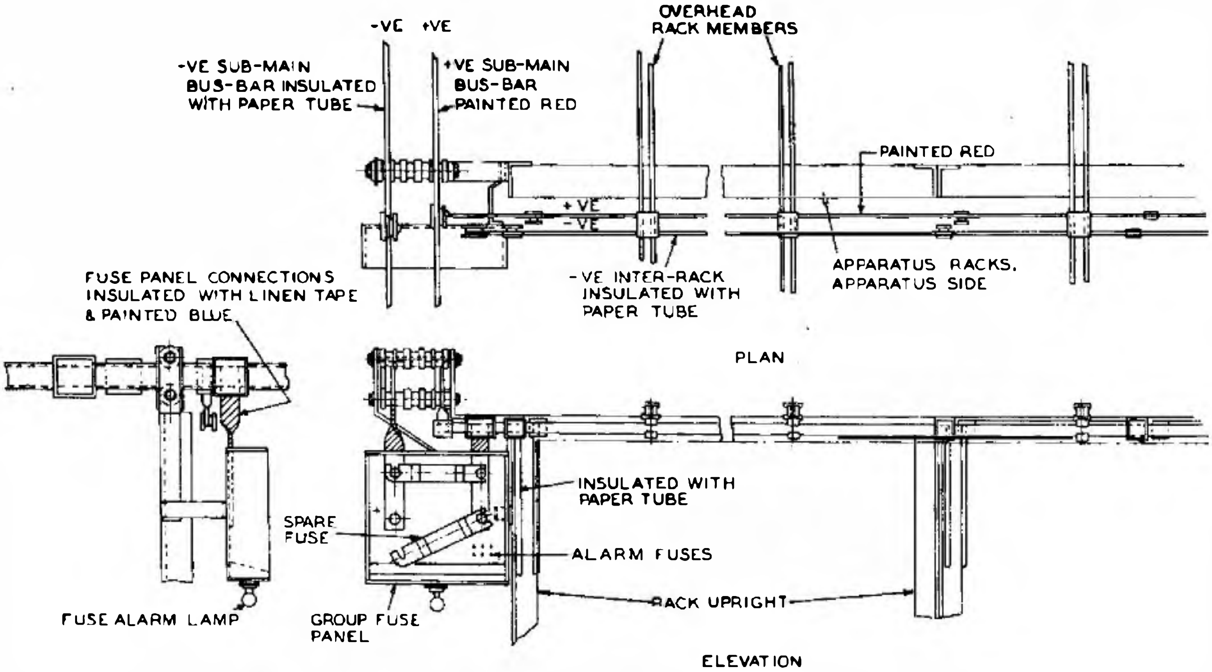


FIG. 5.—GENERAL LAYOUT OF INTER-RACK AND RACK BUS-BARS.

ith phenol fibre insulation are provided. Illustrations f lap, butt, and tee joints are given in Fig. 6.

roup Fuses.

The connection betwcen the inter-rack bus-bar nd the sub-main bus-bar may be either direct as escribed in the previous paragraph or via a group ise. The size of the battery is the factor which ifluences the provision of this fuse. Group fuses are tted when the box capacity of the exchange battery xceeds 500 ampere hours. A fuse is fitted at the ource of supply, but this is included in the circuit rimarily to protect the battery, and it is considered hat it would not provide adequate protection for the ıs-bars on the racks in the larger exchanges. The rated current of the group fuse is 125 amperes and is chosen to safeguard the rack bus-bar which is 0·125 square in. in cross section.

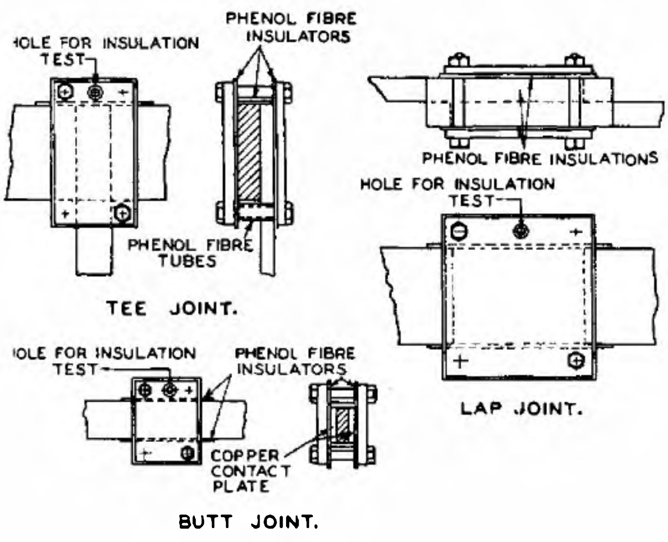


FIG. 6.—BUS-BAR JOINTS.

Group Fuse Panels.

The group fuses (see Fig. 7) are of the cartridge type and are housed in a box-like panel made of phenol fibre. Each panel houses two group fuses one in circuit and the other spare. The spare one is held by two wing nuts in such a position that it can be moved into the working position with the minimum of trouble and loss of time. There is also accommodation on the panel for alarm-type fuses of low capacity and an alarm lamp.

Rack Fuse Panels

As mentioned earlier in this article, rack fuse panels may be fitted in any position over the length of the rack bus-bar. This condition is effected by the shape of the fuse panel which is a black bakelite-moulded item designed in such a way as to fit in front of the bus-bar and yet expose the front face of the bar. Front and back views of a typical rack fuse panel are shown in Fig. 8. Although all rack fuse panels are designed on the same basic principles, they vary in respect of the number of fuses that can be accommodated and also in respect of alarm facilities, an alarm bar common to all the fuse positions or individual alarm studs being fitted as required.

Covering for Bus-bars.

Bus-bars have a protective or insulating covering of a distinctive colour. Earth bars, except rack earth bars, are painted red (BSS No. 381, Colour No. 38); no covering is provided on rack earth bars.

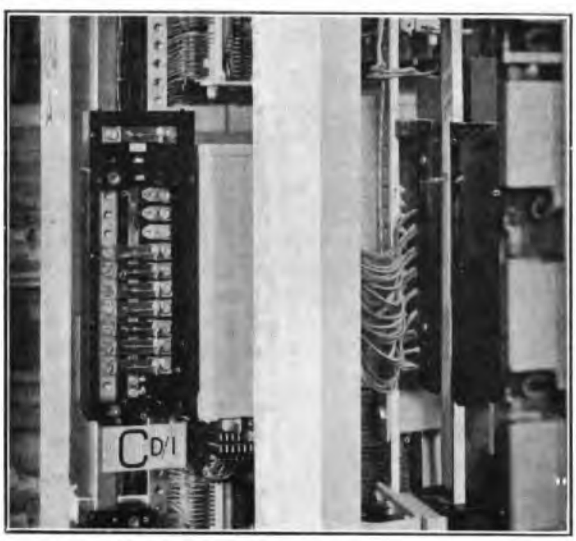
All negative supply bus-bars have a blue covering

(BSS No. 381, Colour No. 4). That of the sub-main negative bus-bar is a tube of manilla paper reinforced with bookbinders' cloth. The inter-rack, inter-suite and rack bus-bars also have a covering of manilla paper tubing: there is no reinforcement in this tubing but it is specified that it shall be untearable. The side of the tubing is removed over the portions of the rack bus-bars which form the negative side of the rack fuse panels.

The manilla tubing is supplied in standard lengths and special steps are taken to ensure that the bars are protected at junctions of the lengths. For example, on rack bus-bars it is required that the junctions shall be in the clamps which secure the bars to the rack uprights.

In certain instances it has been found necessary to fit positive battery bus-bars on apparatus racks. The usual position for these is on the lower part of the rack in line with the negative battery bus-bars and secured in a similar manner. The covering of these bars is of manilla paper tubing coloured blue as for the negative battery bar but with a narrow red line 3/16 in. wide painted centrally down its front face.

FIG. 7.—GROUP FUSE PANEL AND INTER-RACK AND RACK BUS-BARS.



FRONT VIEW. REAR VIEW.

FIG. 8.—RACK FUSE PANEL.

Conclusion.

The arrangements outlined in this article cater for the requirements, so far as power distribution in apparatus rooms is concerned, for the great majority of exchanges. The arrangements to be adopted in the very large exchanges, where the use of the standard sizes of bus-bars is insufficient to meet the load and potential drop requirements, is at present under consideration.

The standardisation of the main feeders from the apparatus room to the power room is also being considered. There must, however, be a greater variation in the sizes of main feeders since the distance between the power and apparatus rooms, as well as the total load, varies considerably from exchange to exchange, and under the scheme outlined the main feeder forms the principal variable link to adjust the potential drop to the furthest point in the exchange under full load conditions to be not greater than 1 volt.

In conclusion the author wishes to thank Messrs. Automatic Telephone & Electric Co., Ltd., for the supply of the photographs illustrating this article.

Carrier Frequency Synchronisation

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It is becoming increasingly important that transmission channels produce at the output exactly the same frequency as that applied at the input. Most carrier systems have until recently used free oscillators to generate the carrier frequencies, but it is now proposed to synchronise rig'dly all carrier oscillators so that there shall be no frequency error at all. This article describes the theory of synchronisation methods, and points out some of the difficulties met with and also the design considerations.

Introduction.

FOR many years most carrier systems in this country have worked with free oscillators as the source of supply of the carrier frequencies. In single channel systems, and systems in which no high carrier frequencies are used, this has generally been found satisfactory enough for ordinary speech, though the operation of V.F. telegraph circuits on such systems has sometimes been troublesome. In multi-channel systems using fairly high carrier frequencies,[1] e.g., the 12-circuit systems, special precautions have been taken to reduce the possible frequency errors, and the equipment of one manufacturer is supplied complete with a system of synchronising the carrier frequencies at the two terminal stations. Carrier synchronisation is also employed on the coaxial cable carrier system.[2]

2 V.F. signalling is now being introduced on trunk routes, and the operation of this signalling system requires a very much greater frequency stability than free oscillators can give reliably. Therefore it has been decided to synchronise all carrier systems in the country. There are several methods by which this may be done, and these have been investigated by the Post Office with a view to determining the most suitable method for the different carrier systems. All methods of synchronisation, however, depend on a transmitted pilot signal which must control the frequencies generated at the terminal stations.

One of the chief considerations in the use of a pilot signal transmitted over a working transmission system is that of disturbance due to noise and other signals on the line. This is explained fully in this article, but it should be noted at this stage that the problem has not been found very severe in practice.

In some of the work described, co-operation has been obtained from the Standard Telephones & Cables Co. and the General Electric Co. The opportunity is taken here to acknowledge this co-operation.

METHODS OF SYNCHRONISING

Two general methods of synchronisation are available : (*a*) direct locking of the oscillator by an injected synchronising tone, and (*b*) synchronisation of the oscillator by a mechanical (motor) control of the resonant circuit. The following paragraphs describe ways in which these may be applied in practice.

Straightforward Direct Locking.

The simplest method of locking an oscillator is to inject the locking tone into the grid circuit of the oscillating valve. This can be done, for example, by connecting a resistance in series with the coupling coil, and feeding the locking tone across this. Fig. **1**

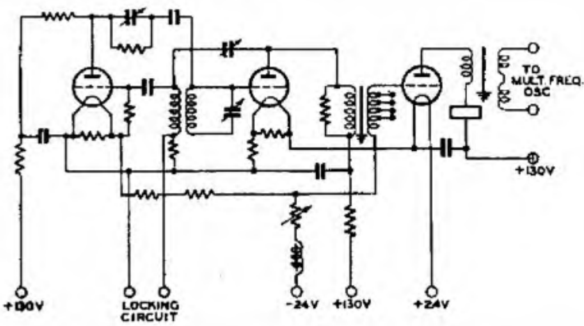

FIG. **1**.—4 KC/S MASTER OSCILLATOR.

shows a particular multi-channel carrier system master oscillator (4 kc/s) with such a locking circuit.

The requisite magnitude of the locking tone is determined by the largest difference likely to arise between the natural frequency of the oscillator and that of the locking tone (or " pilot " tone). A greater voltage of pilot is required to pull the oscillator in from a greater frequency difference ; the measured locking characteristic of the oscillator mentioned above is shown in Fig. **2**. The stability

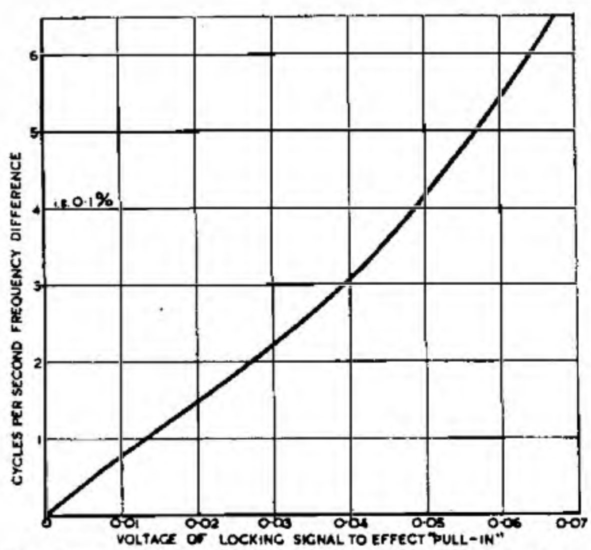

FIG. **2**.—LOCKING CHARACTERISTIC OF 4 KC/S MASTER OSCILLATOR.

of an oscillator of this type is generally about 25 parts in 10^6 per 1°C. as far as temperature is concerned ; the effect of battery voltage variations is generally negligible. Thus, in practice, if a tempera-

[1] In this article, the expression "carrier frequency" means the *virtual* channel carrier frequency where more than one stage of modulation is used.

[2] *P.O.E.E.J.*, Vol. 30, p. 276.

ture variation of 20°C. may be expected, a variation of natural frequency of about 0·05 per cent. must be provided for. Actually, to provide an ample margin against variations that may occur due to bad adjustments, sufficient pilot is injected to pull in from a difference of $\pm$ 0·1 per cent. or $\pm$ 4 c/s.

Special Circuits for Direct Locking.

In connection with a scheme of synchronising incorporated in a certain 12-circuit carrier system, a special locking circuit arrangement had been developed employing rectifier networks which so distort the locking signal that only the peaks are left. It had been anticipated that this would result in less disturbance due to line noise. Tests carried out to compare this system with the direct injection of a sine wave locking signal indicated, however, that the special circuit gave no improvement, and was indeed generally less satisfactory than the simpler method.

Direct Injection of a Pilot Tone Modulated with a Harmonic of the Local Oscillator.

A further system of synchronisation which has been tried out uses a 60 kc/s pilot tone which, at the receiving terminal, is modulated with the 14th harmonic of the local 4 kc/s oscillator. If this oscillator has a natural frequency of $4 + \triangle$, where $\triangle$ is the frequency error, then the 14th harmonic is $56 + 14 \triangle$ The result of modulating this with 60 kc/s is $4 - 14 \triangle$ (lower sideband). This tone of $4 - 14 \triangle$ is now injected into the local oscillator as a locking signal and tends to pull the local oscillator frequency in such a direction as to reduce $\triangle$. The smaller $\triangle$ becomes, the stronger the pull-in action, so that the oscillator finally locks to an exact 4 kc/s, i.e., $\triangle = 0$. It is found, in practice, that the locking characteristic of an oscillator locked in this way is almost identical with the characteristic obtained when the oscillator is locked by a constant 4 kc/s tone, both characteristics being expressed in terms of $\triangle$.

Electromechanical (Motor) Synchronisation.

The transmission of a pilot tone may be affected by an effect known as flutter. This is the term given to momentary variations in the transmitted pilot frequency caused by interference from noise at frequencies close to its own, or by other signals if intermodulation occurs and sidebands fall close to the synchronising signal in the frequency range. The effect on the synchronising signals, which is examined in more detail later in the article, may be serious and can be reduced by employing a synchronising system having a large inertia. Systems employing either mechanical or electrical inertia arrangements have been tried.

In one electromechanical synchronising system a received pilot tone of 60 kc/s is modulated with either the 14th or 16th harmonic of the local 4 kc/s oscillator. If the actual frequency of the local oscillator is $4 + \triangle$ then the wanted modulation products will be either $4 - 14 \triangle$ or $4 + 16 \triangle$. This frequency is applied to a pair of frequency changers. One of these frequency changers has applied to it a carrier frequency of $4 + \triangle$ obtained directly from the oscillator, while to the other, the $4 + \triangle$ supply is applied via a network which gives it a phase shift of $\pi/2$ radians. The wanted output frequencies of each of the frequency changers will be $\pm 15 \triangle$ but with a phase difference of $\pi/2$ radians. If these currents of equal frequency but of $\pi/2$ radians phase difference are applied to the poles of a small synchronous motor, a rotating field of velocity $2\pi \times 15 \triangle$ radians/second will be set up and the rotor revolved. To this rotor is geared the shaft of the variable condenser of the 4 kc/s oscillator circuit, and the direction of rotation can be so arranged that the condenser is adjusted towards the point at which $\triangle = 0$. When $\triangle = 0$ the field produced in the motor is stationary, and the output of the 4 kc/s oscillator is at the correct frequency.

Flutter effects cause small irregularities in the velocity of the rotating field, but by reason of the inertia of the rotor of the synchronous motor these will not seriously affect the frequency generated by the 4 kc/s oscillator.

A particular advantage of this arrangement is that in the event of failure of the "pilot" there is no tendency for the controlled oscillator to drift suddenly from the correct frequency.

Electrical Synchronisation Equivalent to the Motor System.

It is possible to use an electrical circuit to provide a synchronising system of high inertia. Such a system has been tried out. It provides frequency control of an oscillator by varying the feedback resistance by using a valve impedance in parallel with the normal resistance. The valve impedance is varied by the rectified but unsmoothed (if slow) beat frequency, which is applied to the grid, and is derived from the pilot and local frequency in a manner corresponding to that described in the previous paragraph. The valve impedance thus varies according to the beat frequency, the oscillator frequency varies with the valve impedance, and consequently the beat frequency itself is changed. Provided the direction of the changes is correct, the result is a stable condition in which the oscillator is held at the pilot frequency. The inertia of the system is made high by inserting a resistance-capacitance combination of high time constant in the grid circuit of the control valve; a relay contact operated by the pilot tone arranges that, in the event of an interruption of the pilot, the condenser alone is left connected to the grid of the control valve, and thus the oscillator frequency will remain steady until the charge leaks away; in this way the chief features of the motor control system are reproduced.

The Mechanism of Locking

Since so many synchronising systems depend on the injection of a locking tone into the oscillator circuit, a brief consideration is given here of the manner in which this locking takes place.

Basic Oscillator Circuit.

The basic circuit of a feed-back type of oscillator is shown in Fig. 3. E_g is the alternating voltage between grid and cathode. E_u is the voltage induced in the tuning circuit L, C, R from the anode circuit. E_c is the voltage across the condenser C. E_L is the injected locking voltage.

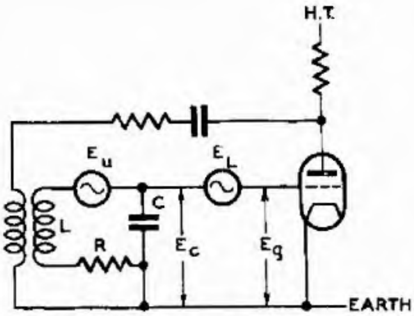

FIG. 3.—BASIC FEEDBACK OSCILLATOR CIRCUIT.

Consider first the condition of free oscillation, i.e., $E_L = 0$. Measuring magnitudes of E_g and E_u along co-ordinate axes OX and OY respectively, E_u is plotted against E_g, giving a curve, as shown in Fig. **4a**, owing to the non-linearity of the valve characteristic. If E_c is plotted against E_u, values of E_c being measured along OX, a straight line is obtained since E_c is the voltage developed across one element of a linear circuit containing an E.M.F. E_u. Now if E_c and E_g are to be equal, as they clearly must be since $E_L = 0$, the straight line and the curve must intersect in some point remote from O, otherwise oscillation will not take place. The position of the point of intersection determines the magnitude of the oscillatory voltage E_g. If $\omega_o/2\pi$ is the frequency at which free oscillation takes place, then the phase difference between E_u and the oscillatory current is given by $\tan\phi_o = \dfrac{\omega_o L - 1/\omega_o C}{R}$ which is, in general, not zero. The voltage E_c, and so, for the present case, E_g also, is always in quadrature with the oscillatory current. Let AB (Fig. **4b**) be

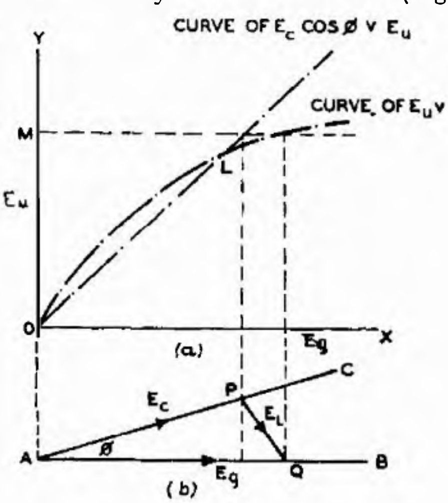

FIG. 4.—DERIVATION OF THE VECTOR DIAGRAM FOR OSCILLATOR.

taken as the direction of the vector E_g. If now the oscillator is forced to oscillate at a different frequency, $\omega/2\pi$, the phase difference between E_u and the oscillatory current becomes ϕ_1 where $\tan\phi_1 = \dfrac{\omega L - 1/\omega C}{R}$. Since the phase relation between E_u and E_g is unchanged, there is now a phase difference ϕ between E_c and E_g where $\phi = \phi_1 - \phi_o$. The direction AC of the vector E_c in Fig. **4b** can now be indicated.

It is convenient to arrange that point A of the vector diagram is in line with OY and to replot the straight line graph to represent the relation between $E_c \cos\phi$ and E_u. Let the intersection of this line with the curve be L. If a horizontal line through a point M on OY is drawn to cut the curve and straight line above L, and from the point of intersection with the straight line a perpendicular is dropped to the E_c vector line at P, and from the point of intersection with the curve a perpendicular is dropped to the E_g vector line at Q, then complete vectors $E_c = AP$ and $E_g = AQ$ are obtained corresponding to a certain value of E_u. It is evident that to lock the oscillator stably in this condition at this frequency $\omega/2\pi$, it is necessary to add a locking vector $E_L = PQ$ to complete the vector triangle.

If less locking voltage than that corresponding to PQ is injected, then the E_c and E_g vectors adjust themselves to a smaller value, and OM becomes smaller. When the horizontal line passes through L, the vector E_L is vertical. If the horizontal line passes below L, then the vector E_L actually opposes E_c and E_g, so that locking obviously cannot take place. Therefore the vertical position of E_L represents the pull-out point, and here the locking voltage injected is 90° different in phase from the oscillatory voltage E_g. The magnitude of E_L at this point is the locking voltage required to pull the oscillator in from its natural frequency to a frequency $\omega/2\pi$.

If the diagram is drawn for different values of ω, then a curve can be obtained showing locking voltage against the difference between the locking frequency and the natural frequency of oscillation of the oscillator.

Locking Characteristics in Practice.

It has been shown above that if the constants of the oscillator elements are known, a locking characteristic can be drawn. A locking characteristic is a curve of locking voltage against the difference between the locking (or pilot) frequency and the natural frequency of oscillation of the oscillator. Such a theoretical determination of the locking characteristic is, however, long and difficult. In practice, such characteristics are measured directly on typical oscillators of the type concerned. Two typical locking characteristics are shown in Fig. **5**. Curve A was measured on an Oscillator No. 10A (6,000 c/s for Carrier System No. 2) and curve **B** on the 1 kc/s master oscillator of the G.E.C. type 12-circuit carrier system (Carrier System No. 6). It will be observed that the voltages corresponding to the same percentage frequency error are very different in the two cases. This is largely due to the fact that

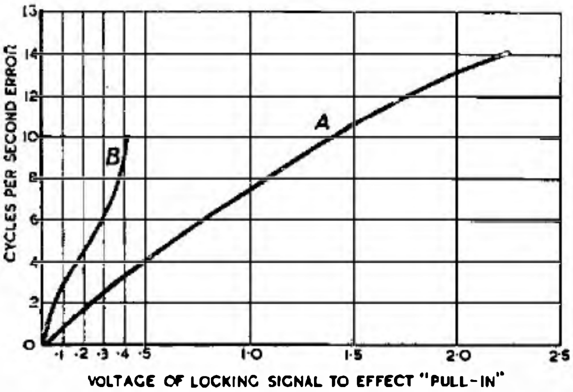

Fig. 5.—Locking Characteristic of (A) 6 kc/s and (B) 1 kc/s Master Oscillators.

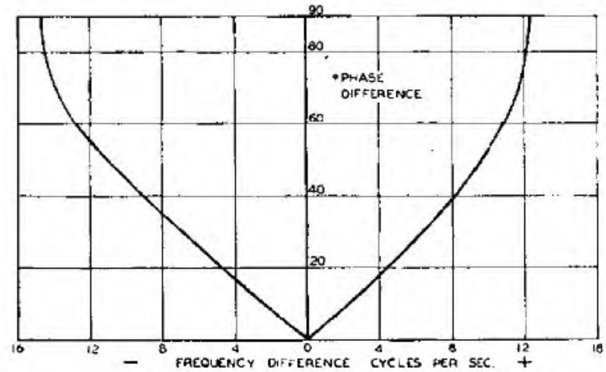

Fig. 6.—Phase Difference in a Locked Oscillator between Locking and Oscillatory Voltages (6 kc/s Oscillator).

the Oscillator No. 10A uses valves V.T.75, which have a grid base of perhaps 16 volts, whereas the 1 kc/s oscillator uses valves with a high impedance and a grid base of only about 3 volts. The proportioning of the oscillator circuit also affects the locking characteristic considerably.

A rather surprising feature of the locking characteristic is that it is never found to be quite symmetrical with regard to frequency differences above and below the locking frequency. That is to say, the voltage required for pull-in for a given frequency difference is not the same when the natural frequency is higher than the pilot as it is when the natural frequency is lower. The lack of symmetry is not very great, and is of no practical importance. The locking characteristics given in this article show only that side of the characteristic which requires the larger locking voltage. The explanation of the lack of symmetry is that the angle ϕ in Fig. **4** is given by

$$\left[\tan^{-1}\frac{\omega L - 1/\omega C}{R} - \tan^{-1}\frac{\omega_o L - 1/\omega_o C}{R}\right]$$

which is not symmetrical with regard to ω_o.

The Phase Relation between Locking and Oscillatory Voltages.

It was shown in an earlier paragraph that at the pull-out point the phase difference between the locking and oscillatory voltages was 90°. If the locking voltage is more than sufficient to lock the oscillator, the phase difference is less than 90°. Fig. **6** shows a typical measured characteristic of the phase difference plotted against the frequency difference. The oscillator in question was an Oscillator No. 10A, 6,000 c/s. It is evident, of course, that when the natural frequency of the oscillator is the same as the locking frequency, the phase difference is zero. The lack of symmetry of the curve is noticeable.

The Pull-out.

When the voltage of the locking signal is insufficient to lock the oscillator, the oscillator frequency does not assume its natural value, but varies continuously in a regular cyclic manner. This can be demonstrated theoretically by considering the vector diagram of Fig. **4b**, in which the vector E_L can be made to rotate relatively to the remainder of the diagram. A more practical and useful demonstration is obtained by beating the output of the oscillator with the locking signal itself. Typical beats obtained are shown in Fig. **7**, which shows a series of oscillograms of the beat of an Oscillator No. 10A. In the first, the oscillator tuning condenser has been rotated until the oscillator just pulls out of lock. The beat obtained is just a series of slow impulses. As the condenser is further rotated, the beat frequency increases, although the impulse itself retains the same form. Finally, the beat note would be almost a sine wave.

Disturbance of a Synchronising Signal by Noise.

As already stated, when a synchronising signal is transmitted over a line, it is liable to interference from noise at frequencies near its own, or by other signals if intermodulation occurs and sidebands fall close to the synchronising signal in the frequency range. It is obvious that any signal of frequency well removed from that of the pilot will have no noticeable effect on the synchronisation, since a considerable selectivity will normally exist in the receiving equipment. The presence of noise on the carrier supply will not, in modern carrier systems, produce any appreciable amount of noise in the transmission

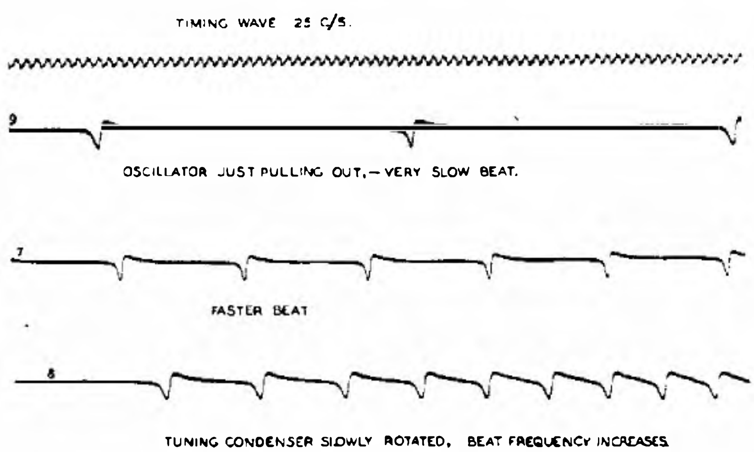

Fig. 7.—Pull-out of a Locked Oscillator.

path in the absence of a signal, since the balanced bridge configuration of the modulators and demodulators substantially suppresses the carrier input in the transmission path. But if a signal is transmitted over the system, carrier noise causes phase modulation or so-called flutter of the signal. The mechanism of this phase modulation is considered later.

Analysis of Carrier Phase Modulation.

To ascertain the effect of noise on a carrier pilot channel it is convenient to consider a single extraneous frequency differing from the carrier frequency f_0 by δ. An addition of the carrier and noise frequencies produces an oscillating vector, as shown in Fig. 8.

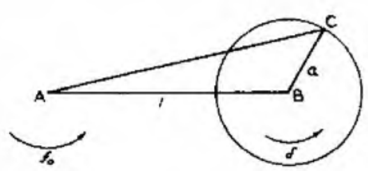

FIG. 8.—ADDITION OF CARRIER AND NOISE VOLTAGES.

It is convenient to consider this vector as a combination of amplitude and phase modulation, i.e., the effective carrier supply will have a varying amplitude and also a varying phase. The amplitude variations will have a negligible effect on the transmitted signal for two reasons :

(*a*) The modulators and demodulators are designed to be insensitive to small variations of carrier amplitude.

(*b*) If the pilot frequency feeds the modulators and demodulators via a locked oscillator, as is usual, the amplitude variations will in any case be substantially eliminated by this oscillator.

Phase variations of the carrier will, however, be freely transferred to the signal by the modulators and demodulators, and even a locked oscillator can be influenced by phase variations. The extent to which the oscillator frequency will be affected by the phase modulation will depend on the oscillator's selectivity.

Suppose the carrier frequency f_0 has unit amplitude and the noise frequency $f_0 \pm \delta$ has an amplitude a, assumed to be small. Then the maximum phase displacement is a ; and the average and maximum rates of change of phase are $4a\delta$ and $2\pi a \delta$ rads per sec. respectively.

The disturbing effect of flutter has been found experimentally to be roughly proportional to the rate of change of phase of the signal, and the highest rate which is permissible for speech has been variously estimated at 200° to 400° per second. Thus it will be clear that the maximum noise amplitude which can be tolerated is inversely proportional to the difference frequency δ.

If we assume a maximum permissible rate of change of phase of 200° per sec., then

$$\frac{200 \times \pi}{180} = 2\pi a \delta.$$

$$\therefore \quad a = \frac{5}{9\delta}$$

If a suitably selective circuit is included as an equaliser, at the receiving end of the pilot channel, it will clearly be possible to tolerate equal amplitudes of disturbance at all frequencies, i.e., all frequencies present in a uniformly distributed noise spectrum will be equally effective in producing flutter. In this case the actual frequency distribution of the noise is immaterial, provided that the amplitude is measured through the selective circuit. The selectivity of the receiving circuit will, of course, include the characteristics of the locked oscillator, if one is used.

It is shown above that the maximum permissible amplitude of any noise frequency, differing from the carrier frequency f_0 by an amount δ cycles per sec., may be taken as $a = 5/9\delta$. This, however, will include values of 'a' which are by no means negligible compared with the magnitude of the carrier, and it is necessary to stipulate a maximum value for 'a,' based on the requirements of carrier amplitude at the modulator input terminals. It is convenient to assess this limiting value arbitrarily at 0·5, this allowing such an amount of noise, very near the carrier frequency, that the instantaneous carrier amplitude will vary from 0·5 to 1·5 times its nominal value. The graph of $a = 5/9\delta$ will then be modified to pass through the point $\delta = 0$, $a = 0{\cdot}5$. Such a graph, in which 'a' is expressed as a carrier-to-noise ratio in db., is shown in Fig. 9, Curve 1. The curve obviously has somewhat similar characteristics to

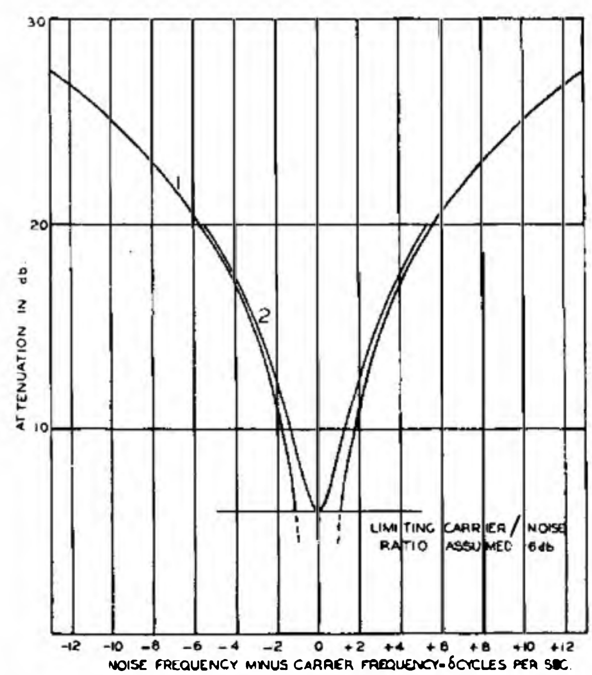

FIG. 9.—THEORETICAL SELECTIVITY CURVES OF RECEIVING CIRCUIT FOR CARRIER SYNCHRONISING TONE.

those of a simple resonant circuit. Curve 2 shows the response of an approximately equivalent resonant circuit, and it will be seen that the agreement is quite close. This response would be required if the ratio of pilot-to-noise were 6 db. In general, such severe conditions would not be met in practice, and the required selectivity could be reduced as the noise conditions improved.

A pilot-receiving equipment should therefore include a selective circuit, which could satisfactorily be a simple resonant circuit. Generally, however, the pilot is used to lock an oscillator, and the selectivity of this would be more than adequate for normal noise conditions. Selectivity is then necessary in the pilot-receiving amplifier only to prevent overloading of valves, etc., by signals other than the pilot.

Methods of Detection of Interference (i.e., " Flutter ").

The chief significance of flutter is its disturbing effect on speech. It is found, however, that tests made to detect flutter by listening to transmitted speech are somewhat unreliable because observations made by different people differ so widely, and so much depends on the actual voice used. It is found that a transmitted tone provides a listening test that is much more reliable and very much more sensitive, i.e., flutter is detected with smaller noise magnitudes than when listening to speech. Tests have also been made using a cathode ray oscilloscope to detect flutter on a tone, but this method gives much the same results as the listening method, and is more troublesome and rather less reliable.

Some results obtained on several synchronising systems are described in the succeeding paragraphs. All refer to multi-channel carrier systems, chiefly to the 12-circuit systems.

Test Results on the Synchronised London-Cambridge System.

Conditions of Test.—Tests were made to determine at what signal/noise ratio (referring to the pilot) any flutter became detectable on the signals transmitted over the carrier system. All observations were made on the channel using the highest carrier frequency (i.e., 60 kc/s). All the carrier frequencies are derived directly from the 1 kc/s by an overloaded valve circuit. Thus no additional discrimination against flutter is provided. The majority of the tests were made with a cathode-ray oscilloscope, but several tests were made by listening to speech. In the oscilloscope tests, an 800 c/s tone was transmitted on the carrier channel, and used to give the deflection on the oscilloscope ; the same tone was transmitted on an audio circuit and used to synchronise the oscilloscope time-base. Tests were made particularly to determine (*a*) the effect of the frequency response of the receiving equipment, (*b*) the effect of the rectifier networks in the locking circuit, mentioned earlier in this article.

The contractor's pilot receiver uses a band-pass filter to separate the 9 and 10 kc/s pilot (which is rectified to give a 1 kc/s locking signal) from other signals and noise. Its frequency response is given

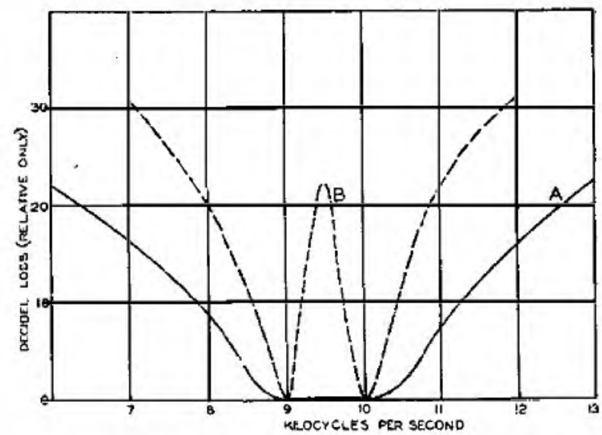

FIG. 10.—FREQUENCY RESPONSE OF 9/10 KC/S PILOT RECEIVERS.

in Fig. 10, Curve A. It will be seen that this is not very selective ; therefore a special unit was made for comparison tests, and its frequency response is given in Fig. 10, Curve B. It is obtained by the use of two tuned circuits, and is much more selective than the filter.

The pilot is transmitted at a level below that of the sidebands, but at least 40 db. above line noise. Under these conditions, no disturbance is observable. To obtain quantitative figures, therefore, it was necessary to put artificial noise on the line. This was done by producing resistance noise and applying it to the line through a filter similar to that used in the pilot receiver.

Effect of Voltage of Locking Signal.—It will be readily appreciated that the amount of disturbance caused on the carrier channel is directly proportional to the voltage of locking signal injected into the oscillator. It does not depend on the frequency difference between the oscillator and pilot. These points were confirmed by tests. The results given below refer, therefore, to a constant condition, in which the locking signal is injected at a level 5 db. higher than that required to pull in from a frequency difference of 0·1 per cent. The locking characteristic of the oscillator for straightforward locking is shown in Fig. 5, Curve B.

TABLE 1

Test	Selectivity condition	Locking circuit	Pilot/noise ratio in db. which gives just detectable flutter on oscilloscope
a	Without special unit (response Fig. 10, Curve A)	Straightforward sine-wave injection	17
b	With special unit (response Fig. 10, Curve B)	do.	17
c	Without special unit	Special rectifier circuit	28
d	With special unit	do.	28

Tests with the Oscilloscope.—The results (given in Table 1) show clearly (*a*) that the selectivity of the pilot receiver has no effect on the flutter, and (*b*) that the special rectifier locking circuit makes the system 10 db. *more* sensitive to noise.

The reason why the selectivity of the pilot receiver has no effect is because the oscillator itself has an extremely high selectivity to extraneous signals injected into the grid circuit. Actually, a certain amount of filtering is essential on the pilot receiver, not because of any flutter effect, but because a constant volume amplifier follows the receiver, and any large stray signal or noise may cause sufficient reduction in the volume of pilot to cause the oscillator to pull out.

Tests with Speech.—Tests to detect flutter on transmitted speech are naturally more difficult to carry out. However, it can be stated as a general conclusion of the tests made that a flutter can be detected on speech when the noise is about 30 db. greater than that required to produce a noticeable flutter on the oscilloscope. Thus, to disturb speech, the noise voltage must actually exceed that of the pilot. In practice, therefore, it is impossible for normal conditions to give rise to disturbance.

Test Results on the Experimental Synchronising System, Bristol-Birmingham.

The Bristol-Birmingham 12-circuit carrier link is synchronised by the direct injection of a 4 kc/s tone into a 4 kc/s master oscillator, this tone being produced by modulating the 60 kc/s pilot tone with the 56 kc/s local frequency. The latter is produced by controlling a free 56 kc/s oscillator directly from the 4 kc/s local oscillator. The 56 kc/s frequency can thus be regarded for most purposes as the 14th harmonic of the 4 kc/s oscillator. The fact that the channel carrier frequencies are obtained by this controlled oscillator method does, however, help to reduce flutter on this system.

Tests made to detect flutter on this system showed that the noise (added resistance noise covering a 3 kc/s band including the pilot frequency) can actually *exceed* the pilot level by 25 db. without any flutter being detectable, even on tone. To make sure that this result was not obtained because of the high selectivity of the pilot receiver, practically all tuning was removed. Still the same result was obtained.

For comparison with the above result, the same system was synchronised by a directly transmitted 4 kc/s pilot, using the 4 kc/s portion of the pilot receiver. Flutter was now detectable on tone with the noise (measured over the same *proportional* band-width as above, i.e., 200 c/s) 20 db. *below* the pilot level. This shows the great superiority of the 60 kc/s pilot system.

Tests on Experimental Equipment between Leeds and Newcastle.

Tests were made using the 60 kc/s system referred to above to synchronise the 4 kc/s master oscillators on an experimental system installed by one of the contractors on two of the four coaxial pairs in the Leeds-Newcastle coaxial cable. In this system all the multiple frequencies required are generated *directly* from the 4 kc/s tone, using a saturated iron-cored inductor. Listening tests were made on a tone transmitted on the 300 kc/s channel. A flutter was just detectable with the noise and pilot levels equal, the noise again being resistance noise covering a 3 kc/s band, including the pilot frequency. Since the magnitude of flutter is directly proportional to the frequency of the signal concerned, i.e., in this case 300 kc/s, this means that a flutter would just be detectable on a 60 kc/s channel with the noise 14 db. in excess of the pilot level. Comparing this with the result obtained above on a 12-circuit system using the same method of synchronisation, it will be seen that a considerable improvement in flutter prevention is obtained when the channel frequencies are not produced directly by multiplication from the master frequency. However, in both cases the margin against flutter production is much more than adequate.

Conclusions.

Synchronising systems as described in this article have been set up on a large number of carrier systems in this country, and it is expected that ultimately the whole carrier network will be synchronised. No difficulty has been experienced in setting up the systems, and the equipment used is very simple and reliable. As indicated in the test results described, no disturbance of the synchronising signal by line noise is likely to arise.

A Resistance Compensated Band-stop Filter

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The article describes a simple type of band-stop filter which can be realised in balanced or unbalanced form and can be made to yield substantially infinite attenuation at a predetermined frequency even when the attenuation-band is very narrow.

Introduction.

ALTHOUGH the technique of designing electric wave filters has advanced considerably in the last few years little attention appears to have been devoted to the question of developing improved types of band-stop filter. This is no doubt due to the fact that telecommunications systems do not often demand the use of such filters. Occasions do, however, arise from time to time when it is desired to eliminate a single frequency or a very narrow band from a frequency spectrum without affecting the level of other components appreciably. For example, a nearby radio station might cause a single interfering frequency to be present in the band occupied by a carrier telephone channel, and if this frequency could be suppressed, the channel might still be usable.

Up to the present it has been usual to employ either one or the other of two general types of network for suppressing a very narrow frequency band ; either a ladder-type band-stop filter, or a bridge network in which one or two of the four arms is reactive and the remainder are wholly resistive. The ladder-type filter is a true electric wave filter and the relevant design data have been available for some time. It may be constructed either in balanced or unbalanced form, and may therefore be connected directly to circuits which are balanced to earth, or are completely unbalanced, and have a common earth terminal. With this type of filter section the maximum attenuation that can be introduced is unfortunately limited by the resistance of the filter inductors, and this limitation is most severe when the attenuation band is very narrow. The bridge networks that are often used, one of which is shown in Fig. 1, have characteristics

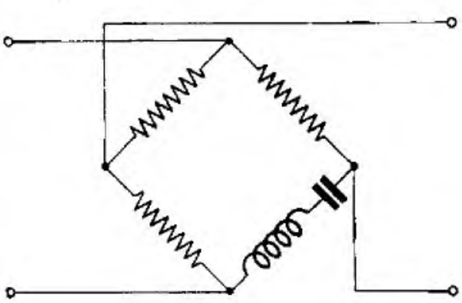


FIG. 1.—TYPICAL BRIDGE FILTER.

that are quite different. Strictly speaking they are not true electric wave filters and, as far as is known, are usually designed on an empirical basis. Owing to their bridge form these networks may not be connected between circuits having a common earth terminal without using transformers. On the other hand the great advantage they afford is that of being able to attain extremely high values of attenuation at a single frequency. Both types of network have certain desirable and certain undesirable characteristics, and it is proposed to show how the desirable characteristics of both types may be combined in a single structure.

Simple Band-Stop Lattice Filters.

If Z_1 and Z_2 are the series and lattice impedances in a balanced lattice network as shown in Fig. 2, the propagation constant P will be given by:

$$P = 2 \tanh^{-1}\sqrt{\frac{Z_1}{Z_2}}$$

In particular, when Z_1 and Z_2 are reactances of opposite sign the attenuation constant will be zero, when they are reactances of the same sign the network

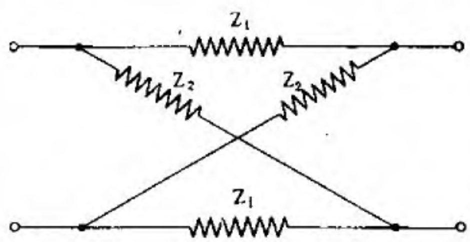


FIG. 2.—BALANCED LATTICE NETWORK.

will attenuate, and when Z_1 and Z_2 are equal the attenuation will be infinite.

In order that the loss introduced by the network shall be as low as possible outside the band in which attenuation is desired, the network should, if possible, be composed of reactances only. This cannot, of course, be realised completely but, if the power factors of the filter elements are low, residual resistance will only increase the loss slightly outside the attenuation band. In spite of the presence of resistance it will moreover still be possible to realise very high values of attenuation at certain frequencies by making the resistive components of Z_1 and Z_2 equal, as well as the reactive components. It will be sufficient to assume for the present, however, that the network is composed of purely reactive elements and to take resistance into account later.

Let $Z_1 = jX_1$ and $Z_2 = jX_2$. If the network is to operate as a band-stop filter X_1 and X_2 must be of opposite sign at all frequencies except in the attenuation band, where they must be of like sign. Further, if the attenuation is to rise to infinity at one or more frequencies in the attenuation band, the two reactances must be equal at these points. By sketching various possible combinations of two reactance curves representing X_1 and X_2 on a common frequency scale, it is easy to show that the simplest lattice filters fulfilling these requirements are those indicated in Fig. 3. Of these filters that shown against (c) is the only one which may be transformed into an equivalent unbalanced structure without using transformers. This, therefore, is the network which will be studied.

Analysis cf Lattice Filter Neglecting Resistance.

Referring to the figure it will be seen that the series arms each consist of an inductance L_1 in parallel with a capacitance C_1 and are antiresonant at a frequency f_1, while each lattice arm comprises an inductance L_2 in series with a capacitance C_2, the combination resonating at a frequency f_2. For the case shown the reactance of a series arm equals that of a lattice at two frequencies $f_{1\infty}$ and $f_{2\infty}$.

The impedances of the series and lattice arms are given respectively by :

$$Z_1 = \frac{j\omega L_1 \cdot \frac{1}{j\omega C_1}}{j(\omega L_1 - \frac{1}{\omega C_1})}$$

$$= \frac{-j}{C_1} \cdot \frac{\omega}{\omega^2 - \omega_1^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where $\omega_1^2 = \frac{1}{L_1\,C_1}$ ....(2)

and $Z_2 = j(\omega L_2 - \frac{1}{\omega C_2})$

$$= jL_2 \cdot \frac{\omega^2 - \omega_2^2}{\omega} \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

where $\omega_2^2 = \frac{1}{L_2 C_2}$ ....(4)

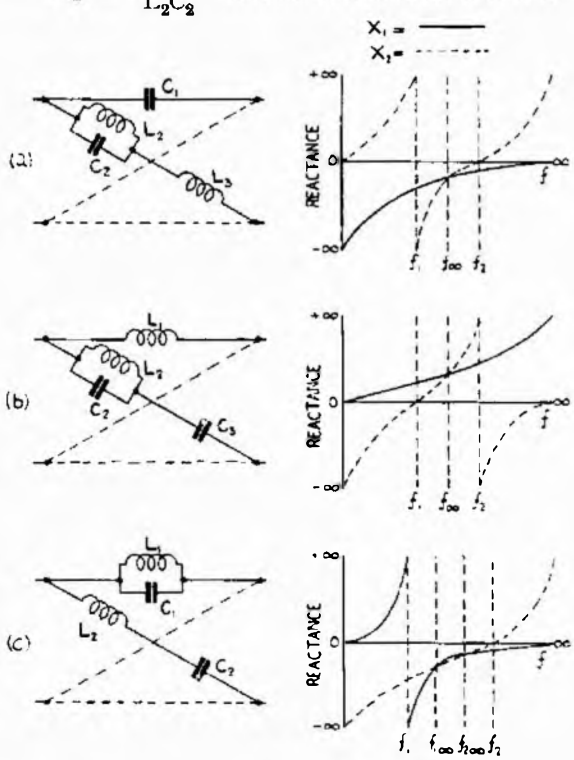


Fig. 3.—Simple Band-Stop Lattice Filters.

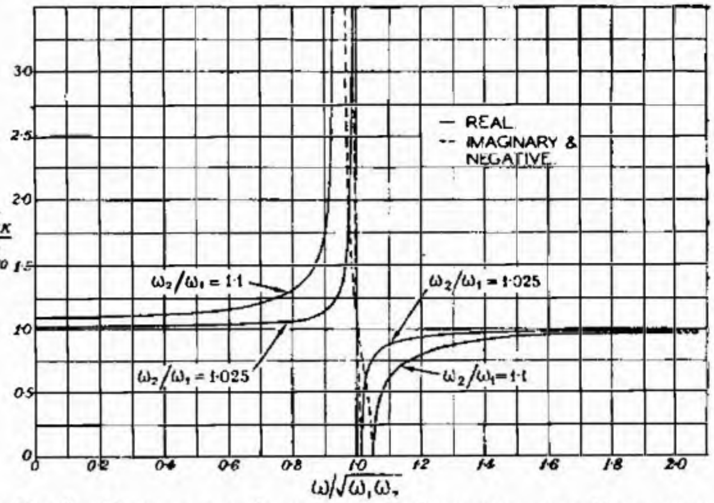


Fig. 4.—Variation of Characteristic Impedance with Frequency.

The characteristic impedance Z_k of the filter is given by :

$$Z_k = \sqrt{Z_1 Z_2}$$

Substituting for Z_1 and Z_2 :

$$Z_k = \sqrt{\left(\frac{L_2}{C_1} \cdot \frac{\omega^2 - \omega_2^2}{\omega^2 - \omega_1^2}\right)}$$

In the upper pass-band, as the frequency increases Z_k tends towards a value Z_o given by :

$$Z_o = \sqrt{\frac{L_2}{C_1}}$$

and in the lower pass-band, as the frequency is reduced Z_k tends towards a value Z_o' given by :

$$Z_o' = \frac{\omega_2}{\omega_1}\sqrt{\frac{L_2}{C_1}}$$

Z_o and Z_o' may be defined as the nominal values of the characteristic impedance for the two pass-bands.

Since consideration is restricted to cases where the attenuation band is narrow the ratio ω_2/ω_1 will approximate to unity and it will be permissible to assume that :

$$Z_o' \doteqdot Z_o = \sqrt{\frac{L_2}{C_1}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Two examples of the way in which Z_k varies with frequency for narrow attenuation bands are shown in Fig. 4.

The attenuation constant becomes infinite when Z_1 and Z_2 are equal. The frequencies $f_{n\infty}$ at which this occurs are therefore given by :

$$\frac{-j}{C_1} \cdot \frac{\omega_\infty}{\omega_\infty^2 - \omega_1^2} = jL_2 \cdot \frac{\omega_\infty^2 - \omega_2^2}{\omega_\infty}$$

Cross-multiplying and substituting for C_1 from equation (5) :

$$\frac{\omega_\infty^2}{(\omega_\infty^2 - \omega_1^2)(\omega_\infty^2 - \omega_2^2)} = -\frac{L_2^2}{Z_o^2}$$

which may be rewritten in the form :—

$$\omega_\infty^4 + \left(\frac{Z_o^2}{L_2^2} - \omega_1^2 - \omega_2^2\right)\omega_\infty^2 + \omega_1^2\,\omega_2^2 = 0 \ldots (6)$$

This equation is a quadratic in ω_∞^2; the roots for ω_∞ will therefore be of the form α, $-\alpha$, β, $-\beta$, where α and β will both be real or both imaginary. When they are real there will be two frequencies $f_{1\infty}$ and $f_{2\infty}$ at which the attenuation constant becomes infinite.

It is, however, unnecessary to obtain explicit solutions for $\omega_{1\infty}$ and $\omega_{2\infty}$ since in practice these quantities will be fixed beforehand by the requirements of the network to be designed. Equation (6) will therefore be used to determine L_2 in terms of Z_o, ω_1, ω_2, $\omega_{1\infty}$ and $\omega_{2\infty}$.

Referring to equation (6), from the theory of equations:

$$\omega_{1\infty}^2 + \omega_{2\infty}^2 = \omega_1^2 + \omega_2^2 - \frac{Z_o^2}{L_2^2}$$

$$\omega_{1\infty}^2 \, \omega_{2\infty}^2 = \omega_2^2$$

From the former L_2 is given by:

$$L_2 = \frac{Z_o}{\sqrt{\omega_1^2 + \omega_2^2 - \omega_{1\infty}^2 - \omega_{2\infty}^2}} \quad \ldots\ldots (7)$$

The second equation is interesting in that it shows that the two frequencies of infinite attenuation are symmetrically disposed on a logarithmic basis between the two cut-off frequencies.

From equations (2), (4), (5) and (7) the values of the other filter elements may be obtained:

$$C_2 = \frac{1}{\omega_2^2 L_2}$$

$$= \frac{1}{\omega_2^2 Z_o} \cdot \sqrt{\omega_1^2 + \omega_2^2 - \omega_{1\infty}^2 - \omega_{2\infty}^2} \quad \ldots (8)$$

$$C_1 = \frac{L_2}{Z_o^2}$$

$$= \frac{1}{Z_o\sqrt{\omega_1^2 + \omega_2^2 - \omega_{1\infty}^2 - \omega_{2\infty}^2}} \quad \ldots\ldots (9)$$

$$L_1 = \frac{1}{\omega_1^2 C_1}$$

$$= \frac{Z_o}{\omega_1^2} \cdot \sqrt{\omega_1^2 + \omega_2^2 - \omega_{1\infty}^2 - \omega_{2\infty}^2} \quad \ldots (10)$$

If the two frequencies of infinite attenuation are made to coincide:

$$\omega_{1\infty} = \omega_{2\infty} = \omega_\infty = \sqrt{\omega_1 \omega_2} \quad \ldots\ldots (11)$$

and the expressions for the filter elements then become:

$$L_1 = \frac{\omega_2 - \omega_1}{\omega_1^2} \cdot Z_o \quad \ldots\ldots (12)$$

$$L_2 = \frac{1}{\omega_2 - \omega_1} \cdot Z_o \quad \ldots\ldots (13)$$

$$C_1 = \frac{1}{(\omega_2 - \omega_1) Z_o} \quad \ldots\ldots (14)$$

$$C_2 = \frac{\omega_2 - \omega_1}{\omega_2^2 Z_o} \quad \ldots\ldots (15)$$

Resistance Compensation

Two Frequencies of Infinite Attenuation.—In practice the filter elements have, of course, some resistance; nevertheless if they are of reasonably low power-factor, and if the attenuation band is narrow, resistance will not affect the performance materially outside the attenuation band. On the other hand at the frequencies corresponding to $\omega_{1\infty}$ and $\omega_{2\infty}$ the presence of resistance will, in general, make the series and lattice impedances unequal, and will reduce the attenuation at and in the neighbourhood of these frequencies. It is necessary to consider whether it is possible to prevent this effect.

Dissipation in the filter may conveniently be represented by shunt and series resistances in the series and lattice arms respectively as indicated in Fig. 5. Assuming for convenience that this dissipation

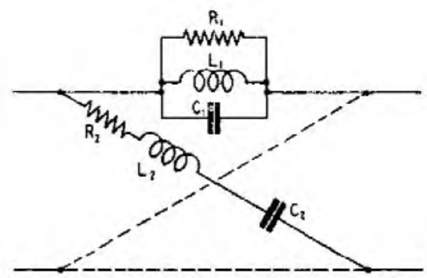


Fig. 5.—Band-Stop Lattice Filter including Dissipation.

is due solely to the inductors L_1 and L_2, having power-factors ρ_1 and ρ_2 respectively, each lattice arm consists of a resistance R_2 in series with a reactance X_2 where:

$$R_2 = \rho_2 \, \omega L_2 \quad \ldots\ldots (16)$$

$$X_2 = L_2 \cdot \frac{\omega^2 - \omega_2^2}{\omega} \quad \ldots\ldots (17)$$

and each series arm consists of a resistance R_1 in parallel with a reactance X_1 where:

$$R_1 = \frac{\omega L_1}{\rho_1} \quad \ldots\ldots (18)$$

$$X_1 = -\omega L_1 \cdot \frac{\omega_1^2}{\omega^2 - \omega_1^2} \quad \ldots\ldots (19)$$

If the attenuation is to rise to infinity at the frequencies corresponding to $\omega_{1\infty}$ and $\omega_{2\infty}$ the series resistance and the series reactance of the lattice arms must be separately equal to the corresponding series components of the series arms at these frequencies. The equivalent series resistance R_1' and series reactance X_1' of a series arm are given by:

$$R_1' + jX_1' = \frac{jX_1R_1}{R_1 + jX_1}$$

$$= \frac{jX_1R_1(R_1 - jX_1)}{R_1^2 + X_1^2}$$

whence

$$R_1' = \frac{R_1 X_1^2}{R_1^2 + X_1^2}$$

$$= \frac{R_1}{1 + \frac{R_1^2}{X_1^2}} \quad \ldots\ldots\ldots\ldots (20)$$

$$X_1' = \frac{R_1^2 X_1}{R_1^2 + X_1^2}$$

$$= \frac{X_1}{1 + \frac{X_1^2}{R_1^2}} \quad \ldots\ldots\ldots\ldots (21)$$

The values of power-factor ρ_1 and ρ_2 will only change slowly with frequency and within the attenuation band, which is assumed to be narrow, R_1 and R_2 will not change very much. The reactance X_1, on the other hand, is infinite at the lower cut-off frequency; the expression R_1^2/X_1^2 therefore varies rapidly in the attenuation band. Considering R_1 in the numerator of (20) as constant but substituting for R_1^2/X_1^2 in the denominator, using (18) and (19):

$$R_1' = \frac{R_1}{1 + \frac{\left(1 - \frac{\omega^2}{\omega_1^2}\right)^2}{\rho_1^2}} \quad \ldots\ldots\ldots\ldots (22)$$

Inspecting this expression, remembering that ρ_1^2 will be of the order of 0·0001 or less, it is clear that R_1' will vary rapidly with frequency for values of ω in the neighbourhood of ω_1, the variation being moreover in the same direction for all frequencies above the lower cut-off. Therefore, since R_2 is approximately constant it will be impossible to make R_1' equal to R_2 at more than one frequency in the attenuation band, and complete resistance compensation cannot be accomplished.

One Frequency of Infinite Attenuation.—Passing to the condition where the two frequencies of infinite attenuation coincide, it will be remembered that when this holds,

$$\omega_{1\infty} = \omega_{2\infty} = \omega_\infty = \sqrt{\omega_1 \omega_2}$$

It is necessary therefore to make R_1' and X_1' equal to R_2 and X_2, respectively, when ω is equal to $\sqrt{\omega_1\omega_2}$, if the attenuation is to become infinite. The procedure adopted is to make R_1' and R_2 equal by adding resistance either in series with the lattice arms if R_2 is smaller than R_1' or in parallel with R_1 if R_1' is smaller than R_2; X_2 is then made equal to X_1' by altering the value of capacitance in each lattice arm. Since condensers are practically free from dissipation, changing the value of the series capacitance in a lattice arm does not alter the series resistance R_2 appreciably, and the adjustment of the reactances to equality does not therefore upset the resistance adjustment previously made.

Conditions for Equating Resistance Components.—The conditions under which R_2' and R_2 can be made equal will be examined. If R_2' and R_2 are assumed to be equal then from equations (16) and (22):

$$\rho_2 \omega L_2 = \frac{R_1}{1 + \frac{\left(1 - \frac{\omega^2}{\omega_1^2}\right)^2}{\rho_1^2}}$$

Writing $\sqrt{\omega_1\omega_2}$ for ω and substituting for L_1, L_2, R_1, using equations (12), (13), (18), the requisite value of ρ_2 is given by:

$$\rho_2 = \frac{\rho_1}{1 + \frac{\rho_1^2}{\left(\frac{\omega_2}{\omega_1} - 1\right)^2}} \quad \ldots\ldots\ldots\ldots (23)$$

or the requirements may be written in the alternative form:

$$\rho_1 = \frac{\left(\frac{\omega_2}{\omega_1} - 1\right)^2}{2\rho_2}\left[1 \pm \sqrt{1 - \frac{4\rho_2^2}{\left(\frac{\omega_2}{\omega_1} - 1\right)^2}}\right] \quad \ldots (24)$$

When R_2 is initially less than R_1' it is necessary to increase the former and the final value of ρ_2 required is that given by equation (23). When on the other hand R_2 is initially greater than R_1' the latter should be increased until equality is reached. Referring to equation (24) it will be seen that there are in general two values of ρ_1 which make R_1' equal to R_2 but that these values are only real when:

$$2\rho_2 \leqslant \frac{\omega_2}{\omega_1} - 1$$

hence R_1' can only be made equal to R_2 when this latter condition is satisfied. The reason for this limitation lies in the fact that R_1' cannot be increased beyond a certain minimum value by increasing ρ_1, i.e., reducing R_1. Substituting for R_1 in equation (22) using (18) and making ω equal to $\sqrt{\omega_1\omega_2}$:

$$R_1' = \frac{\sqrt{\omega_1\omega_2}\, L_1}{\rho_1 + \frac{\left(1 - \frac{\omega_2}{\omega_1}\right)^2}{\rho_1}}$$

When ρ_1 is very small R_1' will vary in the same direction as ρ_1. If however ρ_1 is increased continuously a point will be reached where R_1' attains a maximum value and decreases thereafter. By differentiating R_1' with relation to ρ_1 and equating to zero it is easy to show that this maximum occurs when:

$$\rho_1 = \frac{\omega_2}{\omega_1} - 1 \quad \ldots\ldots\ldots\ldots (25)$$

The maximum value that R_1' can be made to assume limits the values of R_2 and ρ_2 for which compensation is possible. Substituting for ρ_1 in equation (23) using (25) the upper limit for the value of ρ_2 is given by:

$$2\rho_2 = \frac{\omega_2}{\omega_1} - 1.$$

For higher values of ρ_2 complete resistance compensation is impossible.

If the initial value of ρ_1 should happen to be greater than that which yields the maximum value of R_1' and if at the same time it were necessary to increase R_1' in order to equal R_2 then the only possibility of achieving resistance compensation would be to reduce ρ_1 which would probably be impracticable.

It can therefore be stated that the initial values of power-factor ρ_{10} and ρ_{20} of the series and lattice inductors, respectively, should not exceed the following values :

$$\rho_{10} < \frac{\omega_2}{\omega_1} - 1$$

$$2\rho_{20} < \frac{\omega_2}{\omega_1} - 1$$

in order that it may always be possible to make the resistances R_1' and R_2 equal. If these conditions are observed R_1' and R_2 can then be made equal by :—

(*a*) Adding resistance in series with L_2 when :

$$\rho_{20} < \frac{\rho_{10}}{1 + \dfrac{\rho_{10}^2}{\left(\dfrac{\omega_2}{\omega_1} - 1\right)^2}}$$

or (*b*) Adding resistance in parallel with L_1 when :

$$\rho_{20} > \frac{\rho_{10}}{1 + \dfrac{\rho_{10}^2}{\left(\dfrac{\omega_2}{\omega_1} - 1\right)^2}}$$

Conditions for Equating Reactance Components.— To complete compensation for the effect of resistance it is necessary to alter the reactance of the lattice arm from its original value X_2 to a value X_2' equal to the equivalent series reactance X_1' of the series arm. Rewriting equation (21), X_1' and hence the required value X_2' are given by :

$$X_1' = X_2' = \frac{X_1}{1 + \dfrac{X_1^2}{R_1^2}}$$

Substituting for X_1^2/R_1^2 in the denominator using equations (18) and (19) and remembering that ω is equal to $\sqrt{\omega_1\omega_2}$:

$$X_2' = \frac{X_1}{1 + \dfrac{\rho_1^2}{\left(\dfrac{\omega_2}{\omega_1} - 1\right)^2}}$$

But X_1 is equal to X_2 hence, substituting for X_1 :

$$X_2' = \frac{X_2}{1 + \dfrac{\rho_1^2}{\left(\dfrac{\omega_2}{\omega_1} - 1\right)^2}}$$

Let the requisite value of lattice capacitance corresponding to X_2' be C_2', then substituting for X_2 and X_2' :

$$\frac{\omega_1\omega_2 L_2 C_2' - 1}{C_2'} = \frac{\omega_1\omega_2 L_2 C_2 - 1}{C_2} \Bigg/ \left[1 + \frac{\rho_1^2}{\left(\dfrac{\omega_2}{\omega_1} - 1\right)^2}\right]$$

whence :

$$\left[1 + \frac{\rho_1^2}{\left(\dfrac{\omega_2}{\omega_1} - 1\right)^2}\right]\left(\omega_1\omega_2 L_2 C_2 - \frac{C_2}{C_2'}\right) = \omega_1\omega_2 L_2 C_2 - 1$$

but L_2C_2 is equal to $1/\omega_2^2$, hence substituting for L_2C_2 :

$$\frac{\rho_1^2}{\left(\dfrac{\omega_2}{\omega_1} - 1\right)^2} \cdot \frac{\omega_1}{\omega_2} + 1 = \left[1 + \frac{\rho_1^2}{\left(\dfrac{\omega_2}{\omega_1} - 1\right)^2}\right]\frac{C_2}{C_2'}$$

and C_2' is given by :

$$C_2' = C_2 \cdot \frac{1 + \dfrac{\rho_1^2}{\left(\dfrac{\omega_2}{\omega_1} - 1\right)^2}}{1 + \dfrac{\omega_1}{\omega_2} \cdot \dfrac{\rho_1^2}{\left(\dfrac{\omega_2}{\omega_1} - 1\right)^2}}$$

It will be seen that for narrow attenuation bands C_2' is very little larger than C_2. The small change in capacitance will have the effect of reducing the upper cut-off frequency slightly.

Filter in Unbalanced Form.

The filter has been studied in its original lattice form. The final step is to transform the network into an equivalent unbalanced structure. It is easy to show that no equivalent T or π networks can be realised, but the filter may be changed into any one of a number of bridged T networks using the well-known lattice/bridged T transformation. Perhaps the most convenient bridged T equivalent is that shown in Fig. 6. The element values of this network including the resistances due to dissipation are given in terms of those of the original lattice filter shown in Fig. 5. The only condition imposed by the transformation is that C_2 shall be less than C_1 ; in the light of equations (14) and(15) this will always be satisfied.

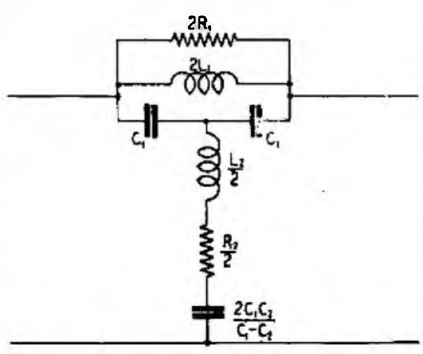


FIG. 6.—BRIDGED T NETWORK EQUIVALENT TO FIG. 5.

The power-factors of the two inductors in the bridged T network are, it will be seen, the same as those of the corresponding inductors in the lattice structure, the same power-factor limitations therefore apply to both networks. Resistance compensation in the bridged T network is carried out by adding resistance either in parallel with $2L_1$ or in series with $L_2/2$, and increasing the value of capacitance in series with $L_2/2$; this follows from a consideration of the element values.

Practical Designs.

Examples are given below of the measured performance obtained from two networks designed in accordance with the foregoing principles.

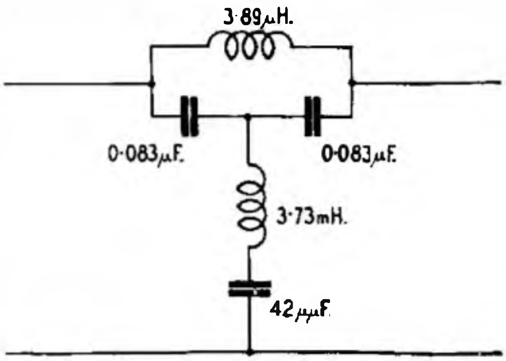


FIG. 7.—ELEMENT VALUES FOR 400 KC/S FILTER.

The first design was made with the object of realising the narrowest possible attenuation band expressed as a percentage of the mid-band frequency. From a consideration of the power-factors likely to be realised in practice it appeared that the ratio of the higher to the lower cut-off frequency could not with safety be made less than 1·016. A filter was accordingly designed where :

$$\frac{\omega_2}{\omega_1} = 1{\cdot}016$$

$$\frac{\sqrt{\omega_1\omega_2}}{2\pi} = \frac{\omega_\infty}{2\pi} = 4 \times 10^5 \text{ cycles/second}$$

$$Z_o = 300 \text{ ohms.}$$

The resulting network had the capacitance and inductance values shown in Fig. 7. Measurements

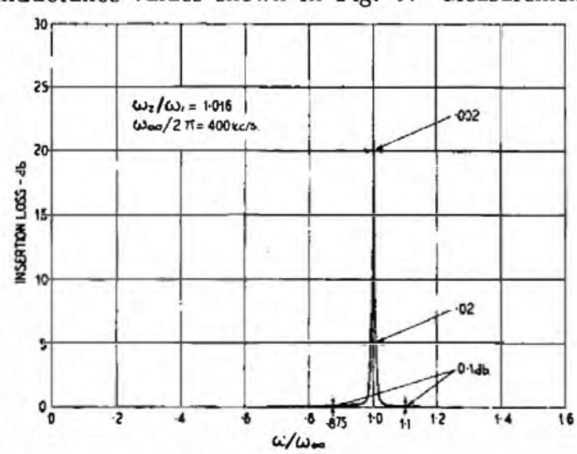


FIG. 8.—ATTENUATION CHARACTERISTIC FOR 400 KC/S FILTERS.

of the actual power-factors of the filter elements showed that the compensating resistor should be connected across the bridging inductor. This resistor and the capacitance in the stem of the bridged T were adjusted empirically until substantially infinite attenuation was obtained at 400 kc/s. The attenuation characteristic shown in Fig. 8 was finally obtained although the extreme narrowness of the attenuation band and the high frequencies at which the filter was working made the adjustments very critical. This characteristic is interesting in that it shows the extreme narrowness of attenuation band that can in the limit be obtained, nevertheless it would be unwise to use such a narrow band in practice if a high degree of attenuation were required, in view of the difficulty of achieving and holding the final adjustments.

The performance of a design more typical of what might be used in practice is shown in Fig. 9 ; here

$$\frac{\omega_2}{\omega_1} = 1{\cdot}047$$

$$\frac{\sqrt{\omega_1\omega_2}}{2\pi} = \frac{\omega_\infty}{2\pi} \doteqdot 1{\cdot}265 \times 10^5 \text{ cycles/second,}$$

$$Z_o = 75 \text{ ohms}$$

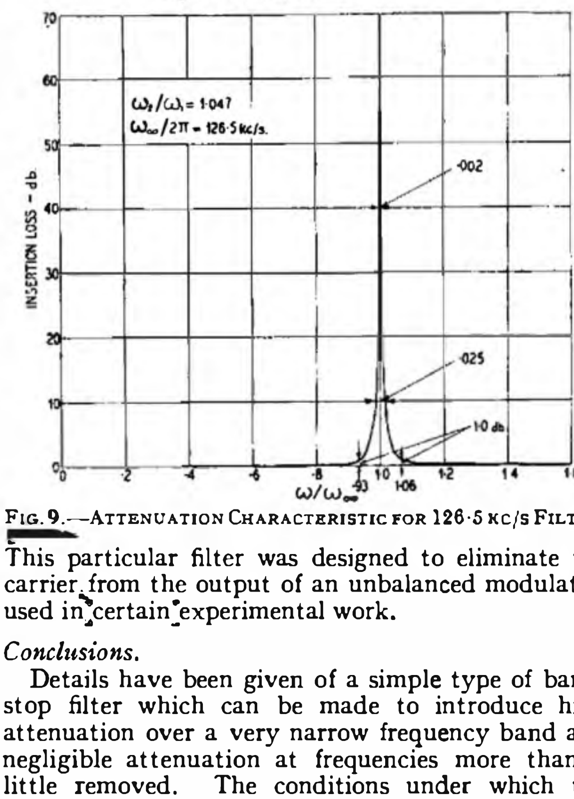


FIG. 9.—ATTENUATION CHARACTERISTIC FOR 126·5 KC/S FILTER.

This particular filter was designed to eliminate the carrier from the output of an unbalanced modulator used in certain experimental work.

Conclusions.

Details have been given of a simple type of band-stop filter which can be made to introduce high attenuation over a very narrow frequency band and negligible attenuation at frequencies more than a little removed. The conditions under which the attenuation can be made substantially infinite at a particular frequency have been determined. The filter may be realised in alternative forms suitable for direct connection either between balanced circuits or between circuits having a common earth terminal.

Acknowledgments.

The author has pleasure in acknowledging his indebtedness to Messrs. E. R. Broad and G. Gray who were largely responsible for the development of this filter.

Special Machines and Tests Devised to Facilitate the Mechanical Examination of Materials

K. L. BEAK, A.I.Mech.E.

U.D.C. 620.15

The Author describes a number of unusual machines and tests devised to investigate the properties of new materials used by the Post Office.

Introduction.

THE use by the Post Office of many of the products of modern research in the field of plastics, rubber substitutes and alloys, has led inevitably to the result that many unorthodox tests for manufactured parts made of these materials have become necessary. None of these tests, the descriptions of which appear below, stands as a specification requirement, but they all have the characteristic that they give a very real insight into the behaviour of the materials they were designed to test, in respect of the particular use the Post Office makes of them.

All the various pieces of apparatus were designed and constructed at the Post Office Research Station. Some of them, having served their purpose, no longer exist as a separate entity, but have been rebuilt to fulfil the requirements of some entirely different test.

The machines described below are intended to be indicative only of the versatility of design necessary.

Strip Fatigue Machine.

The evaluation of the fatigue resistance of metals in sheet and strip form is a matter of primary importance when it is intended to use the materials concerned in positions where they are, or might be, subject to vibration. This is especially important with lead and its alloys when used for cable sheathing. The strip fatigue machine was designed and constructed to carry out this type of work.

Fig. 1 is a general view of the machine and counting mechanism. The motor driven mainshaft carries at each end an adjustable eccentric E, the bearings of which are phosphor bronze lined. Accuracy of adjustment is obtainable to 0·001 in., as measured on the oscillating shaft C by a travelling microscope. The connecting rod from the eccentric terminates in a crosshead D, and the oscillating shaft C is supported at the end remote from the crosshead by the bearing F. On each of these shafts are six pairs of adjustable clamps B, each insulated from the shaft. Behind these shafts are two sets of six fixed clamps A, each pair insulated from the parallel bars G which hold them in position. The specimens S under test are located in position in the clamps A by dowels, and the part under test protrudes from these clamps and passes between the adjustable clamps on the oscillating shaft. These clamps are so adjusted that when the specimen is flexed it bends about the point of emergence from the clamps A, but no bending takes place at the adjustable clamps B. It is very necessary to obtain the "free end" condition at the clamp B, for should bending take place there, stresses, the magnitude of which cannot be determined, are exerted on the specimen and interfere with the true flexing of the specimen at the clamps A. The normal test length is 2 in., but this can be increased to 4 in. should the nature of the test demand it, by shifting the fixed clamps A back towards the centre line of the machine. To obtain quietness in running, the whole machine is supported on the helical springs shown at H. The specimens are wired individually to the terminals fixed to the machine as shown.

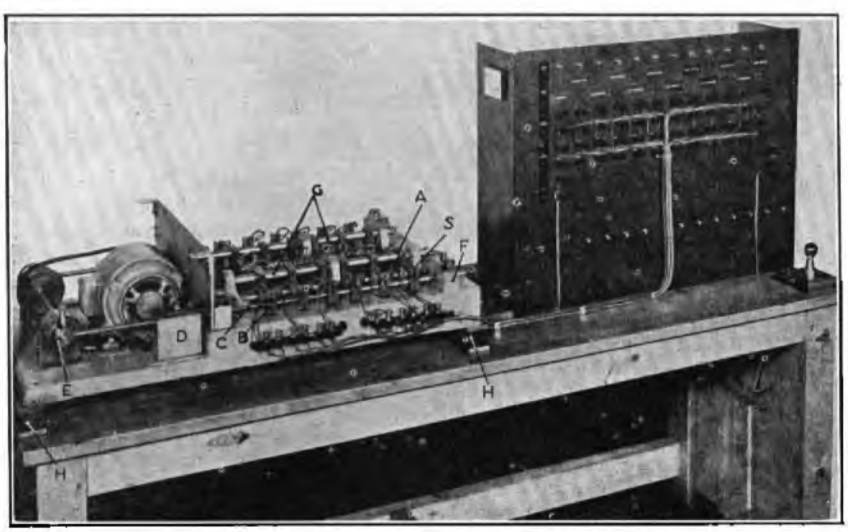


FIG. 1.—STRIP CANTILEVER FATIGUE TESTING MACHINE.

Reference to Fig. 2 will show the circuit arrangements of the counting mechanism. Each specimen is provided with two pairs of leads, one pair from the power terminals and one pair from the test terminals. This arrangement was adopted in preference to one pair serving both purposes to shorten the length of the test leads, and achieve greater sensitivity. One of each pair is soldered to each end of the specimen. The specimen is in series with the power terminals, and a current of 2 amp. passes through the specimen when under test for continuity. The potential difference across the specimen, which at the commencement of the test is about 2 mV, is applied via the test terminals and banks 1 and 2 of uniselector DM/2 to the Weston relay WR. As the

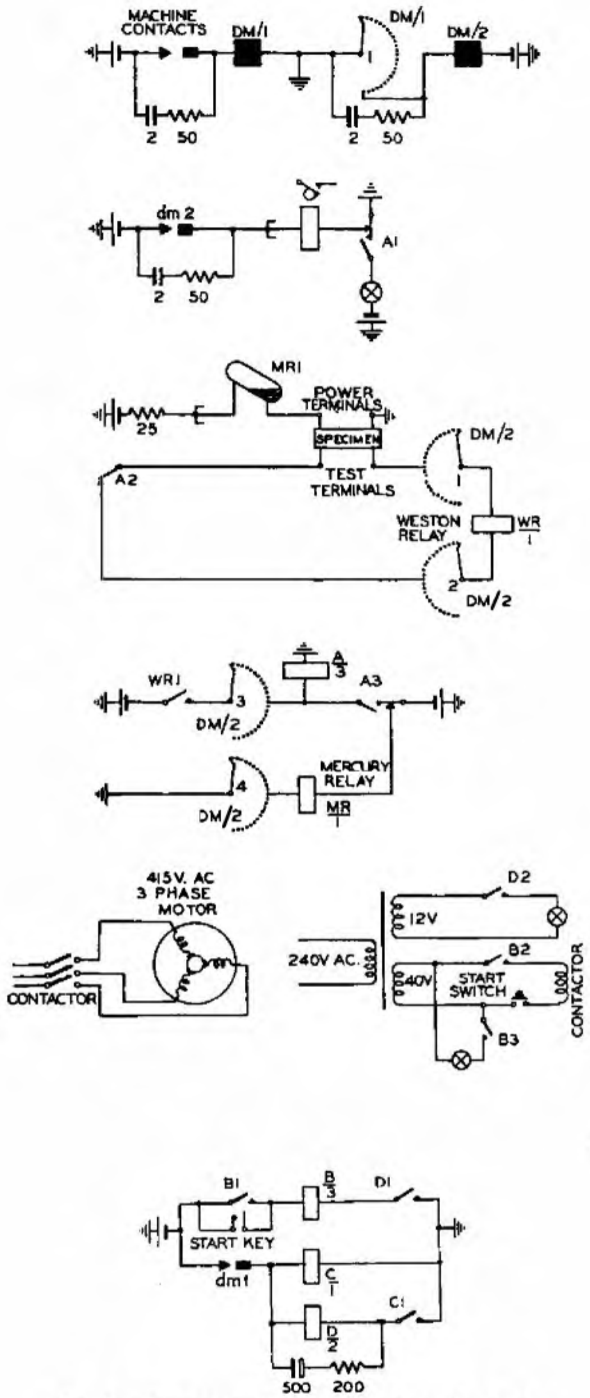


FIG. 2.—CIRCUIT OF STRIP CANTILEVER MACHINE.

process of fatigue proceeds the specimen progressively fractures at the point of flexure. The area of metal available to conduct the current is thus reduced and the resistance increased with a corresponding increase of potential difference across the specimen. This proceeds until the specimen is about to break into two parts and the potential difference rises to about 15 mV, sufficient to operate the relay WR.

Considering the circuit operation in detail, there is, on the mainshaft of the machine a 100 : 1 ratio worm reduction gear, which is used to operate the machine contacts. These contacts step the uniselector DM/1 once every 100 oscillations of shaft C. Uniselector DM/2 is stepped from the DM/1 bank once every 25 operations of DM/1. DM/2 is used to do the actual circuit switching which consists of changing the testing circuit from specimen to specimen, each one being examined for continuity in turn once every 2,500 oscillations of the shaft C. This corresponds to a periodic test once every 20 to 21 minutes. As the fracture usually occurs after between 5 to 15 million operations of shaft C or from 2·5 to 7·5 days of 24 hours each, every specimen can be considered as being under constant supervision from the start to the finish of the test. Each specimen has its own associated 7 digit counting meter, mercury relay MR, relay A, lamp, power and test leads all wired via the DM/2 banks, the counting meter operating once every 2,500 oscillations of shaft C. As the wipers of DM/2 step on to any specific contact the mercury relay MR operates via contact A3 and bank 4, and current flows through its associated specimen and the counting meter of that specimen operates via contact A1.

Assuming the potential difference across the specimen reaches a value where relay WR will operate, contact WR/1 makes and relay A operates. Contact A1 changes over and the counting meter is cut out of circuit and the lamp associated with that specimen lights. Contact A3 changes over and the relay MR/1 is disconnected, relay A locking itself. The test current is therefore permanently removed from the specimen. Contact A2 breaks as an extra safeguard and that specimen is isolated from any subsequent test on that position. The Weston relay is therefore guarded against injury from excess potential.

Certain alarm and safety provisions are provided. The motor is started by a manually operated starter switch which energises a contactor from a 240 to 40 V transformer. Relay B is operated by the start key and locks itself via contact B1, D relay being normally operated. Contact B2 breaks the start circuit should relay B drop out owing to the 50 V D.C. supply failing, and a lamp is lit via contact B3 from the 40 V transformer circuit. If, owing to oil, pitting or wear, the machine contacts do not make, the uniselector DM/1 and therefore the interrupter springs dm1 and relay C do not operate. The circuit comprising relay D, electrolytic condenser and 200 ohm resistance, has a delayed release time slightly longer than the time between consecutive operations of the machine contacts and therefore of relay C. If, therefore, relay C fails to operate, relay D does not receive a holding impulse, via contacts C1 and DM1, and no longer remains operated, the electrolytic condenser having become exhausted of charge. Contact D1 breaks and relay B drops out breaking contact B3, thereby de-energisng the contactor and stopping the motor.

This machine and counting circuit has been in constant use for 6 to 7 years and, apart from periodical renewals of the phosphor bronze bearing liners and replacements of the counting meters, has given faultless service.

Cable Vibration.

Although the strip fatigue machine evaluates the fatigue resistance of lead and its alloys intended for cable sheaths, it does not give any information about the behaviour of a cable when sheathed. The cable vibrator subjects the cable in the completed form to a wide range of amplitudes of vibration, but no calculations on a stress basis are possible. Empirical comparisons between cables sheathed in differing alloys, but built up around the same type of core are possible, using, say, a pure lead sheath as the basis of comparison.

Fig. 3 gives a general view of the cable vibrator with a length of armoured submarine cable in the testing position. The overall length of cable between the supporting shackles A is about 18 ft. In the centre of the span a flexible shackle B is attached. Rubber linings prevent the cable being deformed when the shackle is tightened up. This shackle B is attached by a connecting rod C to an oil-immersed eccentric, which is housed in a cast-iron box shown at D. This eccentric is constructed in the form of a liner keyed on to the shaft of the motor E, and is machined to give the desired amount of throw to the connecting rod. The liner forms the centre spindle of a large ball race, and the connecting rod is fitted over the outside of the race, being held in position by two collars fitted on to the motor shaft. The whole eccentric assembly is immersed in oil, a felt oil-retaining ring being fixed to the cast-iron box D to prevent oil leakage. This box is bolted firmly on to the motor so that they form one unit. The motor is mounted on adjustable slides so that the central vertical axis of the connecting rod and eccentric may be adjusted directly under the centre line of the cable. The oscillating movements of the connecting rod are thus applied vertically in the plane of the cable which vibrates in a single or an odd number of loops depending on the speed of oscillation. At the speed used for this test three loops are formed.

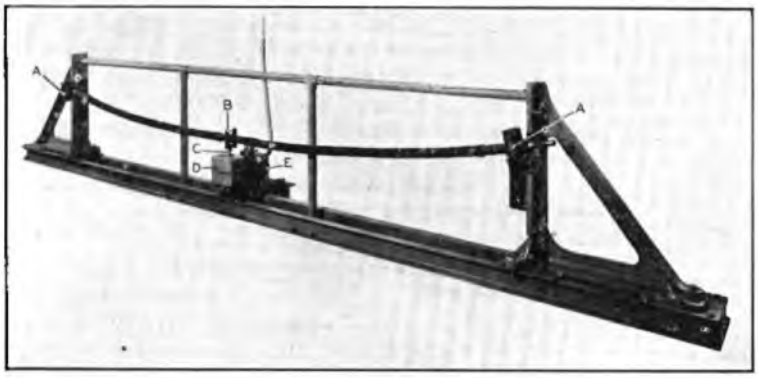


Fig. 3.—Cable Vibrating Machine.

In addition to tests with the cable swung free as shown in Fig. 3, provision is also made whereby the cable can be placed under tension during test. This is done by fixing one end of the cable to a dynamometer and the dynamometer to the frame of the machine by a long screw. By tightening up the screw, tensioning is effected via the dynamometer to the cable, and a direct reading is thus obtainable of the load applied. The dynamometer is coupled to the cable by a cable grip of standard design.

The cable is placed under a vacuum of about 10 lbs. absolute, the ends having first been plumbed, one end solid and the other with a brass tube let in. When, owing to fatigue, the cable sheath eventually cracks, the air pressure inside the cable rises to normal. A mercury manometer attached to the brass tube provides a circuit which breaks when the height of mercury in the tube falls. This break circuit is utilised to stop the motor by a simple switching device.

To determine the number of vibrations to fracture, the speed of the motor is accurately determined and a recording voltmeter is wired into the cut-off circuit. The product of the motor speed in r.p.m. and the time of running in minutes as given by the recording voltmeter denotes the actual number of vibrations to fracture. As the time of running is usually in hours, accuracy to plus or minus five minutes is not an essential.

This method of determining fracture has been found to be very sensitive. Cracks in the cable sheath not visible to the unaided eye show up readily. It has been found that the sheath, where the fracture has occurred, must often be bent considerably before the cracks become apparent.

Resistance to Cutting.

The covering of cables with thermoplastic materials necessitated an investigation into the resistance offered by these materials to the cutting or abrasive action of small stones or other sharp objects which might be present in duct routes. Again no fundamental calculations can be made but this machine gives information from which it is possible to compare various types of thermoplastic material. This machine was constructed in the first place to examine the special properties of rubber waxes but was found to be applicable to other similar types of material.

The whole of the machine is not shown in Fig. 4; only the cutter and specimen carriage are depicted. The part not shown consists of the main driving motor coupled to a 100 : 1 worm reduction gear, and the eccentric, connecting rod and crosshead.

The 3-in. dia. cutter A has 0·5-in. wide cutting faces and is of the ordinary type found on most milling machines. It is pin-coupled to the pulley G and rotates freely on the arbor, being driven at 14 r.p.m. by a belt from the worm reduction gear.

The specimen B under test is glued firmly to an oak back-plate C. Two vertical pillars H are fixed to the back-plate and slide freely in the guides F. To the top of the pillars is screwed a flat plate which carries the loading weights D. The total weight of the specimen carriage with weights is 2·5 lb. The guides F are a driven fit into the block J which is firmly attached to the sliding rod E. This sliding rod is

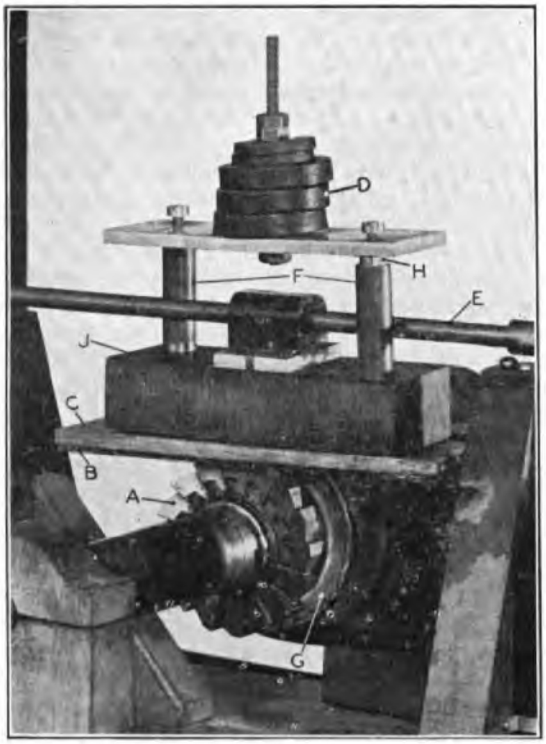


Fig. 4.—Machine for Testing Resistance to Cutting.

joined by a crosshead and connecting rod to an eccentric driven from the worm reduction gear. The rate of reciprocation of the sliding rod is 30 strokes per minute, one stroke being taken as a complete movement in one direction and back again.

An electrical counting circuit is provided; a modified 1A-type meter with 7 digit wheels is operated by a contact on the sliding rod.

The test is assumed as complete when the specimen is cut through in any one place, and the colour of the oak back-plate becomes visible. There is no automatic cut-out on this machine for this necessitated a metal back-plate, and it was found difficult to fasten the thermoplastic specimen sufficiently rigidly to the metal.

The results of tests are quoted as the number of operations necessary to cut through a specimen 0·1 in. thick. This allows material of various thicknesses to be tested, and gives comparable results between all types.

Drift of Spring Material.

It is well known that certain alloys, when fabricated into flat spring form suffer from an effect known as "drift." In plainer terms drift means that flat springs tend to lose set or position and move back to the position they occupied before the set was applied. In order that this effect might be investigated in connection with nickel silver spring material, the drift machine was constructed, not only to discover if drift in the ordinary accepted sense of the term occurred, but also to find out whether a measure of permanent set took place when the material was sprung past its "set" position.

It should be noted that the test to be described is the second condition stated above in which the spring material is deflected as a cantilever past its "set" position, the amount of stress applied being predetermined by the conditions of test. The stress is applied for many millions of operations and is below the elastic limit of the material.

The machine, Fig. **5**, consists of a shaft A on which are fixed six cams B, cut to give the requisite stress by deflection of the spring material C being tested. This shaft is mounted on self-aligning ball bearings, and is driven by an electric motor D at a speed of 2,000 r.p.m. The specimens, which are ¼ in. wide, 0·02 in. thick and with an effective length of 2 in., are clamped in a block E at the back of the machine. This block is of such a height that when any one cam is in the position of minimum throw the specimen is just clear of the cam periphery. By this means the stress is applied from zero to a maximum when the spring is deflected. Any permanent set or drift taken up by the specimen is denoted by a change in the distance between the top of the springs and the bottom of the adjacent vertical rods F as measured by a microscope. The points of the vertical rods are set at the commencement of test to be a known distance from the top of the specimen when no deflection is given by the cams.

To make sure that the springs follow the cam periphery correctly and that "bounce" does not take place, the cams, when moving at full speed are stroboscoped by a mercury vapour lamp of the Edgerton type. The speed of flash is adjusted to be sufficiently out of phase with the rotational speed of the cams that a slow motion view of the specimens following the cams is obtained.

A counting device and automatic motor cut-out is fitted. The counting device is driven direct from the cam shaft by meccano gearing G, giving a 5,000 : 1 reduction. The high speed members of this gear assembly run in an oil bath to reduce wear and noise.

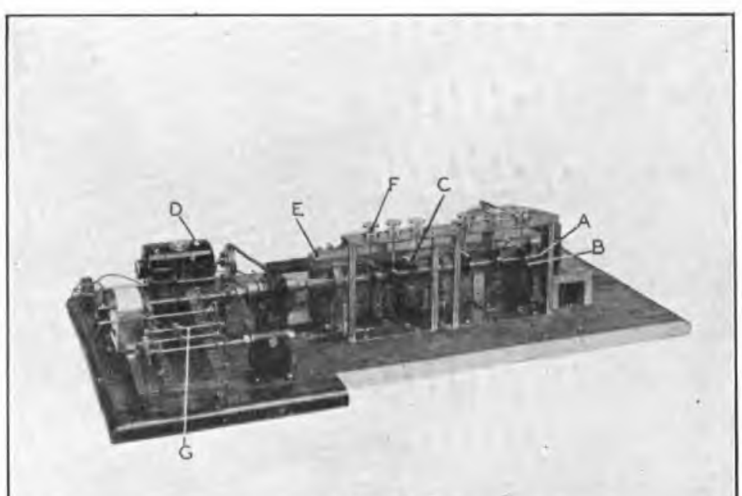


Fig. 5.—Machine for Examining the Drift of Spring Materials.

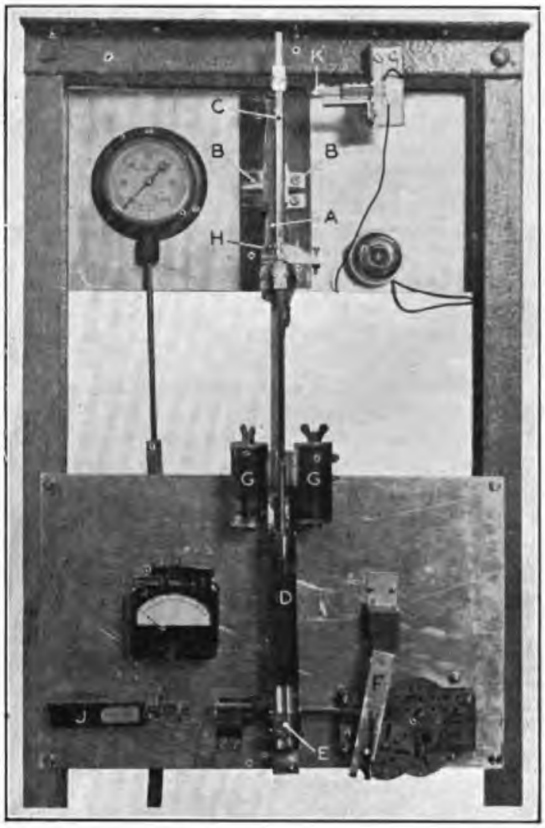


FIG. 6.—MACHINE FOR TESTING POUCHES WITH ZIP FASTENERS.

A contact operated by the final gear unit is used to step a "bypath" type switch, this operating once every 5,000 operations of the camshaft. By connecting a second uniselector to the bank of the bypath switch the revolutions of the camshaft can be counted in multiples of 5,000 up to 12×10^6 and, by a relay, the motor circuit can be broken at any multiple of 5,000 so that measurements may be made.

"Zip" and "Press Stud" Fastenings.

The "zip" fastener is supplanting the more commonplace "press stud" fastener in many places where the security of the contents of bags or purses is of prime importance, especially where those contents are not personal but public property. The two machines described here were constructed to test the relative life of these two types of fastenings.

First the "zip" machine: a general view is given in Fig. **6**. It was necessary in this test to obtain a very quick operation in both the opening and closing motions.

The pouch to which the fastener A is attached is packed with paper to give it body, and is then fitted between the two rubber-faced clamps B. The operating wedge of the fastener is held, by the loose ring usually provided on these fasteners, in a self-aligning holder attached to the vertical sliding bar C. This vertical bar is fixed to a piston operating inside the cylinder D. The travel on this piston was adjusted so that a slight tug was given to the fastener at both ends of the stroke. At the bottom of the cylinder is a valve E which slides circumferentially about the vertical axis of the cylinder and is operated by the crank F and bar attached to it. The crank itself is moved by meccano gearing driven by a 12 V windscreen-wiper motor. Air at 30 lb. per square inch admitted via the rotating valve forces the piston quickly upwards opening the pouch. As the valve is shut the piston travels downwards equally quickly under the influence of the weights G shutting the pouch as it moves.

Fig. **7** gives a general view of the machine used for testing press studs. The pouch L, to which the press stud is seen to be attached, is packed in the same manner as the zip pouches with paper to give it body. The bar **M** holds the pouch firmly in position although allowing freedom of movement to the flaps. The top flap, which has in it the upper part of the stud, is held at its edge by the clamp O against the rocking arm W. This arm has a hole cut in it behind the clamp O to allow free movement of the top part of the stud. The rocking arm is fixed to the shaft **Z** and moved about its axis by the wheel P which in turn is moved by the crosshead U. The included angle of travel of the rocking arm is about **45** deg., and when in the lower position the arm places the top part of the press stud accurately over its lower counterpart but does not snap it to. The crosshead U is driven from the adjustable eccentric N which is itself rotated by the motor and gearbox seen on the left of Fig. **7**.

On to the shaft which connects the gearbox and eccentric is fitted a cam S against which a follower

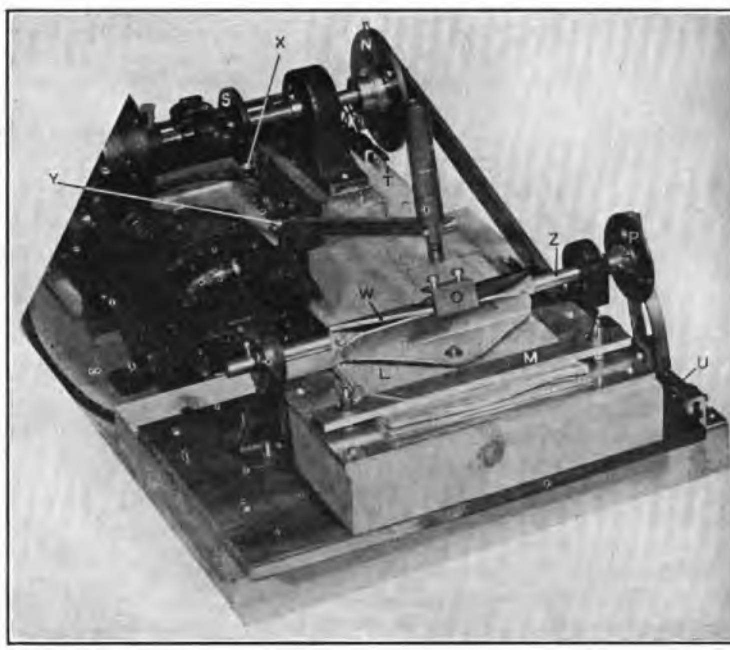


FIG. 7.—MACHINE FOR TESTING POUCHES WITH PRESS-STUD FASTENERS.

X presses. This follower, pivoted at Y, terminates in the adjustable hammer R. The cam is cut away at one point in its periphery in such a manner that the hammer falls under its own weight, through the hole in the rocking arm on to the top part of the stud, giving it a sufficiently hard tap to snap it to, the flap being at that moment correctly positioned by the rocking arm. The cam then lifts the hammer out of the way while the rocking arm pulls the press stud apart and then replaces it in position again in readiness for the next closing tap. The striking face of the hammer carries a rubber plug to cushion the blow, forming in effect a rubber-headed hammer. The contacts at T operated by a screw on the eccentric periphery serve to operate a counting circuit.

Impact (Dropping Ball) Tests.

A non-standard but necessary method of impact test has been devised to determine the energy necessary to crack or shatter splinter-proof glass and transparent plastics when held in a rigid support.

A steel ball of known weight was allowed to fall freely on to specimens of non-splinterable glass and transparent plastics, the height of fall being known. The size of specimen was such that the effect obtained by the falling ball was comparable with what might be expected to obtain when a small object struck the eyepiece of a pair of goggles, the specimens being circular. The specimens were held rigidly between thick metal clamps, a ring of very thin rubber being interposed between the metal and the specimen.

The ball was allowed to fall down a glass tube striking the specimen centrally. A powerful electro-magnet acting through the wall of the glass tube was used to hold the steel ball at the required height above the specimen ; when switched off the ball fell freely without any initial impetus being given, such as might happen if it was held and released by hand.

It was possible with this test to obtain comparable figures expressed as impact resistance in foot pounds, between splinter-proof glass and transparent plastics, and to form some idea of the manner in which they might be exposed to fracture.

Scratch Hardness Tester.

The rapid increase in the use of plastics in the Post Office called for some method of test for those trans-parent types which, in certain circumstances, could be used as a substitute for glass. It is generally accepted by those who have developed other types of scratch hardness testers that a diamond edge gives the most reliable results. It was therefore decided to construct a scratch hardness tester capable of being fitted to the Vickers Pyramid hardness testing machine.[1]

[1] *P.O.E.E.J.*, Vol. 29, p. 116.

The hardness tester has not been altered in any way but a simple addition to the rising stage S (Fig. 8) converted the machine into a very useful scratch hardness tester. A flat plate A provided with angle guides was made to slide smoothly on the top of the stage. On the end of the plate was fitted another plate L which carries the mechanism for moving the plate. A 12 V windscreen wiper motor D was fitted on to the end of the plate L to drive the horizontal shaft H through a meccano worm reduction gear, part of which is seen at J. Under the plate is a 100 : 1 worm reduction gear driven by the horizontal shaft. In the centre of the stages there is, normally, a 1-in. diameter hole. This was plugged and on the underside a hole drilled and a screw thread tapped through the plug. The output side of 100 : 1 reduction gear was fitted with a threaded shaft which screws through the hole in the plug. Thus, as the motor rotates, the plate A is moved over the stage S by the screw action described above. It was necessary to standardise the rate of motion relative to the plate and this was fixed at 0·001 in. per minute in either direction and kept constant by a stroboscopic disc N on the motor shaft, the basis of synchronisation being the 50 c/s mains. On the front of the plate L are the control switches giving forward, reverse, on and off. A flexible lead G provides the necessary connection to the source of supply.

The method of making a test is as follows. A specimen B is placed on the plate A and held rigidly in position by the clamps E. Using the microscope on the machine, a part of the specimen is chosen for test that is free from defects or scratches, the final positioning being done by the handwheel K. The microscope is swung away and the stage raised until the specimen is in the correct position under

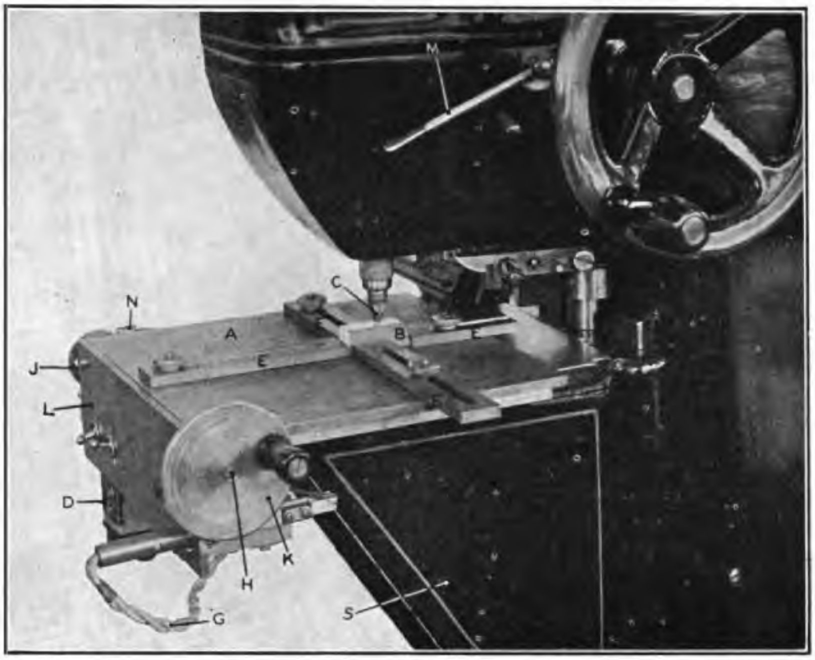


FIG. 8.—APPARATUS FOR SCRATCH HARDNESS TEST.

the diamond indentor C. The motor is then switched on, the speed being checked, and the load applied in the usual way by releasing the trigger M. The load remains applied for 30 seconds, during which time a scratch is made on the specimen by the diamond indentor. At the end of this period the load is automatically removed and the stage is lowered. The microscope is then swung in position and the width of the scratch mark measured.

The Combined Effect of Oil Friction and Impact on Rubber and Its Substitutes.

It has long been known that oil has a deleterious effect on rubber and it therefore follows that the added effects of impact and friction will accelerate the breakdown of this material. Synthetic rubber in some forms has a longer life in this respect and to obtain comparative results the following machine was constructed.

The rubber or rubber substitute for test is moulded in the form of a circular stamp such as might be used for franking purposes. These, shown at A (Fig. 9), are fixed on short adjustable stems which screw into the arms B pivoted at L. These arms are lifted by the cams C which are of such a profile that the arm is lifted to a known height above the horizontal and then allowed to drop under its own weight on to the moving paper D. This cam mechanism is driven by the motor E through a worm reduction gear M. A further reduction gear N on the output side of the gear M makes a pair of contacts and operates a counting meter once every 100 falls of any one of the arms B.

The paper D is an oil impregnated 30-yard length of brown paper of the Kraft type. It was found necessary to use a tough paper of this nature as finer grades would not withstand the rather severe hammering they were subjected to, becoming brittle and tearing during the test. The paper is wound on the two rollers F and G, driven by the motors H and J respectively, via the belting, pulleys and chain drive seen in Fig. 9. The paper is wound off roller F on to roller G, and when the end of the roll is approached the motors are reversed and the direction of winding changed. On the end of the shaft which carries roller G a reduction gear is fitted which rotates the contact P. This contact moves between two adjustable stops, the position of these stops being set to make the contact when the end of the paper is nearly reached. The contacts operate the mercury change-over relay R thus reversing the motors H and J.

The paper passes over a piece of oil impregnated millboard K and the specimens hammer on to the paper with this slightly yielding backing. The paper moves under the specimen while the latter is in contact with it, and thus drag or friction is produced. The time of impact is only a fraction of a second but is sufficient to produce appreciable distortion of the specimens.

It is not feasible to make direct measurements of the wear so imprints of the specimens are taken on a piece of white paper every few thousand operations. The specimens are placed horizontally and gently on the paper so that the imprint is not blurred. It is therefore possible to watch the progress of wear and to be able to state the point at which, after a known number of operations, the characters moulded on to the specimens become too worn to give satisfactory service.

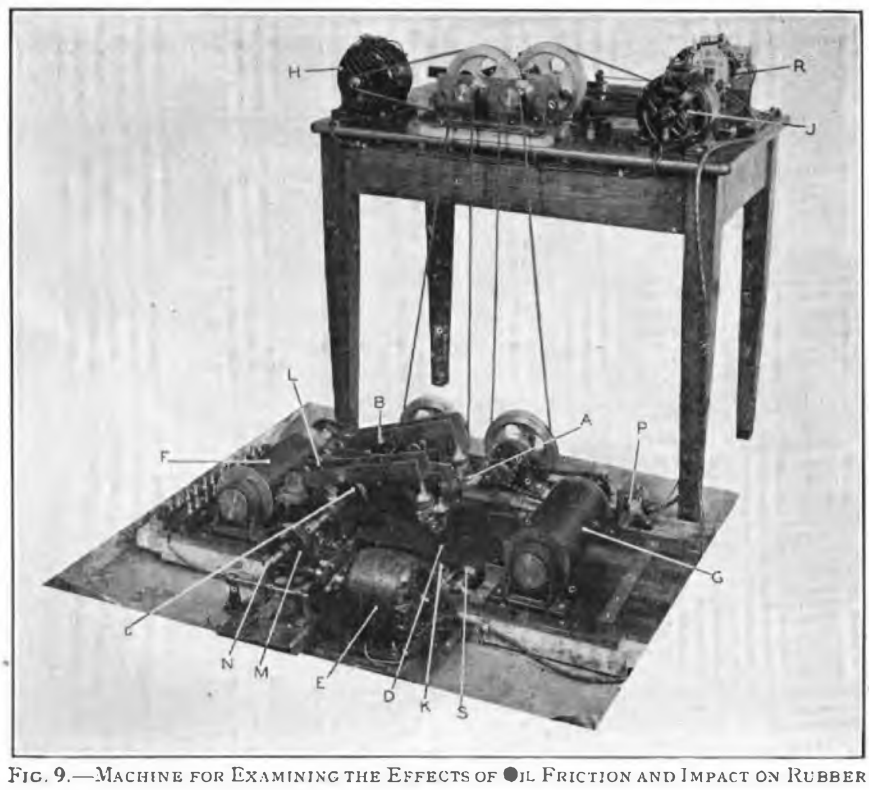


Fig. 9.—Machine for Examining the Effects of Oil Friction and Impact on Rubber.

Conclusion and Acknowledgments.

No attempt has been made to go into very great detail when describing the above pieces of apparatus, but the author hopes that he has made clear the general lines of approach to each specific type of test, and the methods used, with the sometimes somewhat limited facilities and constructional materials available, to produce a machine, which, although not always without fault, is capable of giving reliable results. He would also like to place on record his appreciation and thanks for the advice, criticism, and encouragement given by Mr. C. E. Richards and Mr. E. V. Walker, and also to those members of his staff who have from time to time so ably assisted him in the construction of the very varied range of mechanisms required.

Rubber

A. D. W. DOWNES, B.Sc., A.I.C., A.I.R.I.(Sc.).

U.D.C. 678

A short account is given of the nature of raw rubber and of the processes by which it is converted into everyday articles.

Introduction.

OF the very great number and variety of materials employed by the Post Office, rubber in various forms plays a not inconsiderable part. Like many other substances, which, thanks to scientific research, have been brought into general use, little thought is usually bestowed upon it by the ordinary user until reasons for complaint occur! The following brief account of what is involved to produce rubber may therefore be of some interest.

First mention of rubber is found in the account by an early 16th century traveller of how the Mexican natives used "rubber" playing balls. Much later, in 1773, a French expedition noted that the Mexicans obtained from the Hevea tree a milky liquid which coagulated and hardened in air, and that they used it, among other things, to coat fabrics and even make boots. From this beginning sprang a small industry of which as an example may be quoted the production of the "Mackintosh" proofed coat in 1825, but the field of application of rubber was enormously increased by the discovery of vulcanisation by Goodyear in America in 1839, and independently by Hancock in England in 1844. Although the name of Goodyear is familiar, chiefly in association with vehicle tyres, it may not be generally known that the firm founded by the English inventor still flourishes in London.

Latex.

The sap (or latex, as it is generally known) of the Hevea tree is obtained by cutting the bark and fixing below the cuts cups into which the sap exudes.

The latex, when fresh, is a liquid not unlike milk in appearance, consisting of small rubber particles dispersed in a watery medium.

The composition of latex is approximately as follows :—

Rubber	35 %
Water	60 %
Proteins	2 %
Fatty and waxy constituents	0·2 %
Mineral matter	0·5 %

It has a specific gravity of about 0·98.

The proteins, complex nitrogenous organic substances, appear to act largely as dispersing or emulsifying agents.

The rubber particles themselves are largely pear-shaped (Fig. 1) and are composed of three main layers.

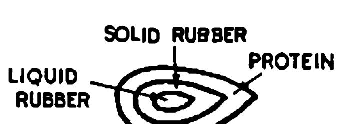


FIG. 1.—COMPOSITION OF RUBBER PARTICLES.

Raw Rubber.

Raw rubber is prepared by coagulating the latex by addition of acid and stirring. The coagulum so obtained is subjected to various washing and drying processes, and finally emerges in its commercial forms of thin cream or brown coloured sheets or blocks.

The raw rubber so prepared is a translucent distensible solid of specific gravity about 0·92, and although possessed of considerable elasticity and strength it suffers from many defects, e.g., cut surfaces are tacky and the physical properties vary greatly with temperature. The rubber soon "perishes" and is attacked by many liquids; it becomes quite plastic when subjected to mechanical working. As an example of the physical properties, it is found that, depending on the rate of stretch, the tensile strength of raw rubber may vary from 25 up to 400 lbs. per sq. inch, with elongation at break of 1,000 per cent. and more. If, however, raw rubber is stretched at intervals by successive small amounts, it may even reach a breaking strength of 2,000 lb. per sq. inch, and extreme elongations of 10,000 per cent. have been obtained! It is interesting to note that under these conditions, provided that its temperature is not altered, rubber becomes non-elastic, and whereas normally it is a colloidal substance, it now shows evidence of crystalline structure.

Whereas formerly practically all rubber was prepared on the plantations, in recent years a considerable amount of rubber is exported in liquid form, usually as a concentrated latex. As latex commences to decompose fairly quickly, a preservative must be added if it is to be kept for a period; the preservative usually employed is about 0·5 per cent. of ammonia.

Vulcanisation.

Goodyear and Hancock discovered that when rubber mixed with sulphur is heated, chemical action takes place, and sulphur actually combines with the rubber to form a new substance called variously vulcanised rubber, vulcanisate, or V.I.R. By varying the time of heating, temperature and amount of sulphur, products varying from a tough elastic substance up to a practically inextensible solid—ebonite or vulcanite—can be obtained.

Generally the combination of from 1 to 3 parts of sulphur produces a soft vulcanised rubber, the properties of which have greatly changed from that of the parent rubber. The cut surface is not tacky, and the compound is comparatively unaffected by many liquids which attack or dissolve raw rubber. It is also much more resistant to the effects of air and sunlight. The physical properties also have changed considerably, and are much less affected by changes of temperature, and the plasticity diminishes to a negligible amount.

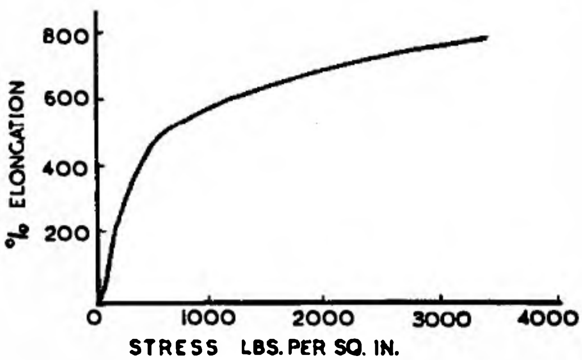


FIG. 2.—TYPICAL STRESS-STRAIN CURVE FOR SOFT VULCANISED RUBBER.

Fig. 2 shows a typical stress-strain curve for a specimen of soft vulcanised rubber. Up to a certain point, the rubber is so elastic that it almost obeys Hooke's Law. Thereafter, and comparatively sharply, resistance to strain rises, and the rubber becomes stiff.

Theories of Vulcanisation.

Many theories have been advanced from time to time to account for the process of vulcanisation. For some time it was held that the hydrocarbon polyprene, the "parent" substance of rubber, combined with the sulphur to form a series of compounds, the lowest containing 2·3 per cent. of sulphur, and the highest 32 per cent. This theory is now discounted, and it is assumed that the very complex change is probably partly chemical and partly physical, the molecules of the hydrocarbon themselves polymerising or aggregating together as well as combining with the sulphur. It is of interest that this "compounds" theory fitted the then known facts, ordinary soft vulcanised rubber containing about 2·5 per cent. of combined sulphur and ebonite about 33 per cent.

Since those days, however, it has been found that soft vulcanised rubber can be prepared having only say 0·5 per cent. of sulphur, and rubber compounds containing no sulphur at all which have similar physical properties can be prepared by using certain oxygen-containing substances instead of sulphur.

Ingredients of V.I.R.

Since the early days of vulcanisation the properties of the vulcanisates have been modified by the addition of divers substances. These may be grouped roughly into five groups, although actually they overlap to some extent :—

(i) *Mineral powders or fillers* are incorporated for various reasons. In small quantities, e.g., 1-5 per cent., certain metallic oxides such as those of zinc, magnesium and calcium act as activators of vulcanisation, i.e., they reduce the period of heating necessary. In larger quantities many, such as carbon black, zinc oxide and china clay actually reinforce the compound and markedly increase the tensile strength and toughness, just as aggregate reinforces cement, and in the same way there is for each an optimum quantity which produces a maximum improvement.

Again, selection of a filler may be made to confer a particular requirement, e.g., chalk for deadness in rubber flooring, and carbon black for toughness in tyres.

Lastly, fillers may be added as such, i.e., simply to cheapen the product—at present a pertinent point, when rubber is about four times the price of a year or two ago.

(ii) *Vulcanisation Accelerators* form a most important branch of rubber compounding ingredients. In the early days of vulcanisation it was found that certain mineral salts such as litharge and antimony sulphide expedited the process. Since then an enormous number of compounds has been investigated and many found to be extremely efficacious in reducing either the time or the temperature of vulcanisation. The accelerators now used are generally complex chemical compounds of an alkaline nature, some themselves containing sulphur, and are generally added in amounts up to 2 per cent., singly or in combinations.

The use of accelerators is now almost universal, and with good reason. They aid processing, save space and plant charges, and economise time and production costs.

(iii) *Softeners.* Materials such as paraffin wax, mineral tars and pitches are frequently added. They act as lubricants, and facilitate the mixing together of the rubber and other constituents.

(iv) *Anti-oxidants.* Frequently a small quantity of an anti-oxidant is included in the mix. These substances, like accelerators, are usually complex organic compounds, and possess the property of minimising or retarding the deterioration which all rubber suffers when exposed to atmospheric influences.

(v) *Miscellaneous.* Various other substances may be added. These include reclaim (regenerated rubber reclaimed from waste rubber) "substitutes" made from linseed oil, ground waste rubber, glue, colouring materials.

These (except the last) although frequently added for the sake of cheapness, are sometimes added to confer specific properties, as for example, glue, incorporated to increase solvent resistance in petrol hose.

It will be obvious that the manufacture of vulcanised rubber is a matter of considerable complexity. The manufacturer has to consider the advisability of using new ingredients, or adopting new processes, or varying one or more of the large number of components and variables, not only to improve quality, in what may be called his repetition production, but also to meet special requirements of the user ; and additionally to cheapen production and so lessen competition.

Vulcanisation Processes.

So far as "raw" rubber is concerned, no matter which particular process is adopted, the first step is the intimate mixing of the rubber and other ingredients. The raw rubber is warmed and softened usually by "masticating" or repeated passing between heated steel rolls under heavy pressure, until it has become sufficiently plastic. The other ingredients are now added to the rubber as it is passing between the rolls, cooling the latter as necessary to avoid the mixture commencing to "set up" or vulcanise. To minimise this danger the sulphur may frequently be added last, after the other additions have been made and mixed.

The mixture is now rolled to a suitable thickness, and cut or formed to the required shape; the compound is then wrapped in cloth, or enclosed in moulds, and heated by steam or other means sufficiently to vulcanise or "cure" it. Where the finished article is of thick section, it is necessary to heat up slowly to the vulcanisation temperature, on account of the low heat conductivity of rubber compounds.

Vulcanisation of thin-walled articles, e.g., balloons and small tubing, may be effected by the cold cure process; in this process the shaped compound (containing no sulphur) is either dipped into a solution, or exposed to the vapour of sulphur chloride. Under controlled conditions the sulphur chloride reacts with the rubber as does sulphur under the influence of heat.

A third process formerly used to some extent, known as the Peachey process, exposed the shaped compounded rubber to the action of sulphur dioxide and hydrogen sulphide. These two gases react to produce sulphur in a particularly active form. The process, however, has not remained in favour, partly for economic reasons.

Latex Vulcanisates.

Within recent years, progress in the rubber industry has resulted in a considerable production of rubber goods direct from the latex, and this in turn has led to the preparation of special latices for the purpose. With suitable precautions, the compounding ingredients can be mixed into the latex so that the whole remains in suspension, and the mixture deposited on to formers or articles to be coated, a sufficient thickness being obtained by dipping or electro-deposition. Where applicable, the process has several advantages over the older method of using rubber compounds dispersed in a solvent. It avoids the fire hazard or danger of fumes from the solvent; water soluble accelerators vulcanising at a much lower temperature can be used, and the products have superior physical properties, due to the avoidance of the mastication process which always destroys, to some extent, the "nerve" of rubber. As an example, it was found that ordinary toy balloons when made with latex rubber were too strong to be blown up by mouth.

A still later development is the production of vulcanised latex. As the name signifies, this is latex compounded and vulcanised while still remaining an emulsion. When applied to fabric or other articles to be coated, simple drying produces a tough and continuous film of vulcanised rubber.

The Testing of Rubber Compounds.

This short topical survey of rubber may conveniently terminate with a few words about the testing aspect.

Testing falls naturally into three sections.

Composition.—This may include determination of the amount and nature of the mineral and other fillers, of sulphur, and of amounts of material extracted from the rubber by various solvents. Consideration of the amount and nature of these extracts may enable conclusions to be drawn as to softeners, substitutes, etc.

General Physical Tests.—Other than dimensional checks, these commonly comprise determinations of tensile strength and elongation at break or certain stresses; also the extent of hysteresis or "set" which specimens exhibit after being stretched for definite periods.

Repeats of these tests may also be made on specimens which have been artificially "aged" by heating in air, steam or oxygen, sometimes under pressure.

Special and Performance Tests.—These are designed to test the suitability of the rubber compound for its specific purpose. Thus tyres and rubber flooring may be tested for resistance to abrasion, and tubing and hose for its resistance to splitting and kinking or pressure.

Conclusion.

The above is necessarily a brief outline of the technology of one of the most remarkable materials in world-wide and ever-increasing use to-day; remarkable not only for its adaptability and versatility, but also because, despite years of intensive study and research, we have yet no exact knowledge of the composition of the compound or compounds to which vulcanised rubber owes its characteristics.

Notes and Comments

Post Office Roll of Honour

We deeply regret to have to record the deaths, while serving with the Armed Forces, of the following members of the Engineering Department :—

Aberdeen Area : Davie, H. S., Unestablished Skilled Workman, Signalman, Royal Corps of Signals. MacDonald, C., Unestablished Skilled Workman, Able Seaman, Royal Navy. Taylor, W. O., Unestablished Skilled Workman, Signalman, Royal Corps of Signals.

Bedford Area : Bagnall, M. W., Unestablished Skilled Workman, Gunner, Royal Artillery.

London Area : Cooper, A. J., Skilled Workman, Class II, Signalman, Royal Corps of Signals, Grierson, S. K., Unestablished Skilled Workman, Signalman, Royal Corps of Signals. Wass, R. S., Unestablished Mechanic, Aircraftman, 1st Class, Royal Air Force.

Newcastle Area : Milne, J., Unestablished Skilled Workman, Lance Sergeant, Royal Artillery.

Ministerial Changes

We take this opportunity of welcoming to the Post Office the Rt. Hon. W. S. Morrison, M.C., K.C., M.P., who recently became the Postmaster-General in succession to Major G. C. Tryon. Major Tryon, who has been created a Baron and appointed Chancellor of the Duchy of Lancaster, carries with him the good wishes of the Post Office staff.

Mr. P. F. Rowell

Members of all classes of the Institution of Electrical Engineers will have heard with great regret of the death of Mr. P. F. Rowell, who, after thirty years of continuous service, retired only last year from the secretaryship of the Institution. After training at the Royal College of Mauritius and at King's College, London, Mr. Rowell served for a short time with the British Thomson - Houston Company before joining the staff of the Institution in 1901. He became Assistant Secretary in 1904 and Secretary in 1909.

Mr. Rowell was an excellent French linguist, and did much to promote the exchange of electrical knowledge between this country and France. For his work in this direction he was made an Officier de la Legion d'Honneur and a Membre d'Honneur de la Société Française des Electricians.

Erratum

It is regretted that an error occurred on page 35 of the April issue in the article dealing with "Storm Damage, January, 1940." It was stated that in the Evesham and Worcester Control Areas wires had been found centred in a covering of ice 8½ in. in diameter, weighing 3 lb. to the foot. This should have read that the ice was 3½ in. in diameter, not 8½ in.

Junior Section Notes

Leicester Centre

During the Winter Session six meetings were held, the programme being as follows :—

November 7th—" Lift Engineering," by Mr. Lindsey Evans, Lifts, Leicester.

November 21st—" Railway Signalling," by Mr. Somers, L.M.S. Railway, Derby.

December 18th—Series of ten-minute papers for the Chairman's and Centre prizes.

This is the second year that we have held this series of ten-minute papers, and, although the entries were smaller than last year, it was a most enjoyable and interesting evening. The reason for the drop in entries is owing to several of last year's competitors being on army service.

January 9th—" Underground Construction carried out by Contractors," by Mr. G. E. Gent.

February 19th—" Main Works Control," by Mr. H. R. H. McKail.

March 19th—" Local Line Underground Development," by Mr. Richards.

Considering the present conditions of black-out and the number of members serving with His Majesty's Forces, we have had a fairly successful session.

The officers for the past session were :—

Chairman : Mr. A. J. Read.
Vice-Chairman : Mr. E. Keyworth.
Secretary : Mr. P. L. Dunleavy.
Treasurer : Mr. E. C. Dyson.

Horsham Centre

The following programme was carried out successfully during the 1939-40 session :—

November 2nd, 1939—Mr. J. W. Corbett, " Construction of UAX No. 13 and their Conversion from Manual."

November 24th, 1939—Mr. G. T. Sparkes, " The Thermionic Valve."

December 12th, 1939—Mr. Hutchings, "Experiences with Lawrence in Arabia."

January 12th, 1940—Mr. E. Cork, " Siemens 16 System."

April 19th, 1940—Mr. H. C. Dungate, " Some Experiences with the G.P.O. Film Unit."

April 19th, 1940—Annual General Meeting.

The following have been elected as officers for the 1940-41 session :—

Chairman : Mr. A. S. Grout.
Vice-Chairman : Mr. S. T. Stringer.
Treasurer : Mr. K. J. Green.
Secretary : Mr. H. C. Dungate.

Regional Notes

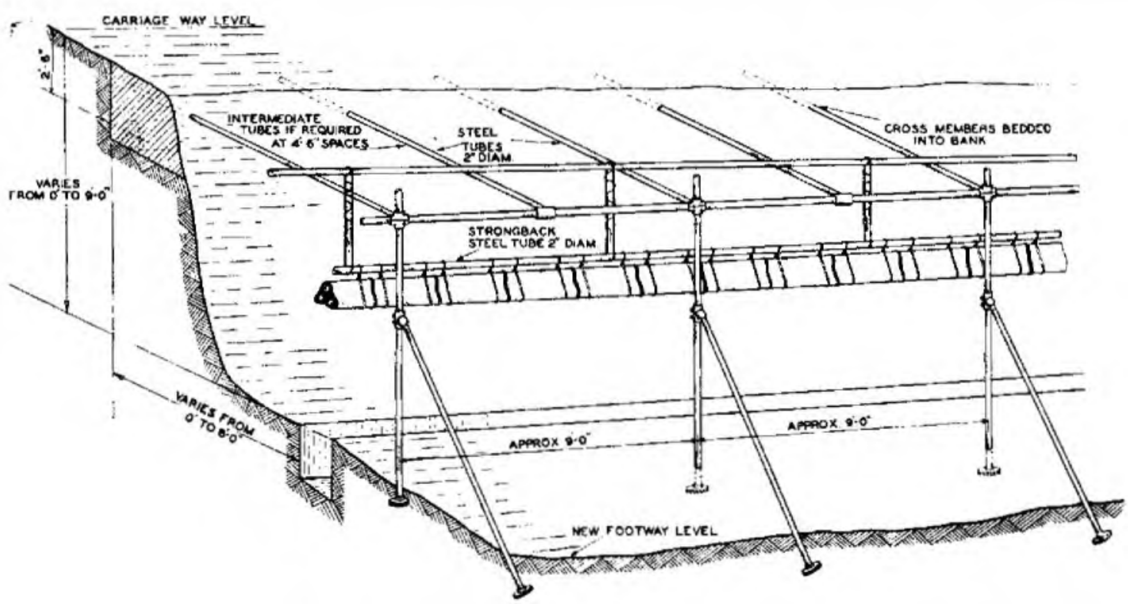
North Eastern Region

SLEWING AND LOWERING A 3-WAY DUCT

An unusual case of slewing and lowering a 3-way duct, one way of which contained the Leeds-Newcastle co-axial cable, has recently been completed. In connection with a road improvement scheme, which involved the removal of two humps in the carriageway, it was necessary to lower and slew the duct in two separate sections of 300 yards each: the highest point of lowering being 9 ft. and that of slewing being 8 ft.

To avoid an increase or decrease in the route length of the co-axial cable, and to minimise any risk of distortion at the four jointing points in the sections concerned, careful consideration had to be given to the line of the new track.

The Highway Authority removed all surplus earth down to the new level by mechanical means, the approach to the existing track being as close as possible consistent with the safety of the Department's plant, and the small quantity of earth remaining was sloped from the old trench to the new, which was excavated to receive the duct. The duct was then bared and jointing boxes demolished. Steel scaffolding was erected as indicated in the sketch (a contract having already been let for carrying out the work in this manner).



Each duct was lashed to a strongback consisting of a 2 in. steel tube, by undercutting the duct sufficiently to permit the sling being taken round the barrel, the strongback then being tied to the sling poles with an adjustable slip knot at approximately 7 ft. intervals until the whole length of 300 yards was securely held. The earth was then undercut to permit free suspension and movement. The actual lowering and slewing was commenced at the midway point in each section, which was also the greatest depth of lowering and width of slewing. Approximately 30 yards of track were dealt with in each movement, 12 men, one on each sling between the strongback and sling poles being engaged in the operation. Instructions were given as to the degree of lowering to be made in each movement, and such slewing as was necessary on the conclusion of the operation was made by pulling over the sling poles to a predetermined line. These operations were repeated until the 3-way duct was directly over the newly prepared track. It was then lowered into the trench, slings and strongback removed, and filling in operations completed.

The time taken for the actual lowering and slewing of each 300 yard section was approximately 7 hours, 12 men being engaged upon the work. Only 8 ducts suffered minor fractures at the collars, and the existing length and curvature of the co-axial cable was maintained throughout.

The method is suitable for wide slewing and deep lowering of any type of multiple way duct.

MAGNETIC STORM

A magnetic storm occurred over parts of the N.E. Region on March 24th and 25th, 1940. Although not severe enough to cause any widespread interruption to communications, the effects were noticeable over a wide area and the following brief reports from fault controls may be of interest.

York. Between 4.45 p.m. on March 24th, 1940, and 8.30 a.m. on March 25th, 1940, certain P.W.'s to Blyth, Catterick and Darlington, and the traffic junctions to Middlesbrough were reported noisy and found to have imposed on them a noise similar to a low dialling tone. Local services were not affected.

Harrogate. Intermittently between 4.30 p.m. on March 24th, 1940, and 8 a.m. on March 25th, 1940, the Boroughbridge, Hutton Sessay, Ripon junction (battery dialling), Huby junctions (loop dialling) and London junctions (generator signalling from Harrogate) were all affected. Complaints of wrong numbers also fairly frequent.

Hull. Short interruptions were experienced, the most important circuits affected being those to Lincoln and Barnsley.

Scarborough. At odd intervals during the day all junctions radiating from Scarborough were reported faulty, the chief trouble being P.G.'s on the C.B. calling junctions and the 17 c/s ringing junctions. A generator signal repeater (D.C. to A.C.) installed on a certain P.W. was continuously being operated by false currents.

It is interesting to note that on the evening of March 29th similar trouble was experienced on this same P.W., the disturbing current coming from beyond Manchester. Manchester Test advised Scarborough that a magnetic storm was causing trouble over Manchester at the time.

Welsh and Border Counties Region

CHESTER SECTION EXCHANGE TRANSFERS

Three important automatic transfers have taken place in the Chester Section since the beginning of the year at Hawarden (January 3rd, 1940), Conway (January 10th, 1940), and Deganwy (February 28th, 1940).

The first two are new exchanges of the new U.A.14 type and are the first to be installed in the Chester Section. Deganwy is a Siemens No. 16 satellite type exchange and completes the automatisation of the Colwyn Bay automatic area. With the automatisation of Conway and Deganwy, there remain only four small manual exchanges out of the total of 20 exchanges in the Colwyn Bay Maintenance Control Area to be transferred to automatic working.

OPENING OF THE TELEPHONE MANAGER'S AREA, CHESTER

On May 6th, 1940, the Chester Engineering Section became the Chester Telephone Area and, due to the prior opening of Shrewsbury and Stoke-on-Trent Telephone Areas, the Chester District Manager's Office ceased to function as such, the remaining staff being incorporated in the new telephone area. The event was marked by a tea at which the Chief Clerk, Mr. G. H. Russell, introduced the new telephone manager, Mr. W. H. Cope, to the local staff. Among the visitors present were Mr. J. T. Foxell, Regional Director, Mr. A. L. Barclay, Telephone Manager, Liverpool, Mr. R. F. Jones, Head Postmaster, Chester.

NEWPORT (MON.) CIVIC CENTRE TELEPHONE INSTALLATIONS

The Civic Authorities at Newport, Mon, decided to centralise the various bodies under their administration in a group of buildings to be erected at a new centre. The grouping and style of architecture for the buildings on the new site was the subject of a prize competition, the prize being secured by T. Cecil Howitt, F.R.I.B.A., of Nottingham, in December, 1936. The building erected initially under the scheme is that which accommodates the Law Courts and Police Headquarters. (See Fig. 1.)

Fig. 1.—Newport (Mon.) Civic Centre.

It will be observed that the building has been erected on a hill, and it is of interest to note that the ceiling of the basement at the rear of the building is higher than the floor level of the top storey at the front or south end of the building. The difference in floor levels would, in the normal course, have caused serious difficulties to the internal cabling network. In making early contact with the architect, however, these difficulties were overcome by fixing conduits in suitable positions when the shell of the building was being erected, and by close co-operation with the builders it was possible to install the complicated cabling scheme without any surface wiring whatsoever. The cabling scheme was further complicated by the domed ceiling effect, which was one of the main architectural features. In consequence, permission was given to run only one conduit through this area.

The services catered for include 17 exchange lines, 4 multi-coin box lines, 15 internal extensions, 1 house exchange system comprising 11 individual extensions, and miscellaneous police lines.

To cater for these services and to give full flexibility it was decided to run one 74-pair cable from the M.D.F. in the basement through all floors with a 240-wire distribution case on each floor, as shown in Fig. 2.

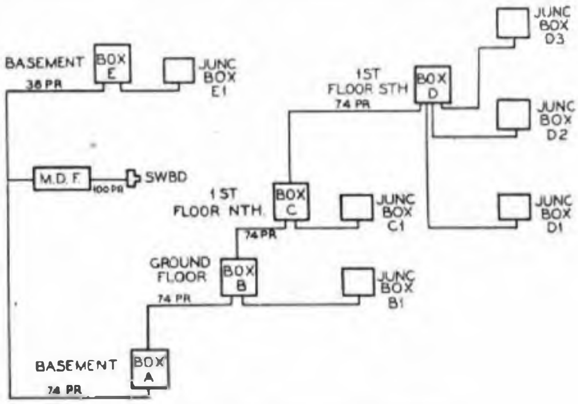


Fig. 2.—Main Cabling Scheme.

An additional 38-pair cable was also run from the M.D.F. to feed the north and east portions of the building.

The cabling method employed was briefly as follows:

The first twenty pairs of the 74 and 38-pair cables were teed together and terminated on tags 1 to 40 of each distribution case and were used exclusively for the house exchange system. From this point the house exchange system was wired in accordance with standard practice, i.e., via junction boxes and thence to jacks, two house exchange telephones being served by one junction box wherever this was practicable. The remaining 54 pairs were then terminated on tags 41 to 148 on the incoming side of the distribution case, the outgoing portion of the cable being terminated on tags 281 to 388. This layout of the tags was used for all distribution cases throughout the installation, complete flexibility thus being obtained by jumpering. For maintenance purposes and to facilitate the speedy installation of any future equipment, a schedule of all wires terminated in each distribution case has been made.

P.B.X. Switchboard.

The switchboard is a standard 2-position police alarm type and weighs approximately one ton when fully equipped. Terminations are provided for standard automatic exchange lines and extensions, police lines, etc.

Since intercommunication between the various house exchange telephones is available without the aid of the P.B.X. operator there is some saving in operating costs.

House Exchange System.

During the installation of this equipment, apprehension was felt regarding the reaction of the police authorities to the type of system, but it is satisfactory to know that its effectiveness in speed and efficiency is now much appreciated.

The H.E. instruments were of the standard 2 + 10 type modified to cater for eleven stations. The two exchange outlets were connected directly to the P.B.X. and modified to provide plan 9 facilities at each extension, the second outlet being used jointly by all extensions having the plan 9 facility. The re-arrangement of the standard wiring scheme of the house exchange system necessary to provide the foregoing modifications was supplied by the Engineer-in-Chief's Office.

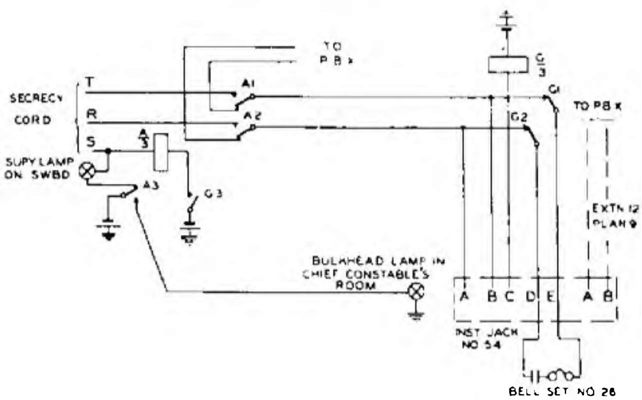


FIG. 3.—CHIEF CONSTABLE'S EXTENSION.

Additional modifications were also made on the Chief Constable's telephone to provide secrecy facilities on all exchange lines terminated on the P.B.X. A schematic diagram of the circuit is shown in Fig. 3. A brief description of the circuit is as follows :

The A and B wires of the Chief Constable's individual house exchange extension are intercepted at the P.B.X. and wired via the " resting " springs A1 and A2 to the standard extension termination. The " make " springs of A1 and A2 are wired to the tip and ring of a special cord fitted on the P.B.X. The sleeve of the cord is connected to the A relay and to a supervisory lamp mounted on the stile bar of the P.B.X.

In this installation the G relay was provided with additional springs G3 to control the operation of the A relay.

To originate a call the receiver of the house exchange telephone is lifted and the red press button associated with the first exchange outlet depressed. Relay G operates to the earth applied to the coil, and at G1 and G2 disconnects the bell from the speaking circuit. G3 prepares the circuit for the A relay. The call now proceeds as for an ordinary extension call, but should the originator of the call indicate to the operator that he desires secrecy conditions, the operator then calls the desired subscriber, and when the called subscriber answers the P.B.X. operator throws the hold key associated with the exchange jack in use, withdraws the standard calling plug and inserts the plug of the secrecy cord into the exchange jack.

The A relay operates to the earth extended via the bush of the exchange jack. A1 and A2 switch, and extend the A and B wires to the tip and ring of the secrecy cord. A3 connects battery to a bulkhead lamp fitted near the calling subscribers' telephone; the lamp glows during the conversation, thereby indicating to the Chief Constable that secrecy conditions have been applied. On the completion of the call, the red button releases when the receiver is replaced.

The G relay releases and at G3 restores the A relay, which extends battery via A3 (normal) to operate a supervisory lamp on the stile bar of the P.B.X.; the lamp is disconnected when the secrecy cord is withdrawn from the jack.

Miscellaneous.

Due to the international situation, great difficulty was experienced in obtaining switchboards, and it was decided to make use of the switchboards in use at the old police headquarters for the new headquarters. Appreciation was expressed by the authorities concerned as to the manner in which the whole of the work was carried out and the efficiency of the equipment provided and installed by the Department.

It is desired to thank the Newport Police Authorities for use of the photograph used in this article. C. C. H.

Book Reviews

" Electrical and Engineering Science." A. Morley, O.B.E., D.Sc., M.I.Mech.E., and E. Hughes, Ph.D., D.Sc., M.I.E.E. 256 pp. 152 ill. Longmans. 5s.

Those who are familiar with the first-year book, " Elementary Engineering Science," by the same authors, will be glad to learn that second-year course books, " Mechanical Engineering Science " and " Electrical Engineering Science," are now available. It is the second of these that is the subject of this review.

There is little which calls for criticism in this excellent volume, for the authors with their vast experience of teaching, present the subject in a very clear fashion and without recourse to any but the simplest mathematics. It is therefore admirably suited from this standpoint to the average student at Post Office Classes in Technical Electricity; but, unfortunately, the ground covered does not coincide exactly with that of the Technical Electricity Grade II syllabus. The differences are, however, small, being mainly that there is hardly enough information on secondary cells and, such matters as Leclanche cells and the megger are not included. On the other hand, D.C. machines are covered rather more fully than is necessary for this examination.

Numerous examples to be answered by the student are included, and the solutions, together with a set of logarithm tables, are given at the end of the book.

The work can be thoroughly recommended to second-year students.

H. L.

" Records and Research in Engineering and Industrial Science." J. E. Holmstrom, Ph.D., A.C.G.I., Assoc.M.Inst.C.E. 302 pp. London : Chapman & Hall. 15s.

Scientific workers should have a lively appreciation of the importance of documentation. This " ugly but comprehensive " word, as Dr. Holmstrom calls it, embraces all the processes necessary for effectively collating and disseminating the knowledge that is available in the world to-day. Some 750,000 articles and about 14,000 books are published annually, whilst the number of reports, specifications, drawings and other sources of information is probably too great to be estimated. The special libraries and information bureaux of research and industry provide the link between the scientific worker and this vast amount of knowledge. The author, who is an engineer with a wide experience of information work, has produced a concise guide to these resources which should be appreciated by the scientific worker and business man as much as it will be by the information officer and the librarian.

With a thoroughness which characterises this book, Dr. Holmstrom traces the production and utilisation of knowledge. He describes the methods used in scientific investigation, including sampling and statistical methods and shows how the knowledge so acquired is applied to practice, to design, manufacture and testing and to the management and development of industry. Under this section the author discusses inventions and patents. The two chapters devoted to a consideration of the organisation of university, government and other research organisations, and the activities of learned societies and conferences are particularly useful. The author, in what he considers the two most important chapters in his book, discusses technical libraries and information bureaux and the problems of documentation, such as the co-ordinating of abstracting services, with which they are faced. He gives a description of the Universal Decimal System of Classification and the Kaiser system, and illustrates the use of the personal index-file by a description of his own system. The chapter on technical dictionaries, translating and interpreting is backed by much experience.

This very readable book contains a great amount of information arranged in an orderly manner, and its opportune appearance at a time when the war is providing many scientific workers with new problems enhances its value.

J.E.W.

" Radio Interference Suppression." G. W. Ingram, B.Sc. 154 pp., 56 ill. " The Electrical Review." 5s.

This little book is intended by the author to be " a standard practical work and a theoretical treatise on the subject of radio interference and its suppression." The book is divided into five sections. Section 1 deals briefly with the nature of electrical interference, and methods of detecting its presence. Section 2 deals with the production of interference by electrical plant; the design of suppression apparatus is dealt with in some detail. In Section 3 practical information is given about the types of interference suppressors appropriate to a large number of types of domestic and industrial plant. The book concludes with Sections 4 and 5 and three appendixes, which give a certain amount of miscellaneous data and a bibliography.

A number of omissions and minor inaccuracies are noticed. It is a pity that no clear idea is given of the precise mechanism whereby radio interference is produced, and the section on the basis of design of suppression apparatus (pp. 43-45) is perhaps a little misleading in that undue emphasis is given to the use of inductors for suppression, whereas in practice capacitors are of rather more wide application. Some mention could usefully have been made here of the impedance properties of a capacitor at radio frequencies, and their effect on interference suppression. A more serious omission is the absence of any reference to the question of protection of the user from shock, when capacitors are connected from the supply mains to the framework of an unearthed or portable electric appliance.

The author makes the common mistake of showing shunt capacitors used for interference suppression at the source as being connected to earth, whereas fundamentally they should be connected to the frame of the interference-producing machine, connection to earth being purely incidental. Anti-interference aerial systems are barely mentioned, with the exception of one particular trade type.

The book serves as a general introduction to radio interference suppression, regarding which, however, it is almost entirely non-theoretical. An amount of space which could ill be afforded in a book of this size has been devoted to audio frequency induction and interference problems.

B.

Staff Changes

Promotions

Name	Region	Date
From Reg. Engr. to Deputy C.R.E.		
Brown, C. W.	L.T. Reg.	To be fixed later
From Asst. Engr. to Exec. Engr.		
Balcombe, J.	E.-in-C.O.	1.4.40
Mortimer, H.	H.C. Reg.	5.5.40
Meldrum, F. A.	N.W. Reg.	19.4.40
Cosh, L. G.	E.-in-C.O.	1.9.39
Christie, G. C.	W. & B.C. to N.E. Reg.	14.5.40
Irwin, A.	E.-in-C.O.	30.4.40
From Prob. Asst. Engr. to Asst. Engr.		
Parton, J. E.	E.-in-C.O.	16.5.40
From Chief Insp. to Asst. Engr.		
Edmondson, J.	N.E. Reg.	12.4.40
Osborne, A. D.	E.-in-C.O.	19.4.40
Grainger, C. H.	Scot. Reg.	14.5.40
Whitmore, L. H.	Mid. Reg. to E.-in-C.O.	1.6.40
Davies, R. C.	N.W. Reg.	1.6.40
Matthews, R. F.	L.T. Reg.	To be fixed later
From Chief Insp. to Chief Insp. with allowance		
Thornley, H. G.	N.W. Reg.	24.3.40
Anderson, J. B.	N.E. Reg.	To be fixed later
From Insp. to Chief Insp.		
Jones, H.	L.T. Reg.	28.8.39
Fudge, G. A. E.	E.-in-C.O.	31.1.40
Robinson, R. B.	E.-in-C.O.	12.9.39
Williams, L. A.	E.-in-C.O.	19.12.39
Herbert, L. J.	E.-in-C.O.	25.2.40

Name	Region	Date
Draughtsman Cl. I to Chief Insp.		
Morris, A. J.	E.-in-C.O.	1.4.40
From Unest. Draughtsman to Insp.		
Whitlock, A. F.	E.-in-C.O.	To be fixed later
From Actg. Chief Officer to Actg. Asst. Sub. Supt.		
Betson, J. P. F.		16.3.40
From 2nd Engr. to Actg. Chief Engr.		
Middleton, W.	"Monarch"	To be fixed later
From 3rd Engr. to Actg. 2nd Engr.		
Sloss, J.	"Monarch"	To be fixed later
From 4th Engr. to Actg. 2nd Engr.		
Fisher, H. C.	"Monarch" to "Alert"	To be fixed later
From 4th Engr. to Actg. 3rd Engr.		
Parker, C.	"Alert" to "Ariel"	To be fixed later
From 5th Engr. to Actg. 4th Engr.		
Cassingham, J.	"Alert"	To be fixed later
From Temp. 4th Officer to Actg. 2nd Officer		
Finlayson, J. R.	"Alert" to "Ariel"	To be fixed later
From Temp. 4th Officer to Actg. 3rd Officer		
Evans, C. M. G.	"Alert" to "Ariel"	To be fixed later
Ramshaw, A.	"Monarch" to "Alert"	To be fixed later
Garnett, F. J.	"Monarch"	To be fixed later

Transfers

Name	Region	Date
Exec. Engrs.		
Barron, D. A.	N.W. Reg. to E.-in-C.O.	7.4.40
Britton, F. T.	N.E. Reg. to H.C. Reg.	14.5.40
Asst. Engrs.		
Irwin, A.	N.W. Reg. to E.-in-C.O.	24.3.40
Glover, R. P.	E.-in-C.O. to S.W. Reg.	8.4.40
Young, J. E.	L.T. Reg. to E.-in-C.O.	26.4.40
Hawkins, C. F. W.	E.-in-C.O. to L.T. Reg.	1.5.40
Foulger, E.	E.-in-C.O. to W. & B.C. Reg.	1.5.40
Prob. Asst. Engrs.		
Billen, J. C.	W. & B.C. Reg. to E.-in-C.O.	22.3.40
Easterbrook, A. B.	L.T. Reg. to E.-in-C.O.	18.3.40
Warner, M.	Mid. Reg. to E.-in-C.O.	8.4.40
Pilling, T.	Mid. Reg. to E.-in-C.O.	8.4.40
Horner, G. H.	L.T. Reg. to E.-in-C.O.	7.4.40
Chief Insps.		
Osborne, A. D.	L.T. Reg. to E.-in-C.O.	26.2.40
Towle, E. H. N.	E.-in-C.O. to N.E. Reg.	1.6.40
Insps.		
Bennett, H. V.	N.W. Reg. to E.-in-C.O.	7.4.40
Heaton, N.	N.W. Reg. to E.-in-C.O.	14.4.40
Herbert, L. J.	L.T. Reg. to E.-in-C.O.	25.2.40
Sundewall, J. R.	E.-in-C.O. to H.C. Reg.	21.4.40
Aspinall, E.	N.W. Reg. to E.-in-C.O.	21.4.40
Branston, E. C.	N.E. Reg. to E.-in-C.O.	19.4.40
Rowe, J. F.	E.-in-C.O. to S.W. Reg.	29.4.40
Alston, R. E.	Mid. Reg. to E.-in-C.O.	19.5.40
Middleton, A. M.	E.-in-C.O. to Mid. Reg.	20.5.40

Name	Region	Date
Insps.—continued		
Benton, G. C.	H.C. Reg. to E.-in-C.O.	26.5.40
Smith, W. J.	E.-in-C.O. to H.C. Reg.	1.6.40
Collins, F. L.	E.-in-C.O. to Mid. Reg.	31.5.40
Prob. Insps.		
Humber, A. J.	H.C. Reg. to E.-in-C.O.	26.3.40
Davies, W. M.	L.T. Reg. to E.-in-C.O.	17.3.40
Curry, W. R.	H.C. Reg. to E.-in-C.O.	26.3.40
Pearson, D. O.	Scot. Reg. to E.-in-C.O.	31.3.40
Jeffery, D. A.	H.C. Reg. to E.-in-C.O.	31.3.40
Yates, A. W. J. J.	S.W. Reg. to E.-in-C.O.	1.4.40
Slough, H. R.	L.T. Reg. to E.-in-C.O.	8.4.40
Williams, M. B.	L.T. Reg. to E.-in-C.O.	8.4.40
Baker, L. M.	L.T. Reg. to E.-in-C.O.	10.4.40
Fielding, H.	N.W. Reg. to E.-in-C.O.	8.4.40
Cook, S. W.	N.W. Reg. to E.-in-C.O.	14.4.40
Griffiths, R. J.	L.T. Reg. to E.-in-C.O.	15.4.40
Wraight, F. A.	N.W. Reg. to E.-in-C.O.	21.4.40
Parsons, R. J.	H.C. Reg. to E.-in-C.O.	28.4.40
McKane, J. C.	H.C. Reg. to E.-in-C.O.	28.4.40
Sparkes, G.	N.E. Reg. to E.-in-C.O.	28.4.40
Ross, J. M.	S.W. Reg. to E.-in-C.O.	28.4.40
Shore, A.	L.P. Reg. to E.-in-C.O.	28.4.40
Easton, K. J.	S.W. Reg. to E.-in-C.O.	12.5.40
Dodd, G. A.	S.W. Reg. to E.-in-C.O.	12.5.40
Jones, J. R.	W. & B.C. Reg. to E.-in-C.O.	15.5.40
Rudge, M. S.	Mid. Reg. to E.-in-C.O.	19.5.40
Thompson, R. H.	Mid. Reg. to E.-in-C.O.	26.5.40
Taylor, R. E.	Mid. Reg. to E.-in-C.O.	26.5.40
Hughes, L. S.	W. & B.C. Reg. to E.-in-C.O.	30.5.40
Ash, W. S.	W. & B.C. Reg. to E.-in-C.O.	30.5.40

Retirements

Name	Region	Date	Name	Region	Date
Submarine Supt.			*Chief Insps.*		
Ramsay, F. G.	E.-in-C.O.	11.3.40	Lester, J. R. B.	H.C. Reg.	30.4.40
Exec. Engrs.			Scarborough, H.	W. & B.C. Reg.	13.5.40
Morell, E. J.	E.-in-C.O.	29.2.40			
Lonnon, W. U.	E.-in-C.O.	31.3.40	*Insps.*		
Linsell, F. A.	N.E. Reg.	31.3.40	Ede, C. E.	N.E. Reg.	14.6.40
Beighton, T. A.	H.C. Reg.	30.4.40	Marsden, M.	Mid. Reg.	23.5.40
Baldwin, D. Z.	E.-in-C.O.	14.6.40	Turner, F. G.	L.T. Reg.	1.6.40
Asst. Engr.					
McMeeking, J. M.	E.-in-C.O.	31.3.40	*2nd Officer*		
Young, D.	H.C. Reg.	31.3.40	Ryan, F. N.	" Alert "	10.6.40

Deaths

Name	Region	Date	Name	Region	Date
Chief Insp.			*Insp.*		
Green, S. W.	H.C. Reg.	28.3.40	Mantle, A. W.	Mid. Reg.	18.4.40

CLERICAL GRADES

Promotions

Name	Region	Date	Name	Region	Date
From Staff Officer to Principal Clerk			*From C.O. to E.O.—continued*		
Farries, L. J.	E.-in-C.O.	1.4.40	Carter, L. A.	E.-in-C.O.	29.2.40
			Knight, H.	E.-in-C.O.	19.4.40
From H.C.O. to Staff Officer			Nelson, H. W.	E.-in-C.O.	19.4.40
Simpson, W. W.	Mid. Reg.	18.3.40	Ridland, L.	E.-in-C.O.	21.5.40
			Quartermaine, H.	E.-in-C.O.	21.5.40
From C.O. to E.O.			*From C.O. to H.C.O.*		
Garratt, F. F.	L.T. Reg. to E.-in-C.O.	11.9.39	Bruce, A. M.	Scot. Reg. to S.W. Reg.	18.3.40
Woodford, G. C. R. (Miss)	M.O.D. to E.-in-C.O.	2.10.39	Ashton, A.	W. & B.C. Reg. to Mid. Reg.	29.4.40

Communications

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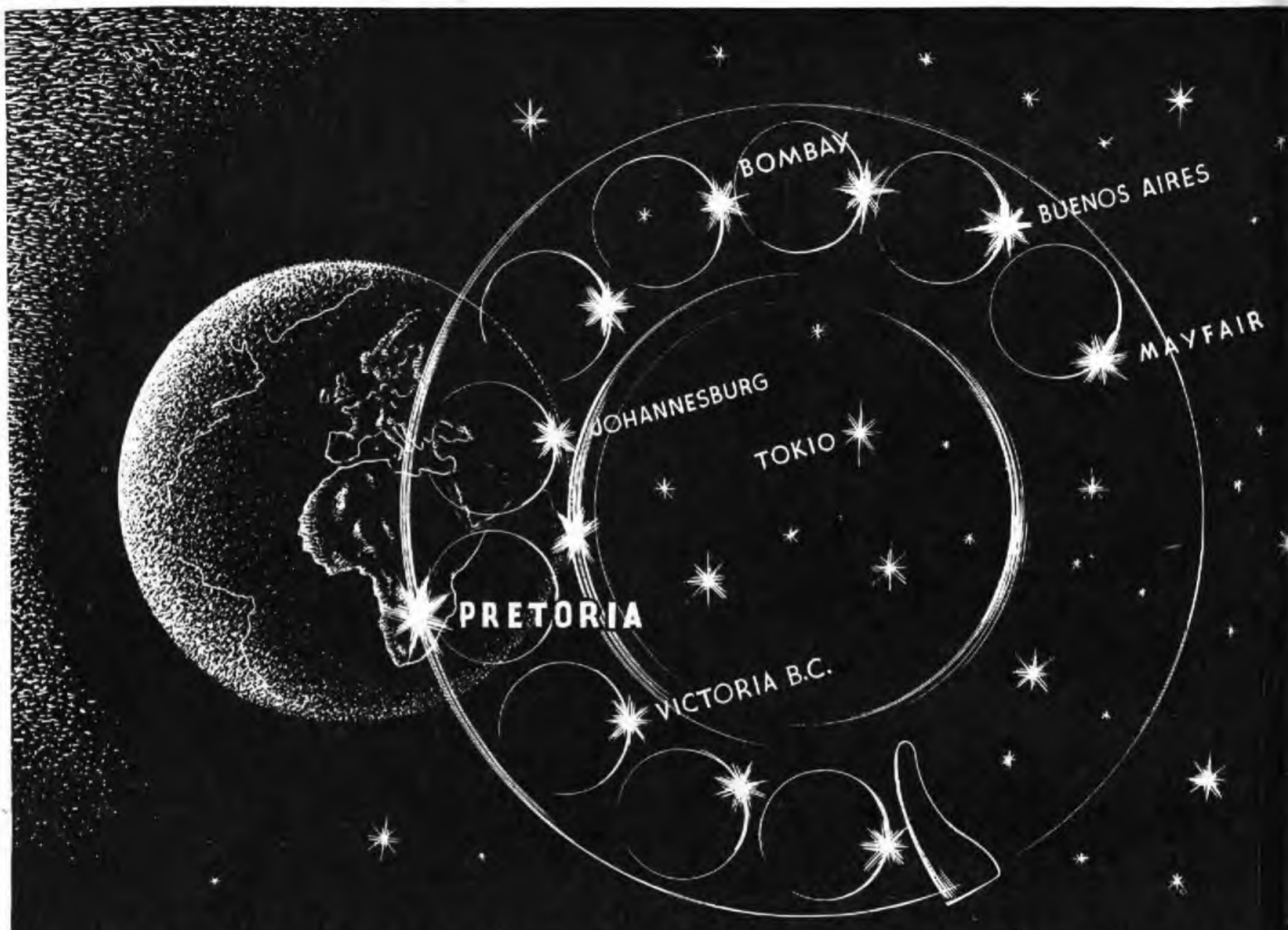

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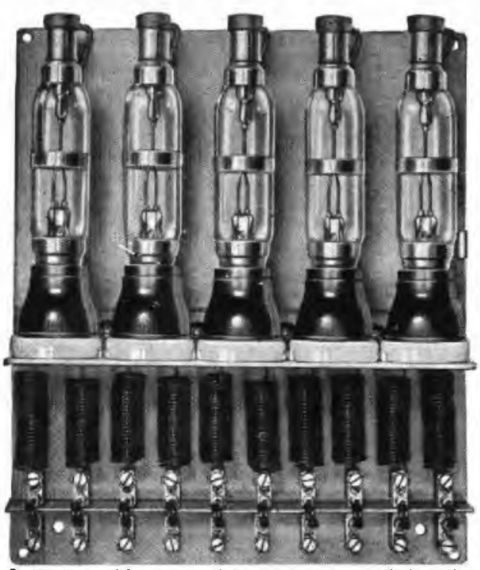

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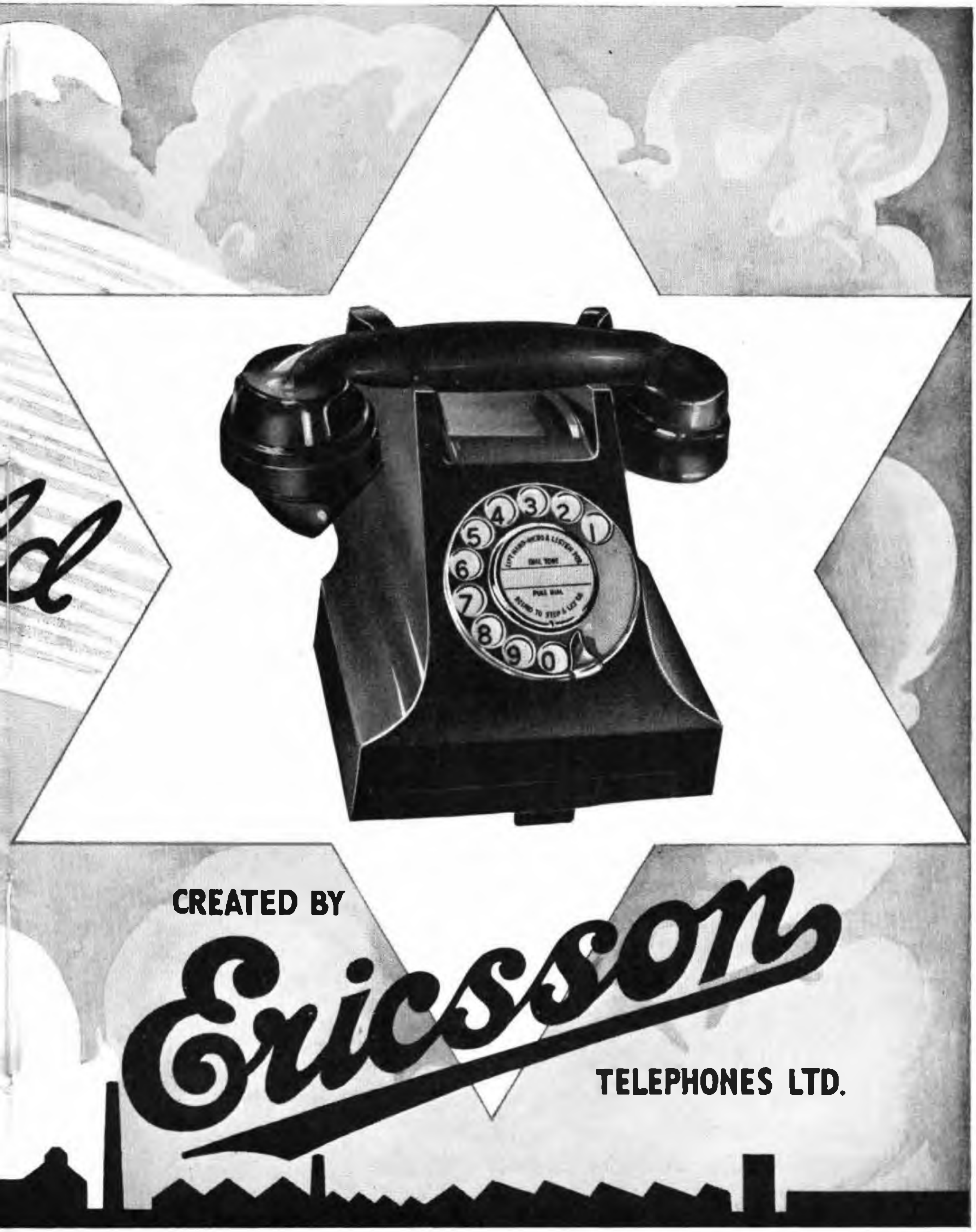
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