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The
# Telecommunication Journal of Australia

*Vol. 7, No. 5* *October, 1949*

# METALS AND ALLOYS IN TELECOMMUNICATION.*
## PART I — FERROUS METALS

*H. Weir*

**Summary:** The first section of Part 1 deals with some terms and tests used in metallurgical practice. An elementary knowledge of these is necessary for a better understanding of the reasons which lie behind the use of a choice of the various metals and alloys for their respective fields of application. These include ultimate tensile strength, yield point, proof stress, elongation and reduction of area, Izod impact, Brinell and other hardness scales, fatigue and creep.

The remainder of Part 1 covers ferrous metals and alloys, including cast iron and its variants, mild steel, carbon and alloy steel and their heat-treatment and special purpose alloys for electrical and communication purposes.

Part 2, which will appear in a subsequent issue of the journal, is devoted to non-ferrous metals and alloys, and includes the brasses, bronzes, cupro-nickel and other copper base alloys, the light alloys of aluminium and magnesium, and a miscellaneous group of special purpose alloys, such as solders. bearing metals, die casting alloys, low melting-point alloys, the specially hard alloys, Stellite and Tungsten Carbide, and high electrical resistance alloys of various types.

**Introduction:** The object in presenting this paper is not to publish any new or original material, for most of the information contained therein will be found in a number of other publications. The purpose of the paper is to present in a form for ready reference a collection of information and data on various metals and alloys which a telecommunication engineer is likely to meet in his daily work. It should assist in a clearer understanding of the reasons why certain metals and alloys are used for specific purposes and may be of some help in an approach to the problems of the engineer in finding the best material for a specific job. A list of references will be found in the Bibliography for those who wish to pursue this subject in greater detail than this paper permits. The science of metallurgy is very closely allied to engineering, is one for which the engineer's training forms a sound groundwork, and is also one which will be found a valuable aid in the execution of the job. In addition, the subject is not without interest.

* Paper presented to the P.M.G. Engineers' Group of the Professional Officers' Association (N.S.W. Branch).

### METALLURGICAL TERMS AND SIMPLE TESTS

In the comparison of the suitability of metals and alloys for their various purposes, it is necessary to have a basis of comparison. For this purpose certain properties such as strength, ductility, hardness, shock resistance, etc., must be known, and tests have been devised for ascertaining this information. As is obviously necessary when comparisons have to be made, the methods of making these tests, and the conditions under which the tests are made, have become fairly well standardised. Some of these will now be described.

#### Ultimate Tensile Strength

This is one of the most usual mechanical tests, and determines the force required to stretch and break the metal. During this test several other important test figures which form standard bases for comparison can be obtained, and will be referred to later. A specimen is first turned to the shape and dimensions in Fig. 1. These have been standardised for reasons that will appear later. The diameter of the narrowest parallel is 0.564" so that the cross-sectional area is 0.25 sq. ins.

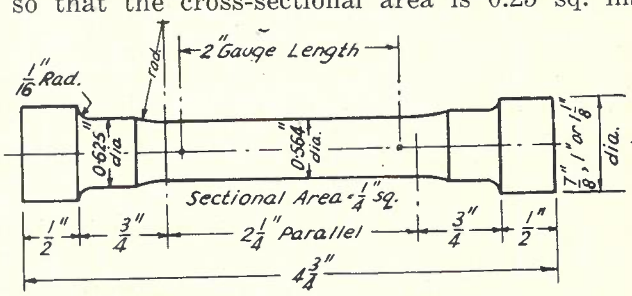


Fig. 1.—Tensile test specimen dimensions.

Two marks are scribed or punched exactly 2 ins. apart. This is known as the "gauge length" and will be used in measuring the amount which the metal stretches.

The specimen is placed in a tensile testing machine, which consists of (a) a straining device such as a screw and nut, or a plunger subjected to hydraulic pressure; (b) means of measuring the load on the specimen, such as the position of a jockey weight on a beam mechanically linked (through a system of levers) to one end of the specimen; and (c) means for measuring the amount of stretch. Usually this amount is small and necessitates the use of magnifying devices, called extensometers. The difficulty of measuring small elongations and errors and limitations arising from this will be referred to later.

Suppose that a piece of mild steel is being tested as referred to in the foregoing. If a load of 3 tons is applied, the length between the gauge marks will be found to have increased by approximately 1/100 of an inch. If the load is removed, the specimen returns to its original length. In other words, it has been elastic. After the load reaches 4 tons the steel will not return to its original length if the load is removed, but remains permanently stretched. The steel is said to have reached its elastic limit. In the case under consideration the stress would be 4 tons/0.25 sq. ins., or 16 tons per sq. in.

If the load be increased beyond 4 tons the extension increases more rapidly until, at about 7.5 tons, the steel continues stretching without any increase of load, a neck appears at the centre and finally the test piece breaks at the necked portion, the pieces being as per Fig. 2. Calculation will

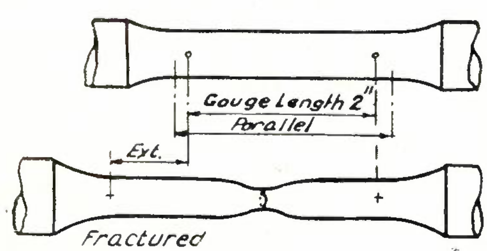


Fig. 2.—Tensile test specimen failure.

show that the piece broke at 30 tons per sq. in., which is known as the ultimate tensile stress. If the two pieces are fitted together, and the original marks denoting the gauge length measured, they will now be found to be 2.5" apart, representing an elongation of 25 per cent. **on 2 inches.** Note specially the latter. It is necessary to specify the length, because the elongation is made up of two components:—

(a) Uniform extension, which is proportional to gauge length, plus

(b) Local extension, due to necking. This is independent of gauge length, but varies with cross-sectional area of specimen.

However, as geometrically similar test specimens behave similarly, the same elongation should be obtained if:—

Gauge length/$\sqrt{\text{Area of section}}$ = Constant

Unfortunately, this has not been standardised, the figures being:—

England, $4\sqrt{\text{Area}}$ (which is 2" for d = 0.564", area = 0.25 sq. in.)

America, $4.47\sqrt{\text{Area}}$

Germany, $11.3\sqrt{\text{Area}}$

If the smallest diameter of the local neck is measured, another test figure may be obtained—the percentage reduction in area. If the relation of extension to applied stress is shown in graphical form (see Fig. 3), several interesting features appear. The first is that the point at which the curve deviates from a straight line is not very definite. This point "P" is called the limit of proportionality and recent investigations show that it becomes lower as more sensitive measuring devices become available. The next is that for some metals the elastic limit "E" does not coincide with "P" but is above it. However, a very definite change in the shape of the curve occurs just beyond "E" and is called "yield point." This is a much more satisfactory basis of comparison than "E" or "P" for reasons given above. In fact one authority (Rollason—Metallurgy for Engineers) states in this respect, "Some of the high values now in use ("E" and "P") are due to the inability of the extensometer to detect small amounts of permanent extension."

However, the very hard steels and non-ferrous metals do not show a sharply defined yield point, and for such it has become essential to specify a stress which corresponds to a definite amount of permanent extension. The usual amount is 0.1% extension and the corresponding stress is called the 0.1% proof stress. The material meets the specification if, after the proof stress is applied for 15 seconds and removed, the permanent extension is not more than 0.1% of the gauge length. The foregoing comprise the usual bases of comparison for strength and ductility. Except for certain metals, such as cast iron and lead, tests of compressive strength are not usually made.

### Hardness Tests

Another property, namely, hardness, is of importance in comparing metals, as it largely determines resistance to wear, machineability, and cutting ability. A large number of methods of measuring hardness have been proposed (some 30 in all) but only four are in general use, viz., Brinell, Vickers, Rockwell and Shore. Only the first two are in common use, so the latter two will not be further treated here. The Brinell test consists of indenting the surface of the test piece with a hardened steel ball, 10 m.m. diameter, under a standard load (3000 k.g. for steel, 1000 k.g. and 500 k.g. for aluminium) for 15 seconds. The diameter of the impression is measured with a low power microscope and the Brinell number H is calculated from,

$$H = \text{Load/Spherical area}$$
$$= P/\pi D/2\ [D - \sqrt{D^2 - d^2}]\ \text{k.g. per sq. m.m.}$$

where P = load in kilograms.
D = diameter of the ball in m.m.
d = diameter of impression in m.m.

area of the impression gives the Vickers pyramid number. The Vickers test is better for hard materials and for thin sheets than the Brinell, although the Brinell and Vickers hardness values are practically identical up to 300. The Brinell number is not reliable over 600. Test figures of hardness, tensile strength, proof stress and

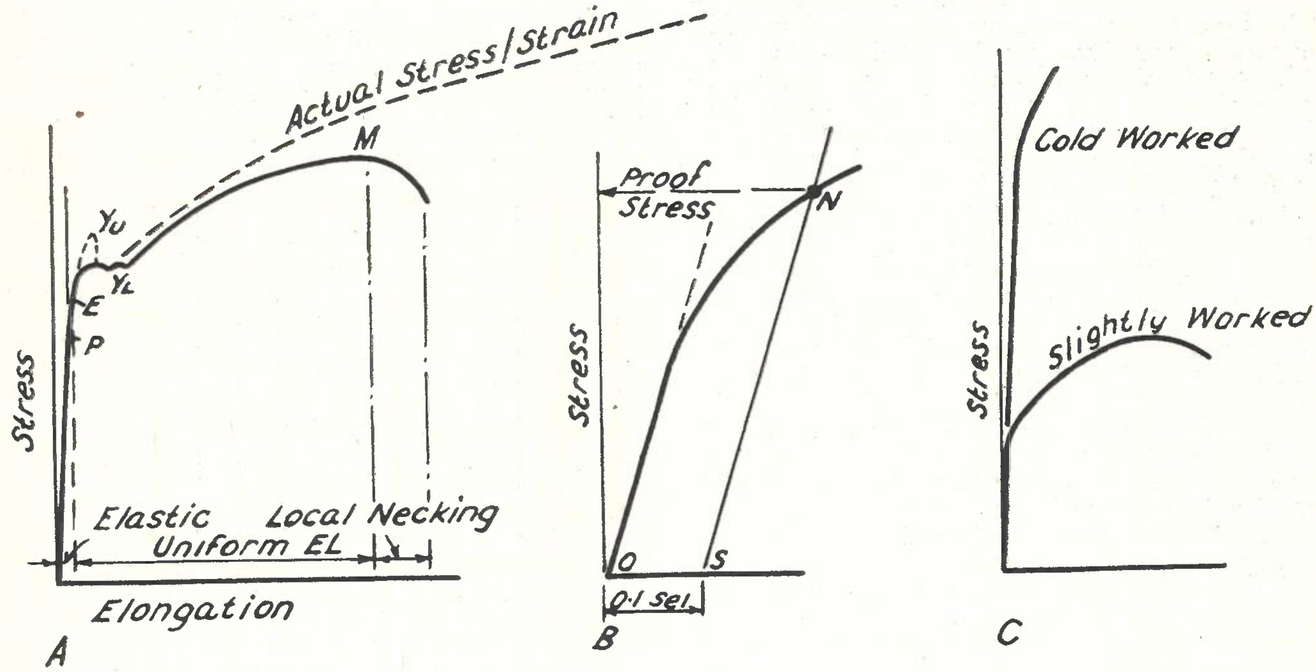


Fig. 3.—Stress/strain curves, mild steel.

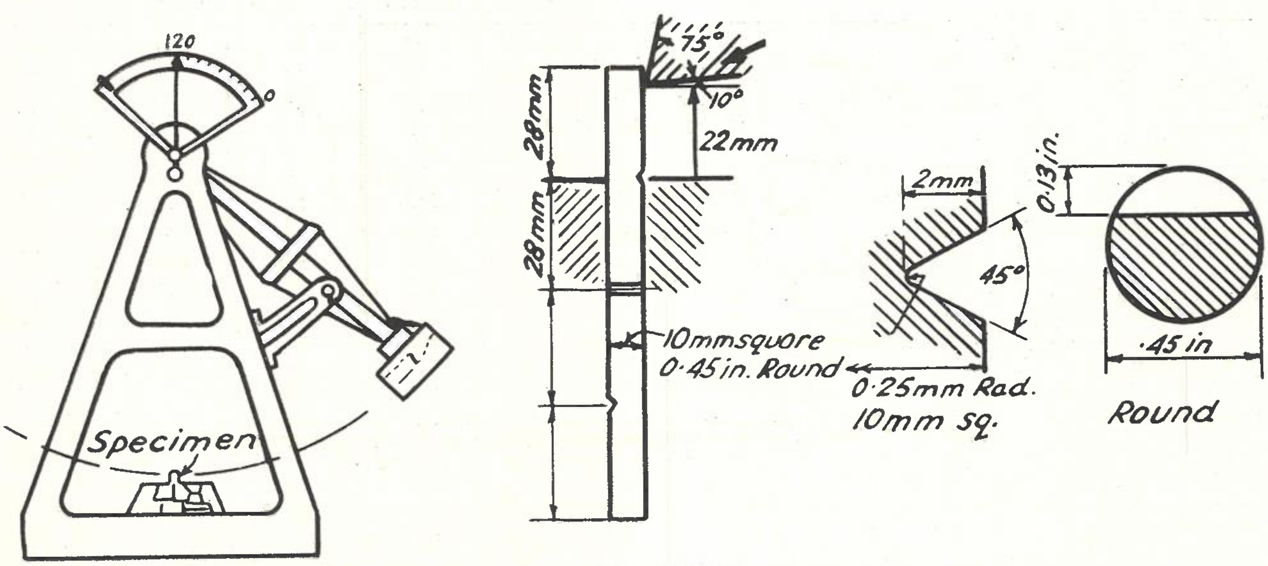


Fig. 4.—Izod impact tests.

Errors arise when the Brinell test is used on very hard materials, due principally to flattening of the ball. These are eliminated in the Vickers test, which uses a diamond in the shape of a square based pyramid. This does not readily deform and gives geometrically similar impressions under different loads. The load divided by the elongation of some well known metals are given in Table No. 1.

### Izod Impact Test

Under conditions of sudden load or shock, some metals behave differently from what might be expected from the tensile tests alone. For example, certain steels may be heat-treated to give high tensile strength, but may snap under a slight impact. Another type with a lower tensile strength might withstand a severe impact without failure. Generally speaking, the lowest impact values are obtained in the fully hardened (i.e., untempered) steels which, although having high tensile strength and hardness, are brittle. The type of test most used in English-speaking countries was developed by Edwin G. Izod (see Fig. 4). In this test a notched bar of standard dimensions is held in a vyce and broken by a heavy swinging pendulum. The amount of energy absorbed in breaking the specimen is measured in foot pounds.

The effect of the notch is to set up stress concentrations at the root of the notch and is well illustrated by the ease with which glass can be cracked when notched with a glass cutter. As a rule, low Izod values go with high tensile strengths and vice-versa, although the nickel-chrome-molybdenum steels show the best compromise in this respect. An Izod value of less than 40 foot-lbs. is regarded as unsatisfactory for parts subject to shock under working conditions, and it is usual to specify this minimum value for most automobile and aircraft steels. Some typical Izod values are shown in Table No. 2.

Further uses of the Izod test are:—

(a) It gives a guide to resistance to failure at a discontinuity, i.e., resistance to stress concentration at a change of section.

(b) An indication is given of the resistance to the spread of a crack, once it has formed.

### Fatigue

So far, tests which have been described indicate the properties of metals when stressed once only, and in one direction. Metals in service often have to undergo many thousands, and sometimes millions, of stress reversal, for instance connecting rods and crankshafts in internal combustion

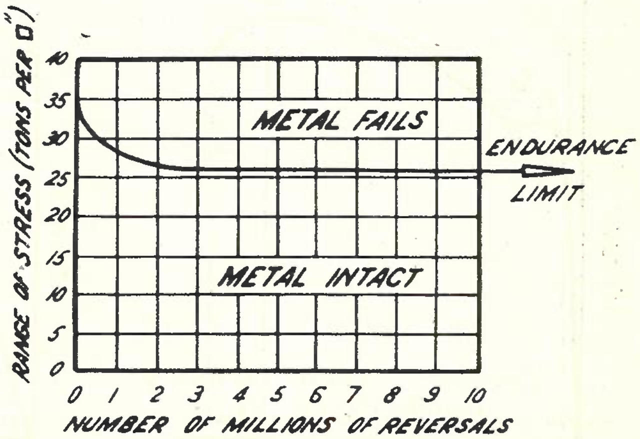


Fig. 5.—Endurance limit steel.

| Metal or Alloy | Condition | As used for | Brinell hardness number | Ultimate tensile stress (tons–sq. in.) | 0·1 per cent Proof Stress (tons–sq. in.) | Elongation per cent on 2 in. |
|---|---|---|---|---|---|---|
| Aluminium | Wrought and annealed | Frying pans | 27 | 6 | 2 | 18 |
| Aluminium alloyed with 7% magnesium | Wrought and annealed | Tubes and sheet for aircraft | 80 | 20 | 8 | 17 |
| Duralumin | Wrought and heat-treated | Aircraft | 115 | 28 | 17 | 15 |
| Magnesium alloy, with 8% aluminium | Cast and heat-treated | Aircraft landing wheels | 60 | 17 | 5 | 10 |
| Copper | Wrought and annealed | Tubes | 50 | 14 | 4 | 55 |
| | Cold-drawn into wire | Copper wire | 110 | 28 | 26 | 4 |
| 70/30 brass | Deep drawn | Cartrides | 160 | 35 | 30 | 10 |
| 70/30 copper-nickel alloy | Drawn into tube | Condenser tubes | 170 | 38 | 30 | 8 |
| Wrought iron | Hot rolled into rod | Chains | 100 | 20 | 13 | 30 |
| Mild steel | Hot rolled into plate | Ships' plates | 130 | 30 | 15 | 25 |
| Nickel-chromium steel 3·7% nickel | Forged, quenched and tempered at 400°C | Camshafts | 400 | 86 | 77 | 14 |
| 0·8% chromium 0·2% carbon | Forged, quenched and tempered at 600°C | Gears | 300 | 65 | 57 | 22 |
| Cast iron | Cast | Lathe beds | 200 | 14 | — | — |

**Table No. 1—Typical values of hardness, tensile strength, proof stress and elongation**
(from "Metals in the Service of Man" page 88)

| Type of Steel | Condition | Ultimate tensile stress (tons–sq. in.) | Yield point (tons–sq. in.) | Izod (foot–lb.) |
|---|---|---|---|---|
| Special H.T. Nickel-Chrome Alloy (Brown's "Duratlas") | Oil hardened 850°C | | | |
| | Not tempered | 117 | 87 | 17 |
| | Tempered 510°C | 85 | 81 | 26 |
| | Tempered 600°C | 71 | 67 | 50 |
| 0·2%C (low carbon) steel | Normalised from 870°C | 30 | >50% | 90 |
| 3·5% Nickel ("Atlas") for tram axles | Oil hardened and tempered | 50 | 39 | 46 |

**Table No. 2—Izod impact values for various steels**

engines. The stress required to cause failure if it is applied a number of times is much less than that necessary to break the metal at a single pull. Failure under these conditions is called fatigue. Steel (but not non-ferrous metals) will withstand a certain range of stress repeated an infinite number of times without failure, but at higher stresses the number of alternations which can be withstood becomes smaller.

It will be seen from Fig. 5 that an alternating stress of 25 tons can be applied to this steel indefinitely without failure. Such a steel is said to have an "endurance limit" of ± 25 tons. If an alternating stress of 26 tons is applied the life would only be $2 \times 10^6$ reversals, and at 30 tons only $5 \times 10^5$ reversals. In contrast to steel, most non-ferrous alloys do not show a definite endurance limit, but have a given life for any stress range. A typical example is shown in Table No. 3 for a duralumin alloy.

| Stress range, tons/sq. in. | Number of reversals before failure |
|---|---|
| ±12·3 | $1 \times 10^6$ |
| ±10·3 | $5 \times 10^6$ |
| ± 9·7 | $10 \times 10^6$ |
| ± 8·0 | $50 \times 10^6$ |
| ± 7·7 | $100 \times 10^6$ |

**Table No. 3—Endurance of a duralumin alloy under stress reversal (Ultimate tensile stress approximately 28 tons per sq. in.)**

It should be specifically noted that light alloy components subject to stress reversal have a finite life and must be renewed if fatigue failure is to be avoided. Machines have been developed to measure endurance limits, the most commonly used being that developed by Wohler. Sometimes failures may occur prematurely under repetitions of stress lower than that indicated by test specimens. The most likely cause is the influence of an abrupt change of section causing stress concentration at a corner without an adequate radius. Such failures are more often the result of poor design or bad machining than the quality of the metal. The endurance limit is also lowered by a corrosive medium such as salt water.

### Creep

There is also another long-term phenomenon in addition to fatigue, which does not appear in the short term tests already described. This is the slow plastic deformation of metals under a constant stress, and is known as "creep." It may take place in:

(a) soft metals used at ordinary temperatures, such as lead pipe and sheet, and white metal bearings;
(b) metals in steam and chemical plants operating at about 500°C.;
(c) metals at higher temperatures such as those in furnaces and gas turbines.

Creep can take place and lead to fracture at static stresses much smaller than those which will break the specimen when loaded quickly as under the usual tensile test conditions. Tests for creep are difficult because of the long time involved (of the order of 100,000 hours), and no satisfactory accelerated tests have yet been devised. Special alloys have been produced for severe service at high temperatures, examples being the famous K E 965 steel specially developed for the exhaust valves of high-duty internal combustion engines, which permits working at a red heat without stretch, and the alloy "Nimonic" which was specially developed for use in gas turbines.

### Resume

Sufficient has now been said to indicate that there is a wide variety of metals and alloys for the engineer to choose from for his specific purposes, and a number of standardised tests to help the engineer to verify in advance the suitability of a metal for the particular purpose required. There is usually more than one type of stress to be met—for instance, a railway coupling should be made of a strong, ductile and shock resisting material (i.e., one with high ultimate tensile stress, high elongation and Izod value over 40) so that any sudden overload can be absorbed without fracture. There are also limitations of manufacture to be considered—including the operations of forging, casting, pressing, machining and heat-treatment. These limitations are, unfortunately, not always given sufficient consideration. Other special circumstances may also be involved, such as resistance to corrosion, or special electrical or magnetic requirements. The latter are specially important in communication engineering.

Having treated certain metallurgical terms and tests somewhat briefly, but in sufficient detail to enable their use and application to be appreciated, the application of various metals and alloys for telecommunication purposes will now be discussed.

## FERROUS METALS

The ferrous, or iron base, metals, include the whole range of materials from pure iron to the special steels so highly alloyed that their iron content may be as low as 50%. The source of iron is iron ore, in the form of oxide or carbonate and which is reduced, melted and carburised in the blast furnace, then run off and cast into sand or chill to produce "pigs"—or transferred in the molten state to Bessemer converters or Open Hearth steel furnaces for processing into steel of various kinds. The process of converting iron ore into pig iron is comparatively well known to engineers and will only be referred to briefly here.

The furnace, often 100 feet high and 28 feet in diameter, is charged with a mixture of iron ore, coke, and limestone plus other fluxing materials as may be rendered necessary by the composition of the ore. Hot air is blown in through tuyeres near the bottom of the furnace. The combustion of the coke produces the necessary heat, and the carbon monoxide thereby produced reduces the iron oxide to metallic iron, which then melts and collects at the bottom of the furnace, where it is drawn off from time to time. The limestone, with or without other fluxing material, combines with the non-metallic residue of the ore and the ash content of the coke to form a molten slag which floats on top of the molten iron, and is also drawn off from time to time. The slag consists mainly of calcium and aluminium silicates, and may be broken up and sold for use as a road surfacing material, or as aggregate for concrete. Some may also be converted to slag wool and used for sound absorption or heat insulation purposes. The limestone also prevents the loss of iron in the form of iron silicate slag, any such formed being converted to calcium silicate.

In the blast furnace process the iron absorbs carbon from the coke, sulphur from the same source, and silicon and manganese which are present in the ore, and is also reduced to metallic state in the process. Some ores also contain appreciable amounts of phosphates, and the resulting iron may therefore contain similar amounts of phosphorus. Pig iron usually contains from 2.5% to 4% total carbon, 0.5% to 3% silicon, and 0.08% to 0.2% sulphur, and from 0.02% to 1.5% of phosphorus, depending on the source of the ore. The crude pig iron as tapped from the blast furnace is seldom suitable for making castings, but must be further treated.

### Cast Iron and Its Variants

Cast iron is produced by re-melting the pig iron referred to in the foregoing, together with steel or iron scrap, in a cupola (this is similar to a small blast furnace), the necessary coke and flux being added. This is then run into sand or chilled moulds to give castings of the shape required. There are different types of cast iron, varying from the grey cast iron of common use, to the more recently developed alloy cast irons. Grey cast iron finds considerable use due to:—

(a) Its cheapness and ease of machining.
(b) Its low melting point, and ability to take good casting impressions.
(c) Its satisfactory physical properties, which combine a very high compression strength and good resistance to wear.

The tensile strength is low and shock resistance poor compared to the steels, but these can be compensated for to some extent by increase of section. Such disadvantages as exist are more than outweighed by its low cost and the ease with which it can be cast into intricate shapes, thus avoiding comparatively expensive fabrication. White cast iron is so hard as to be practically unmachineable, and is only used where such hardness is the determining factor, or as a basis for other processes. Both types contain from 2.5% to 4% total carbon, but the difference lies in the state of this carbon. In grey cast iron, most of the carbon is in the free or uncombined state as flakes of graphite and only a small amount as iron carbide. In white cast iron the carbon is practically entirely in the combined state, i.e., iron carbide. This is the reason why white cast iron is so hard. Whether cast iron is grey or white depends on:—

(a) the rate of cooling;
(b) the presence of other elements.

Slow cooling produces grey cast iron, rapid cooling white. Silicon and nickel retard the formation of iron carbide, and so help to produce grey iron. Sulphur and chromium have the opposite effect. Manganese can have two effects. In small quantities it neutralises any sulphur present, thus assisting the formation of grey cast iron, but in larger amounts the effect is the opposite.

**Malleable Castings:** These are produced from white cast iron by special treatment, have higher tensile strength and ductility than ordinary cast iron, and so can be used for parts which need to have shock resistance. Such purposes include motor car and truck parts, agricultural machinery and bicycle parts and frame lugs. There are two processes in common use, known as white-heart and black-heart, respectively. In the white-heart process, the white iron castings are in boxes with haematite ore, mill scale, or other forms of iron oxide, and heated to 900 to 950°C. for several days, followed by slow cooling. Portion of the carbon is oxidised, and this oxidation, combined with the slow cooling, results in a steel-like structure with interspersed free carbon. The tensile strength of white-heart malleable is about 25 tons/sq. in. with 6% elongation.

For black-heart castings, the iron is carefully adjusted in respect of carbon, silicon and sulphur content before casting, so as to prevent the formation of graphite during casting, but to favour it during heat treatment. The castings are then annealed at 800 to 850°C. (in a neutral packing so that little oxidation occurs) and followed again by slow cooling. This process needs careful temperature control, but gives a tensile strength of about 23 tons/sq. in. with 13% elongation, a yield point of about 15 tons/sq. in., and a Brinell hardness of 115. Malleable iron castings, in general, are cheaper to produce than steel forgings and for this reason are widely used for purposes where higher tensile strengths and ductilities are required than cast iron can provide.

**Alloy or High Duty Cast Irons:** The cheapness and ability to cast intricate forms to close limits, which is an outstanding characteristic of cast iron, has led to considerable research and it has been found worth while to add expensive elements to cast iron to obtain improved characteristics. New cast irons formed by alloying, special melting technique and heat treatment are becoming competitors of steel. A noteworthy example is a special cast iron developed by the Ford Motor Co. and used for crankshafts, brake-drums, etc. This is stated to contain 1.5% carbon, 1% silicon, 2% copper and 0.5% chromium. The castings are heated to 900°C., air-cooled to 650°C., re-heated to 750°C., followed by slow cooling to 540°C. After heat-treatment the tensile strength may be as high as 50 tons/sq. in. A further saving in the case of such a casting for a crank-shaft, as against a forging, is reduced machining time, due to the closer limits to which a casting can be produced.

Other high-duty cast irons are Silal, Nicrosilal, Ni-tensyl, Ni-hard, and Ni-resist. The latter is made by adding 25% Monel metal to ordinary cast iron. The others contain nickel and chromium in addition to the usual components of cast iron.

Special non-magnetic cast iron for electrical purposes has been developed by Ferranti Ltd., and is known as "No-Mag". It contains 10%-12% nickel and 5%-6% of manganese, machines readily and has a tensile strength of 9 to 11 tons/sq. in. The magnetic permeability is 1.03 (grey cast iron 240) and the specific resistance 150 microhms per centimetre cube (cast iron 95).

**Wrought Iron** is little used these days since the large-scale production of steel has resulted in a cheaper, and for most purposes better product. It was originally made by a puddling process in a small reverberatory furnace, by melting grey cast iron and oxidising the silicon, manganese, phosphorus and carbon (in that order) with mill scale or iron oxide. The melting point of the refined iron rises above that of the furnace and it is extracted in pasty masses which are hammered and rolled into bars. Inclusions of slag produce a fibrous structure characteristic of wrought iron.

**Steel:** The need for a better and cheaper metal than wrought iron led to the development of other methods of removing the impurities (mostly carbon) which limited the use of cast iron, and this led to the introduction of the Bessemer and Siemens-Martin processes of making steel. It is convenient at this stage to classify the numerous types of steel for purposes of discussion into two main classes—plain steels and alloy steels. As even the plain steels contain small amounts of silicon and manganese, an exact line of division is difficult, but the definition of the Alloy Steel Research Committee, "Plain steels are those containing less than 1.5% manganese and 0.5% silicon—all other steels are regarded as alloy steels," is convenient and will be adopted here. The two main classes may be further subdivided, plain steels according to the carbon content, and alloy steels according to the alloying elements, the purpose for which they are used, or the tensile strength in the heat-treated condition.

**Mild Steel:** Steels containing less than 0.2% carbon will withstand a remarkable amount of cold working, such as flanging, pressing, drawing, panel-beating, etc. Those from 0.1%-0.2% are used for drop-forgings, mild steel bars, channels and angles, bolts and nuts, and other general purposes. For making bolts and nuts and other components in capstan and automatic lathes so-called "free-cutting" steels have been developed by increasing the manganese content to 0.7%-0.9% and the sulphur to 0.2%-0.25%. Such steels machine easily at high speeds and take a good finish, but the increased sulphur content reduces resistance to shock.

**Medium Carbon Steel:** This steel contains 0.2%-0.5% carbon. It welds less easily than mild steel, the weldability decreasing with increasing carbon content. While hardenable to a certain extent, they are seldom used for work requiring hardening. The principal uses are forgings for general engineering requirements, boiler plate and tubes, agricultural tools, wire, axles and shafts for moderate requirements.

**High Carbon Steel:** This contains more than 0.5% carbon. It is weldable with difficulty up to 0.75% carbon, but is not satisfactory over this value. It hardens readily, but such hardness is obtained at the expense of ductility, toughness and shock resistance. The principal uses are wire ropes, hammers, rivet snaps, saws, drills, cold chisels, reamers, punches, screwing dies, shear blades, woodworking tools and planing and turning tools. Alloy steels, however, have largely superseded high carbon steels, except where cost is an important factor, on account of their superior characteristics for the purposes listed. Typical mechanical properties of carbon steels are given in Table No. 4.

During the last thirty years engineers have demanded steels of increased tensile strength, combined with adequate ductility and shock resistance. This has been particularly so in the automobile and aircraft industries. Increased carbon content does not adequately meet this need, for even in the best heat-treated condition maximum strength obtainable is about 45 tons/sq. in. Higher values are obtainable, but a rapid fall in ductility and shock resistance occurs.

**Alloy Steels:** This class provides high tensile strength and yield point combined with ductility and shock resistance. The use of plain carbon steels necessitates water quenching accompanied by the attendant danger of distortion and cracking and even so only comparatively thin sections can be hardened throughout. Alloy steels do not need such rapid quenching and may be quenched in oil, and some even in an air blast. For resisting corrosion and oxidation, especially at high temperatures, alloy steels are essential. The principal alloying elements added to steel in widely varying amounts—either singly or in complex mixtures—are nickel, chromium, manganese, silicon, vanadium, molybdenum, tungsten and cobalt.

## Manufacture of Steel

The source of all steel is the pig iron of the blast furnace, the problem being to remove the phosphorus and sulphur entirely, and to reduce the carbon, manganese and silicon to specified small amounts. Mild and medium carbon steels are made directly from pig iron by the Siemens-Martin or Bessemer processes; high carbon and alloy steels are further processed in electric arc or high frequency furnaces, or in crucibles. Sketches of furnaces used in steel making are shown in Fig. 6.

separately. The lining of the hearth also plays an important part in the process.

If the pig iron is already low in phosphorus and sulphur, the firebrick lining is "acid," i.e., siliceous (ganister), but if phosphorus and sulphur have to be removed the lining must be "basic," i.e., lime and magnesia (dolomite). The latter removes the phosphorus and sulphur by forming slag. Finally, the carbon is removed as carbon monoxide. At the end of the process, which takes 6-14 hours, and the metal is ready to be topped, ferro-manganese and ferro-silicon are added to bring the steel to the proper composition, and a small amount of aluminium is added to deoxidise the metal. The aluminium oxide so formed is insoluble, and does not melt, and so can be removed. The carbon can be reduced to practically zero and an addition made to make up the correct amount, or, as the carbon is removed last, a more usual method is to arrest the process when just the right amount of carbon remains.

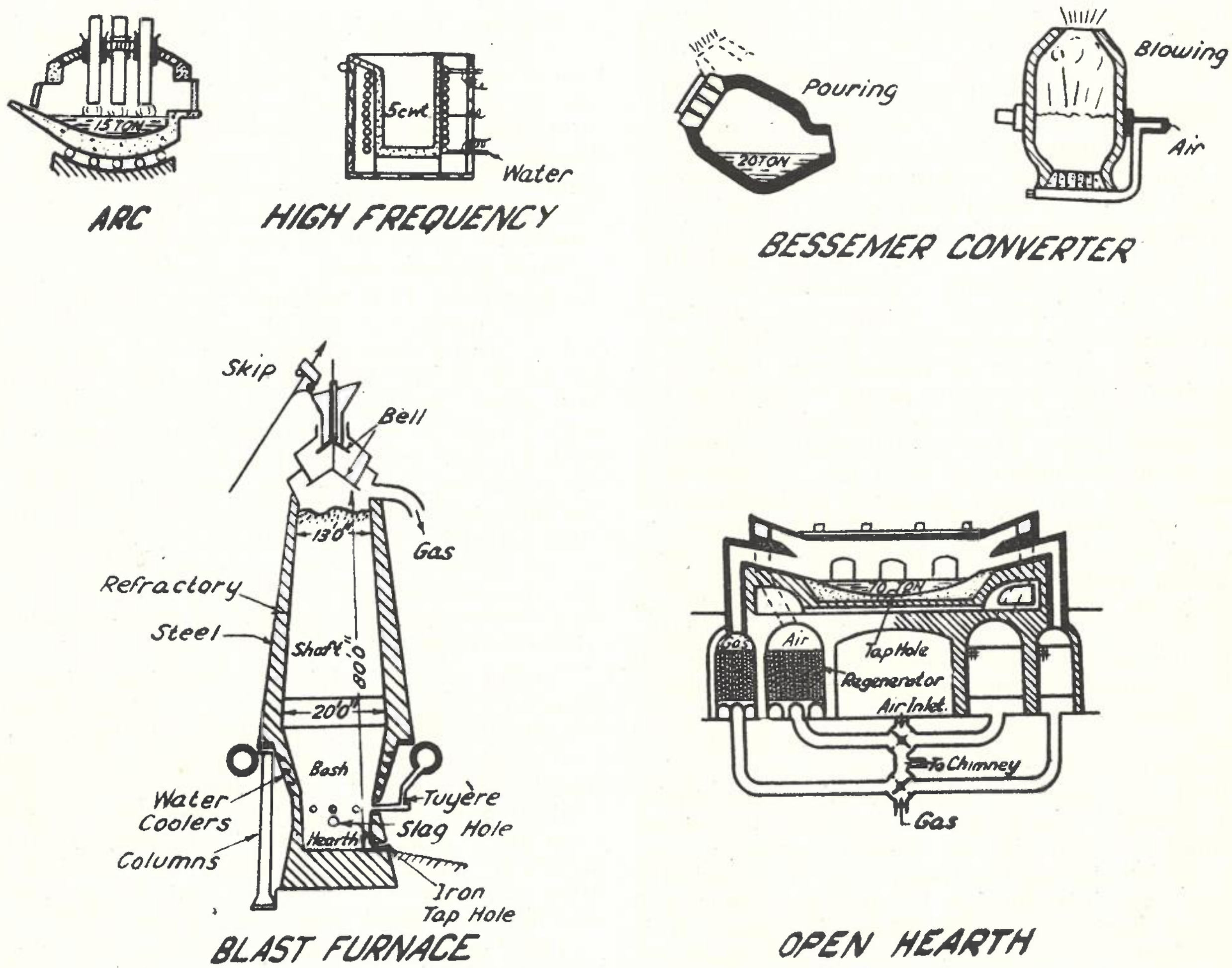


Fig. 6.—Furnaces for making iron and steel.

The Siemens-Martin or open hearth process was devised in the late 1850's and is really a development of the wrought iron process described earlier. Pig iron (either solid or molten direct from the blast furnace) and steel scrap together with iron oxide and flux are charged into a saucer-like hearth with a capacity from 60 to 200 tons. The heat is supplied by gas, usually a mixture of blast furnace gas and coke oven gas. Both the air and gas are pre-heated by regenerators alternatively heated by products of combustion. The regenerators are chambers fitted with firebricks suitably spaced. While the products of combustion are heating the firebricks in one pair of regenerators, gas and air are receiving heat previously delivered by the waste products of combustion to the other pair. Thus a very high temperature is attained when the hot gases and air burn in the furnace. The silicon and manganese are changed to their oxides, and react with the flux to form a slag which is removed

One of the outstanding advantages of the open-hearth process is that the cycle of operation is relatively slow, so that the composition of the steel can be readily controlled, and the progress of manufacture checked by chemical analysis of samples. In this respect it is superior to the Bessemer process, which only occupies about 20 minutes, because in such a short time interval close control is very difficult. In 1856 an Englishman, Henry Bessemer, devised the process which bears his name, the two processes, Siemens-Martin open-hearth and Bessemer converter, being developed round about the same time. Previous to this, steel was made by heating bars of wrought iron surrounded by charcoal in fireclay boxes, for a period of 8-10 days. Such steel has a higher carbon content towards the outside of the bar, and was known as "blister" steel from its appearance. In order to obtain a more homogeneous product, these bars were melted in fireclay crucibles together with graphite and cast into ingots. It was known as "crucible cast steel."

However, this process of turning cast iron into steel was lengthy and correspondingly costly, but Bessemer's process for making steel directly from cast iron was rapid, cheap and made it possible to produce steel in large quantities. It consisted of oxidising the impurities by blowing air through the molten iron. For this purpose a bottle-shaped vessel (see Fig. 6) made of sheet iron is thickly lined with refractory material of the acid or basic type, as necessitated by the type of pig iron used, just as for the open-hearth process, and for the same reasons. It is mounted on trunnions so that it can be tilted to receive and later pour the charge. A supply of air at one or two atmospheres can be blown through tuyeres in the bottom. In the operation the converter is first heated by blowing on a charge of coke. This is then removed, and the converter is tilted to receive a charge of up to 25 tons of molten pig iron. The converter is then moved to the vertical position and the air blast turned on. The oxygen from the air blast combines with some of the iron to form iron oxide, which dissolves in the molten iron and reacts with the silicon, manganese, and carbon which in turn become oxidised. The oxides of iron, manganese and silicon combine to form a silicate slag, and the carbon is removed as carbon monoxide and burns at the mouth of the converter with a large noisy flame. During this process, which is most spectacular, the chemical reactions taking place in the converter liberate considerable heat, so that the temperature rises from about 1300°C. at the start to about 1600°C. at the end.

| Composition (per cent) | | | | | Condition | Mechanical Properties | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| C | Si | Mn | S | P | | Yield point (tons–sq. in.) | Ultimate tensile stress (tons–sq. in.) | Elongation (per cent on 2 in.) | Reduction in area (per cent) | Brinell hardness number | Izod (foot-lbs.) |
| 0·14 | 0·20 | 0·56 | 0·03 | 0·03 | N, 900°C | 14 | 27 | 44 | 61 | 117 | 90 |
| 0·24 | 0·16 | 0·55 | 0·04 | 0·04 | N,870°C ($3\frac{1}{2}$ in.) | 16 | 31 | 34 | 56 | 134 | 60 |
| | | | | | OQ, 860°C; T, 650°C | 20 | 32 | 36 | 62 | 144 | 90 |
| 0·15 | 0·09 | 1·1 | 0·23 | 0·08 | Hot rolled, free cutting | 17 | 27 | 40 | 44 | 118 | 60 |
| | | | | | Cold drawn, 11% | 34 | 36 | 24 | 42 | 155 | 26 |
| 0·2 | 0·25 | 1·0 | 0·03 | 0·01 | Casting | 18 | 31 | 18 | 20 | 149 | 13 |
| | | | | | Casting A, 880°C, 6 hours | 18 | 30 | 30 | 43 | 147 | 34 |
| 0·35 | 0·15 | 0·70 | | | Forging | 20 | 37 | 23 | 36 | 164 | 14 |
| | | | | | OQ, 850°C; T, 600°C | 27 | 43 | 27 | 49 | 190 | 54 |
| 0·58 | 0·37 | 0·79 | 0·04 | 0·03 | N, 850°C | 30 | 50 | 18 | 33 | 220 | 10 |
| | | | | | OQ, 830°C; T, 600°C | 35 | 57 | 20 | 42 | 250 | 20 |
| 0·65 | 0·28 | 0·76 | | | As rolled | 30 | 50 | 22 | 40 | | |
| | | | | | OQ, 820°C; T, 600°C | 37 | 62 | 17 | 36 | 275 | 5 |
| 1·15 | 0·02 | 0·32 | 0·03 | 0·03 | As rolled | 38 | 56 | 7 | 6 | | 2 |
| 1·56 | 0·03 | 0·18 | | | As rolled | 36 | 48 | 2 | 2 | | 1 |

**Table No. 4—Mechanical properties of carbon steels**
N—normalised, OQ—oil quenched, T—tempered, A—annealed

After about 20 minutes operation, a sudden reduction in the flame indicates that oxidation is complete. The metal, however, contains an appreciable amount of dissolved iron oxide, which must be re-converted to iron, as it would make the metal porous, and the amounts of carbon, manganese, and silicon also have to be adjusted to the required amount and this is done by adding ferro-manganese (spiegeleison), ferro-silicon and aluminium. This may be done in the converter itself, or after tilting and pouring into a suitable ladle, after which the metal may be cast into various forms, or into ingots for subsequent rolling into bars and rods, or for re-melting and further processing. The original Bessemer process used a siliceous (acid) lining and required pig iron low in phosphorus, but a later modification used a dolomite or magnesite lining and enabled iron containing appreciable phosphorus to be used.

**Duplex Process:** In order to obtain the rapid production advantage of the Bessemer process and the better control and more uniform quality of the open-hearth method, steel is also made by a duplex method, in which the molten metal from a Bessemer converter is used as a charge for an open-hearth furnace. The Bessemer process removes the silicon, manganese and carbon, and the remaining phosphorus and sulphur are removed, and the final composition of the steel adjusted, in a basic open-hearth furnace.

**Electric Process:** The production of high carbon and alloy steels requires rigidly controlled conditions, and in this respect the furnaces in which fuel is burnt in contact with the metal are not satisfactory as contamination may take place, or some of the components be oxidised, and this led to the introduction of electric furnaces of the arc and high frequency induction type. In the arc type, of which the Heroult is an example, the heat of an electric arc (usually between the electrodes and the metal) is used to melt the charge. (See Fig. 6.) Either acid or basic hearths may be employed. The capacity ranges from 3 to 12 tons and the corresponding power consumption from 600 to 2400 K.V.A. The process is more costly than the Bessemer or open-hearth processes, but produces steel of high quality and to specified analysis.

Another type of electric furnace is based on the heating of the charge by induction. A high frequency (1 to 20 kc/s) alternating current flows through a water-cooled and specially insulated conductor in the form of a coil surrounding a crucible. The latter is of the order of ½″ thick and there is a further thickness of about 1″ of heat insulating material between the crucible and the coil. The heat is generated directly in the charge, so that there is a minimum of heat loss. There is also a continuous motion in the molten metal which promotes uniformity of composition. Furnaces for use at about 1 kc/s have an external laminated silicon steel core to reduce the magnetic reluctance of the magnetic circuit. Such a furnace may have a capacity of ½-ton and a melting period of 2 hours for a consumption of 150 KW at 1 kc/s and 1200 volts.

### Heat Treatment of Steels

The various types of steel, their uses and manufacture have been covered and the subject of heat-treatment of steels will now be discussed. Disregarding work-hardening processes such as cold-rolling, steel containing more than about 0.25% carbon can be hardened by heating it above a point known as its upper critical point and cooling it rapidly in a suitable medium such as water, oil or air. Carbon steels need rapid cooling in water to harden, but alloy steels may be cooled in oil, and some even in air. This more or less rapid cooling is known as "quenching," and the quicker the cooling the harder and more brittle the steel becomes. The upper critical temperature (which is of the order of 800°C. to 900° C—cherry red) varies with the carbon content, and falls with increasing carbon content.

For most purposes steel in the fully hardened state is too brittle, and ductility and shock resistance are increased at the expense of hardness and tensile strength by re-heating the steel to a suitable temperature much below the hardening point and allowing it to cool. This process is known as tempering, and the range of temperatures is from 200°C. to 650°C. The lower part of this range is often judged by the color of the oxide formed, although it must be emphasised that this is not a precision method, and should be replaced by proper temperature measuring equipment whenever possible. It is still very much in use for small articles and the colours and corresponding temperatures are reproduced in Table No. 5 for general information. There is some variation in published information in this respect, but the colours shown are drawn from a number of sources in close general agreement.

| Hardening | | Tempering | |
|---|---|---|---|
| Colour | Temperature, °C | Colour | Temperature, °C |
| Very dull red in darkness | 400 | None | under 210 |
| ,, ,, ,, shade | 475 | Pale yellow | 220 |
| ,, ,, ,, daylight | 525 | Straw | 230 |
| ,, ,, ,, sunlight | 580 | Middle straw | 240 |
| In daylight—dark red | 650–700 | Dark straw | 250 |
| ,, ,, —cherry red | 800 | Brown | 260 |
| ,, ,, —light cherry red | 900 | Brown-purple | 270 |
| ,, ,, —orange red | 1000 | Purple | 280 |
| ,, ,, —yellow | 1100 | Dark blue | 290 |
| ,, ,, —white | 1300 | Blue | 300 |
| | | Light blue | 310 |
| | | Grey-green | 320 |

**Table No. 5—Colour chart for tempering**

The reasons why steels harden when quenched are complex and difficult to explain in simple terms and in the limited space available in this paper, but the following will help in this regard. Carbon is present in steel in the combined form of iron carbide—$Fe_3C$. In the unhardened state, the steel consists of two kinds of crystals, ferrite (pure iron) and pearlite, which is composed of alternate plates of iron and iron carbide (cementite). Ferrite is soft and ductile, while cementite is hard and fairly brittle, so it will be readily seen how carbon content affects steel even in the unhardened state. Pearlite contains 0.9% of carbon, so that an unhardened steel of 0.9% carbon is completely pearlitic, and one of 0.3% carbon is about one-third pearlite and two-thirds ferrite. A steel of over 0.9% carbon consists of pearlite plus free cementite.

When the steel is heated above the critical temperature, the cementite dissolves uniformly in the ferrite to form an alloy called austenite. If the steel is then quenched, there is not time for the original structure of ferrite and pearlite to form, and the uniform distribution of the iron carbide remains fixed and a new substance is formed called martensite, which is extremely hard and brittle. Tempering breaks down the martensite into softer constituents known as troostite and sorbite. It should be noted that the basis of hardening is quick cooling. Plain carbon steels do not harden satisfactorily unless quenched in water, and this drastic action sets up internal stresses which may result in distortion or cracking if there are abrupt changes in section.

Alloy stools do not need such rapid quenching and harden satisfactorily when quenched in oil, and some even in an air blast, so that the risk of distortion is much less. Accurate control of tempering conditions is obtained by immersing the part to be tempered in a metal bath containing molten alloys of lead and tin (210°C. to 320°C.), lead and antimony (230°C to 630°C) or chemical salts such as the chlorides of sodium, potassium or barium. The temperature is indicated by a pyrometer immersed in the bath, and the temperature may be automatically controlled.

There are two other terms which are met with in heat treatment specifications. These are annealing and normalising. They both involve heating the steel to just above the critical temperature for hardening, and allowing it to cool, thus restoring the pearlitic structure. It should be noted here that the pearlitic structure will not be restored unless the steel is taken to the critical temperature. Annealing is obtained by slow cooling in the furnace or in a substance such as lime or sand, and normalising by allowing it to cool in free air. The object of either process may be to release internal stresses or to induce softness. Normalising gives a slightly stronger and harder condition, although the ductility is slightly lowered, and this condition is generally preferred.

Before passing to the alloy steels, there is a variety of mild steel which is of interest to communication engineers, and that is soft magnetic iron in the form of rod and bar and used for the manufacture of relay components. A satisfactory grade has been manufactured at Newcastle, New South Wales, and contains:—

| | |
|---|---|
| Carbon | 0.035% |
| Manganese | 0.07% |

After annealing at 880 to 900°C. for one hour the coercive force was 1.4 oersted and maximum permeability 5000.

### Alloy Steels

The advantages of alloy steels in respect of hardening conditions have already been stressed, but, in addition, the mechanical properties are improved to a marked degree. Elements usually added, either singly or in combination, are nickel, chromium, molybdenum, vanadium, tungsten and cobalt. Alloy steels rarely contain more than 0.4% carbon. Some of the more common alloy steels will now be considered. Nickel was one of the first metals added to steel, and is still one of the most important and most used. It increases the tensile strength, yield point, elastic limit and reduction in area and decreases the elongation, toughens the steel and increases its resistance to shock and alternating stresses. When suitably heat-treated it further increases the tensile strength, yield point and hardness. For instance, plain steels seldom show a yield point much over 50% of their already low ultimate tensile strength. A good nickel steel will show not only a much higher tensile strength, but a yield point equal to 75% of this. The high ratio of yield point to tensile strength is characteristic of all nickel steels. The principal nickel steels contain from 3% to 5% nickel.

Characteristics of a typical 3% nickel 0.3% carbon steel, oil-quenched at 830°C. and tempered at 600°C., is shown hereunder:—

| | |
|---|---|
| Ultimate Tensile Stress | 52 tons/sq. in. |
| Yield Point | 43 tons/sq. in. |
| Elongation | 26% |
| Reduction in Area | 66% |
| Izod Impact | 78 foot-lbs. |

Such a steel is widely used in the automobile industries for connecting rods, steering arms and other parts where strength, toughness and resistance to shock are required.

The addition of a small amount of chromium (up to 1%) to nickel steels further increases the strength and toughness in the heat-treated condition and ensures considerable hardness with a slower rate of cooling than many other alloy steels. It is, therefore, suited to large sections requiring heat-treatment, giving deep and uniform hardening. The effect of adding 0.75% chromium to a 3.5% nickel is shown in the following:—

| Characteristic | Steel | |
|---|---|---|
| | 3.5% Nickel | 3.5% Nickel 0.75% Chromium |
| Ultimate tensile stress, tons/sq.in. | 53 | 62 |
| Yield point, tons/sq.in. | 46 | 57 |
| Elongation, % | 24 | 21 |
| Reduction in area, % | 59 | 62 |
| Izod impact, foot-lb. | 60 | 60 |

Such steels (nickel-chromium) should not be tempered in the range 200°-500°C., as the Izod impact value is a minimum in this range. This is known as "temper brittleness," and may be cured by adding about 0.5% molybdenum. The nickel-chrome-molybdenum alloy steels are widely known and deservedly popular for their excellent characteristics. Chromium added to steel alone in small quantities up to 2.5% produces intense hardness, and is used for ball races and files. In large amounts (over 12%) it confers resistance to corrosion, chemical attack and oxidation at high temperatures. This was accidentally discovered by Brearly in 1913, who threw out, as unsuitable for gun barrels, a steel containing 14% chromium with which he was experimenting. Some months later he noticed it on the scrap pile and that it had not rusted like the others. This led to the development of the famous "18/8" Stainless Steels, containing 18% chromium and 8% nickel. These steels are not only rust-resistant, but resist sea-water and most acids. They are also non-magnetic.

Although manganese is present in most steels in small quantities, and improves carbon steel up to about 1.5%, its effect in amounts of 12%-14% produces some remarkable results. These steels are non-magnetic, and annealing and quenching produce effects opposite to those obtained with most other carbon and alloy steels. In the quenched condition it is only moderately hard, but any abrasion results in the formation of local hard martensite which resists further wear. It is, therefore, used for such components as railway crossings and rock-crushing machinery. Vanadium increases the elastic limit and resistance to shock, particularly in conjunction with chromium, and steels containing 1% chromium, 0.15% vanadium and 0.3% carbon are used for automobile springs and axles.

Some other special steels will now be briefly described:

**45-55 ton steel.** See 3% nickel steel mentioned previously.

**55-75 ton steel.** 3.5% Ni, 0.4% C, oil-quenched at 830°C., tempered at 550°C. for small and medium sections such as studs, bolts, axle shafts and brake rods.

3.5% Ni, 0.7% Cr, 0.2% Mo, 0.3% C for highly stressed parts such as crankshafts, gear wheels and connecting rods. Oil quenched at 820°C., tempered at 600°C.

**75-120 ton steel.** 1.5% Ni, 1.25% Cr, 0.3% Mo, 0.4% C. It is hardened in oil from 820°C. and tempered in three ranges according to use.

These are 200-220°C. for maximum hardness (gears), 400-550° C. for an ultimate tensile stress of 70-90 tons sq. in. and 550-650°C. for medium strength with high ductility (steel axles-steering parts).

**The characteristics are as follow :**

| Characteristic | Tempering Temperature °C | | |
|---|---|---|---|
| | 200 | 450 | 600 |
| Ultimate tensile stress, tons/sq. in. | 122 | 84 | 63 |
| Yield point, tons/sq. in. | 102 | 78 | 58 |
| Elongation % | 13 | 16 | 21 |
| Reduction in area % | 39 | 51 | 61 |
| Izod impact, foot-lb. | 16 | 28 | 59 |

**Air-hardening steel.** 4.25% Ni, 1.25% Cr, 0.2% Mo, 0.34% C, is hardened by cooling in air from 830°C. and tempered at 200-220°C. It is used for back axle shafts, gears, and other parts where high strength and hardness are vital, and for parts of intricate shape where risk of cracking or distortion in heat-treatment must be minimised.

**High thermal expansion steel.** 12% Ni, 5.1% Mn, 3.4% Cr, 0.59% C. This has almost the same thermal expansion as aluminium, and is used in conjunction with this metal for cylinder head bolts and cylinder liners.

**Dilver.** This alloy contains 47% Ni and has the same expansion as glass. For this reason it is used in the manufacture of electric lamps.

**Low expansion steel.** Invar, a steel containing 36% Ni, 0.5% Mn, 0.2% C, has practically zero (one millionth) coefficient of expansion between 0°C. and 300°C. It is used extensively in clocks, measuring tapes and expansion regulators.

**Cold chisel steel.** 3% Ni, 0.4% C. When oil-quenched from 900°C. no tempering is required. The edge is well maintained against hard materials but can be re-sharpened with a file.

**Non-shrinking steel for dies.** The cheapest type contains 1.5% Mn and 0.9% C. A better steel is 0.95% Mn, 0.75% Cr, 0.5% W and 1.0% C. Such steel is used for master tools, gauges and dies which must not change size when hardened after machining.

**Steels for automobile valves.** These components have to work at high temperatures, resist corrosion by exhaust gases and leaded fuels, and resist creep. One such is Silcrome, containing 4% Si, 0.5% Mn, 8% Cr, 0.4% C. A better and much more expensive steel for the most severe service contains 13% Ni, 13% Cr and 2.5% W. The seating face is sometimes covered with 80/20% nickel chrome alloy.

### Special Steels for Electrical Purposes

Silicon steel of approximate composition, 0.07% C, 4% Si, and very low manganese of 0.05% has higher permeability than, and a resistivity 5 times that of, magnetic iron. It is used for cores of transformers, armatures and pole pieces of electrical machinery, and telephone diaphragms. It has a loss of about one watt per kilogram at 10,000 gauss and 50 c/s, and a permeability of 8000.

Permalloy contains 78% nickel and 22% iron, with low carbon, silicon and manganese and has high permeability in small magnetic fields. The permeability is of the order of 100,000, but the alloy has a low saturation value, low electrical resistance, and is very sensitive to heat-treatment and mechanical working. This has led to the development of other alloys where the third element is copper, chromium, molybdenum or manganese, and Mumetal is of this type.

Perminvar has a substantially constant permeability over the range of flux density from zero to about 1000 gausses and is superior to permalloy in this respect. It is used in carrier systems where cross-modulation effects due to core material must be drastically reduced. A typical composition is 45% Ni, 25% Co and 30% Fe. Its greatest drawback is permanent loss of characteristics if flux densities of a few thousand gausses are exceeded even momentarily. Ordinary methods of de-magnetisation are not successful. Non-magnetic irons and steels and soft magnetic iron have already been referred to.

For permanent magnets high carbon steels in the quenched condition have been superseded by steels containing chromium, tungsten and cobalt and later by the Alnico series of alloys. The percentage composition of typical alloys is:—

| C | W | Cr | Co | Ni | Al | Fe | Coercive Force (osersted) |
|---|---|---|---|---|---|---|---|
| 0·6 | — | — | — | — | | 99·4 | 55 |
| 0·6 | 6 | — | — | — | | 93·4 | 65 |
| 0·9 | — | 3 | — | — | | 96·1 | 63 |
| 0·9 | — | 10 | 15 | — | | 74·1 | 170 |
| 0·8 | 6 | 2 | 36 | — | | 55·2 | 230 |
| — | — | — | — | 25 | 13 | 62·0 | 500 |
| — | — | — | 10 | 20 | 10 | 60·0 | 510 |

### Special Cutting Steels

Plain high carbon steels are much used in machining, but fast rates of cutting cause such steels to heat up, over-temper and soften, and special cutting steels have been produced since 1900 which continue to cut at red-heat without softening. These are known as high speed steels, and the main constituents are W 14 to 18%, Cr 3 to 5% and C 0.6%. A super high speed and also more expensive steel contains Co 10%, W 20% and Cr 4.5%, V. and Mo 1% and C 0.7%. All these steels must be hardened from temperatures of 1280°C. to 1300°C.—i.e., near fusion point, and hardened in an air blast. Tempering at 350 to 400°C. slightly reduces the hardness and increases toughness, but tempering at 400 to 600°C. increases hardness. The reason for this secondary hardening is not definitely known. Super-hard cutting materials have been developed by sintering tungsten carbide with cobalt. These contain no iron and consequently will be referred to in the part dealing with non-ferrous metals.

### Surface Hardening

There is another aspect of steel treatment which remains to be discussed, and that concerns steel components which have to withstand wear. A typical case is a gudgeon pin in an internal combustion engine. Carbon steel in the hardened and untempered state is very hard and resistant to wear, but lacks toughness and ductility. If mild steel or alloy steel low in carbon is heated to 920°C. in contact with carbon for some hours, the surface of the steel absorbs carbon, the depth being dependent on the time and temperature, and the carburising medium. Such a composite steel has useful properties, as by suitable heat-treatment the outer layer, consisting of high carbon steel, may be hardened, while the remainder retains the toughness and shock resistance of low carbon steel.

The earlier processes involved packing the steel in charcoal or other carbonaceous matter, contained in airtight boxes, and heating at over 900°C. for from 4 to 15 hours, depending on the depth of hardened "case" required. A period of 6 hours at 920°C. gives a case of 0.030″. Later processes due to Cassel make use of molten chemical salt baths containing sodium cyanide and have marked advantages over the earlier process. These are:—

(a) Saving in time. A depth of 0.030″ can be obtained in 2 hours.

(b) Immersion in a molten bath promotes even heating.

(c) Carbon content in the case is 0.9%, which is the desirable value. Higher values in the exterior may be obtained in the charcoal process, and such when hardened may chip or break off (exfoliation).

(d) Reduced time at high temperature reduces grain growth in the core and leaves it tougher.

(e) Bright finish, as immersion in the molten compound prevents oxidation during carburising.

A typical heat-treatment is as follows:—

(1) Carburise at 870 to 930°C. for the required time, according to the directions of the makers of carburising compound.

(2) Allow to cool slowly.

(3) Re-heat to 850°C. and quench.

(4) Re-heat to 750°C. and quench.

For case depths below 0.015″, the parts may be quenched direct from the carburising process. The first re-heating refines the core and removes the grain growth due to prolonged heating at elevated temperatures in the carburising process, and the second re-heating refines and hardens the case, leaving the core unchanged. Either mild steel or alloy (usually 3% nickel) may be case-hardened by the carburising process. Mild steel gives the harder case, but must be water-quenched with its attendant risk of distortion. 3% nickel steel after carburising may be oil-quenched and gives a satisfactory surface hardness together with a high tensile core, and is thus suitable for more highly stressed parts.

There is another process of surface hardening which does not need a quenching process and its accompanying disadvantages. It has, however, other serious disadvantages. The process consists in heating the steel to approximately 500°C. in an atmosphere of ammonia. The outer layer absorbs nitrogen from the ammonia and forms iron nitride, which is even harder than iron carbide. However, at least 90 hours is required for a depth of 0.030" and this is a serious disadvantage. No quenching is required, so that the process can be applied to thin parts, such as cylinder liners. Steels containing aluminium, chromium and molybdenum (Al 1%, Cr 1.5%, Mo 0.2%) are best for this process and give surface hardness of over 1000 Vickers pyramid number, compared to 750-850 Vickers pyramid number for carburised case-hardened steel.

Nickel-chrome-molybdenum steels can also be nitrided, but give slightly lower hardness. Cast iron containing 1.5% each of Cr and Al can also be nitrided (cylinder liners). The nitrided case retains its hardness up to about 500°C., whereas case-hardened carburised steels lose hardness at temperatures above 150°C.

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# DEVELOPMENT OF THE STANDARD A.P.O. 40-LINE "B" TYPE R.A.X.

*R. R. P. Nelder*

In the Vol. 6, No. 3, February, 1947, issue of the Journal, the main features of the 50/200 line locally developed R.A.X. were given. The pilot model of this type was installed at Kallista, Victoria, in July, 1946, and has given good service. Since that date, units of overseas manufacture have been received and installed at various locations, and reports of their operation in service have also been good. The latter units, although varying in some details from the original pilot model, are in general accordance therewith. They are supplied in 50-line cabinets, the first unit of an installation containing the common equipment such as ring and tones, alarms, etc., being called the "C" unit, and the extension units being called "D" units. As the title implies, this type is designed on the basis of a 200-line maximum, assuming reasonably heavy traffic conditions, although this limit can be exceeded, provided that the traffic is not too heavy. If the latter condition arose, it would be necessary to use standard automatic exchange equipment.

In the article mentioned above, it was stated that the design of smaller type units was being undertaken. The present article describes the "B" type unit, which is a non-extensible unit with a capacity of 40 subscribers' lines. In considering the desirable basic features required in the "B" type unit, it was concluded that the following aims were worthy of achieving:—

(a) **Simplicity of Operation.** Complaints have often been received about the complexity of some former R.A.X. circuits, in addition to the fact that the circuits differed considerably from standard equipment. Fault finding was a lengthy process and circuits were difficult to follow. With a view to rectifying this, standard circuits were used where possible, and some minor facilities were eliminated. Examples of the latter were the extension of alarms and the facility to test over trunks. As these "B" type units are installed in sparsely populated localities, they quite often do not have direct trunks to a technician's station, and such facilities would be of little benefit. On the other hand, their elimination allows the circuits to be simplified. Another factor, so far as the extension of alarms feature is concerned, is that they sometimes pass unrecognised by the operating personnel and no action is taken to inform the technician that a fault may be present at the R.A.X. It was considered that a check at regular intervals by the technician dialling the fault test number and observing for "no fault" or "fault" tone would be a simpler arrangement and satisfactory for this class of unit.

(b) **Use of relays and uniselectors only.** By eliminating bimotional switches, such troubles as release faults are obviated. The routine adjustments on uniselectors are much simpler, piece part stocking is less, initial cost is less, and maintenance is simplified generally. Most of the parts are locally made which is an additional safeguard, both from an installation and servicing point of view.

(c) **Reliability of service.** Elimination of all common switching apparatus which may become faulty means that the only faults which could completely incapacitate the exchange would be the failure of the battery or the ringer. The unit has therefore been designed, as was the 50/200-

line unit, on the basis of individual testing and connecting paths as far as possible.

(d) **Similarity of operation to the 50/200-line type.** The same line relay circuit, 2-party, 2/3-party, and 4/10-party relay sets, ringing code interrupter, public telephone and charge-over trunk relay sets, are used, as are provided in the 50/200-line unit.

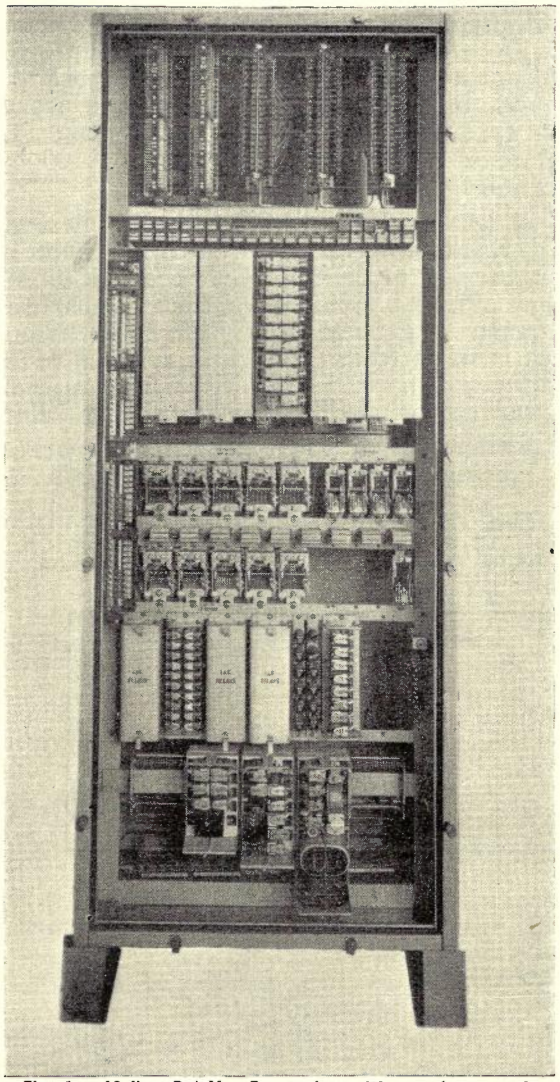

Fig. 1.—40-line R.A.X. Front view with panel removed.

(e) **Flexibility of service.** The wiring is arranged where necessary to go through a local I.D.F. By suitable jumpering on this I.D.F. the R.A.X. may be varied to accommodate as many party lines, exclusive services, trunks, etc., as are required to suit the particular exchange, provided the total number of subscribers and trunks does not exceed 45.

(f) **Compactness and low current drain.** As these units may be required to be installed in restricted spaces, and in view of the small amount of protective equipment needed for 40 lines, the M.D.F. has been incorporated in the unit, being mounted near the top. It is anticipated that local public supply mains will not be available in many instances where these installations are made. Consequently, a vibratory ringer and tones derived from valve oscillators have been installed. These use less current than ring and tone machines, and are also cheaper. Their output is adequate for this size of unit.

**Description of Unit Layout**

The unit is housed in a steel, dust-proof cabinet 7′ high, 2′ 7″ wide, and 1′ 8″ deep. Fig. 1 is a photograph of the unit taken from the front, while Fig. 2 is a side view with the side panel removed. As will be seen from these photographs,

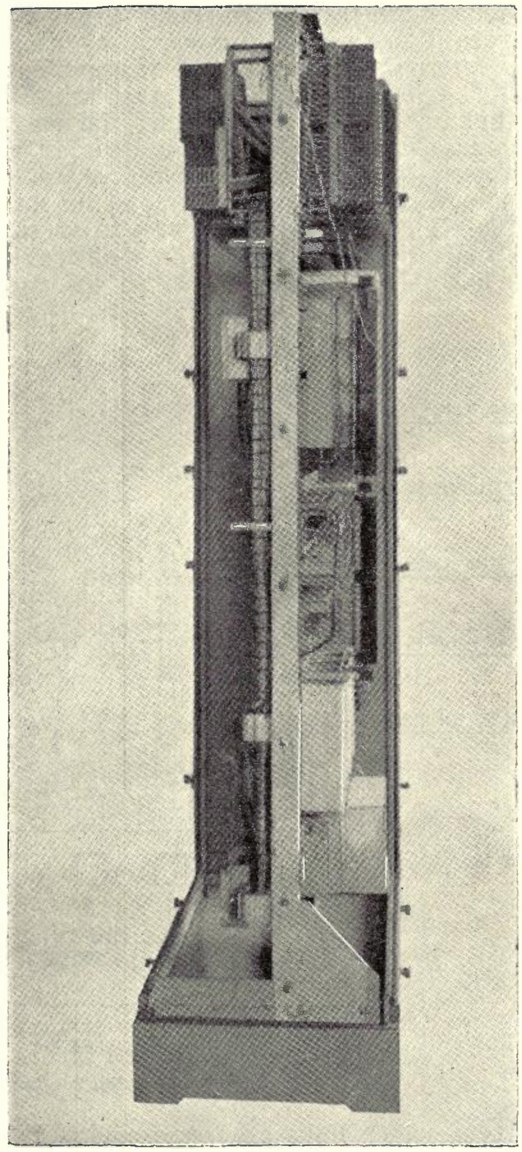

Fig. 2.—40-line R.A.X. Side view with panel removed.

most of the apparatus is mounted on the front of the unit, the space at the rear being reserved for party-line relay sets of the various types, as required. Space is also available at the rear for multi-metering relay sets, if and when they may be required. Drawing No. CE453 gives complete details of the cabinet construction, which was designed to give protection from dust, mechanical interference, etc. It is provided with light, easily removable rear and front covers. In addition, the sides and top may be taken off if necessary by the removal of a few screws, making all parts of the unit and wiring accessible.

The equipment contained in the unit illustrated, which does not include any party line relay sets, comprises a 75/60 pair M.D.F. and an I.D.F. at the top, with a meter plate capable of mounting 44 100A type meters immediately underneath. Below the meters are located 5 link relay sets, mounted in the standard 2000 type manner. Underneath these are the associated uniselectors which incorporate the line finder, group selector, and final selector functions of the link circuits. Each link has two 10-level switches and one 5-level switch associated with it. The line circuit relays, which are of the 600 type, are located on flanged type mountings immediately below the uniselectors. This shelf also accommodates the associated line circuit resistance spools, in addition to the trunk line relay circuits, the latter being of the 3000 type. P.G. links are accommodated at the end of the shelf. On the bottom shelf, located on jack-in relay mountings, are the miscellaneous relay sets such as ring, tone, alarm, charge-over trunk, etc. The disposition of the various classes of equipment is made with a view to locating the various items in the best place, having in mind the amount of servicing which may be required in each case.

### Operation and Trunking Scheme

Fig. 3 shows the trunking diagram of the unit. The trunking scheme is similar in principle to that of the 50/200 line units, except that the "B" unit is not extensible beyond 40 subscribers' lines. In addition, of course, the use of uniselectors only has the effect of combining the group selector and final selector switches into the respective link circuits. In this unit. any party lines are dealt with by special strappings on the banks of the final selector switches in the links. Further details will be given of this aspect later.

Full details of the circuits are given in drawing No. C.E.454, which are not reproduced here. However, in view of the fact that the link circuit is rather different from conventional Departmental equipment, a general description of its main features is of interest. Each link consists of three uniselectors and 22 relays. The main functions of the various switches and relays are as follow:—

(a) **Switches.** The L.F. switch is a 50-point non-homing line finder having 5 banks, viz., + ve, — ve, private, meter and 1 spare (reserved in case of possible multi-metering). As in the C and D units, all line finders hunt for a calling line. Hunting ceases when the first switch to find cuts through. The group selector switch is a 5-level 25 point homing uniselector which accepts the first digit dialled.

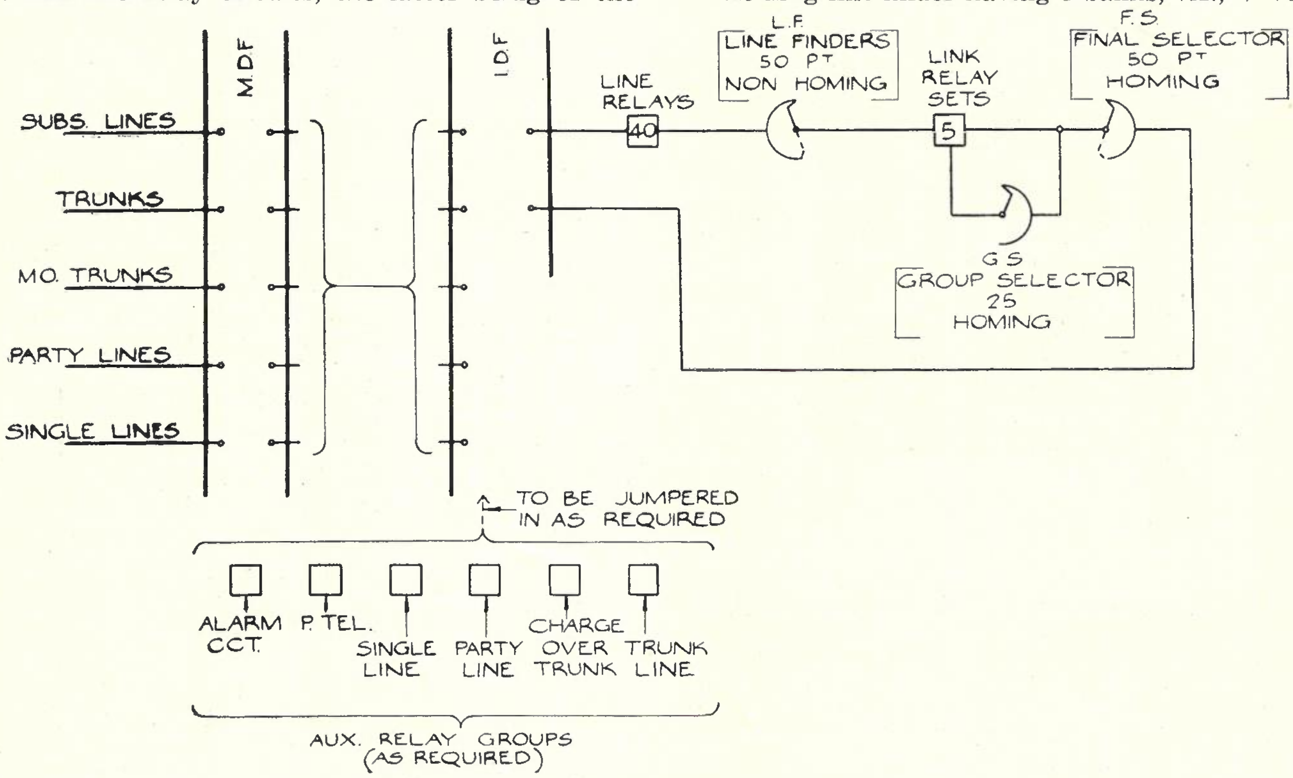


Fig. 3.—Trunking diagram, "B" type R.A.X.

The No. 1 bank is the homing arc. The No. 2 bank is used to drive the final selector switch as described later. The No. 3 bank discriminates as to whether the call is for a party line, trunk or ordinary subscriber. The No. 4 bank is used on trunk calls to prepare for group searching of the trunk group. No. 5 bank is used for tripping the drive of the final selector switch in the appropriate position. The final selector switch is a 50-point homing uniselector having 5 levels, viz., + ve, — ve, private, homing and a T. bank. The first 4 levels are conventional, the 5th being used for subscribers and trunk group marking in addition to party line ringing codes as required.

(b) **Relays.** The relays and their main functions are as follow:—

A. Dialling and battery feed.
B. Holding over impulses.
C. Control of 1st impulse train.
D. Reversing, metering and battery feed.
E. Control of 2nd impulse train.
F. Ring trip.
G. Overflow trip on final selector and busy tone control.
FT. Line finder trip.
H. Test called line.
I. Provide loop to auto exchange.
J. Metering circuit preparation.
JA. Call to auto exchange.
M. Trip final selector switch drive.
N. Relief in M. relay.
P. Party line discrimination.
AZ. Forced release.
DA. Accepts reversal from auto exchange.
FB. Relief on FT.
X & JC. Junction group functions.
RS. Code ring.
TH. Thermal type time delay.

### Numbering Scheme

The numbering scheme normally provides for the use of numbers 20 to 59 for exclusive subscribers. Trunk groups with rotary testing facilities may be provided on 01 or 91. Party or omnibus lines may be accommodated on the subscribers' levels, if required. Levels 6, 7 and 8 may also be used if necessary, for numbering flexibility reasons, although the total number of subscribers' lines is not increased beyond 40 by such use. The I.D.F. is used to suit a particular exchange's requirements of trunks, party lines, etc., to the unit used. An example of trunk group flexibility which can be arranged on this basis is the use of an omnibus trunk as last choice of direct choice group, whilst still retaining separate numbers for the individual stations on the omnibus trunk. Such a case would occur where the omnibus line was connected at a station also served by a group of direct trunks to the R.A.X. The link is suitable for repeating impulses through the R.A.X. between two other exchanges, and also includes facilities for repeating a reversal for metering purposes in such cases. A typical numbering of an exchange could be:—

Exclusive lines, 21-45.
3/4 Party lines, 41-54, 47-50, 61-64 respectively.
2 trunks to Parent Exchange 01, 02 (rotary).
1 omnibus line with 3 stations 68, 69, 60 (the station 68 could also be reached as third choice of the 01 trunk group).
1 trunk to adjacent automatic exchange 91.

### General Operation

When a subscriber originates a call, the line relay operates, earthing the start leads, causing all disengaged finders to hunt for the calling line. The first line finder to arrive at the calling line is accepted and cuts through. Other finders then stop rotating. The link is seized and dial tone is returned to the calling line. The first digit is accepted on the group selector uniselector. The final selector switch commences to drive by self-interruption when the group selector reaches the third contact and stops on the contact preceding the tens group of the digit dialled, this contact having been marked by the group selector switch. The second digit is directed to the final selector switch and steps it to the number dialled. The line is tested and rung in the usual manner.

Calls to a manual trunk group proceed in the same general manner, except that a rotary search by the final selector switch takes place over the trunk group. The alteration in the function to enable this rotary search to be made is carried out by appropriate strapping on the group selector 4 bank. On calls to other automatic exchanges the functions are varied by similar means to enable the link to act as a repeater, both from an impulsing and meter signalling point of view.

On calls to a party line the link functions as for a local call, but such calls operate the party line discriminating relay in the link. This disconnects the normal interrupted ringing supply, starts up the code ringing equipment and directs the appropriate code ring to the line, after testing that the line is disengaged.

Should a subscriber lift the receiver but fail to dial, the link is released automatically by a thermal relay after a delay of one minute and the line circuit placed in the P.G. condition. Calling party release is incorporated in the link circuit. However, should the called party only replace the receiver after a call, the link is released by the thermal relay after a delay of one minute and the calling line placed in the P.G. condition.

### Jumpering

The units are designed to cater for exchanges having different numbers and types of party lines, trunks, etc. In order to fit a unit for a particular location, therefore, it is necessary to insert the correct jumpers to suit the requirements. In order to facilitate this, arrangements have been made to bring out the relevant bank terminals of the link uniselectors on to the I.D.F. tag blocks.

Fig. 4 shows diagramatically a typical "strapping diagram" which would be necessary on the group selector 5 and final selector "T" banks for

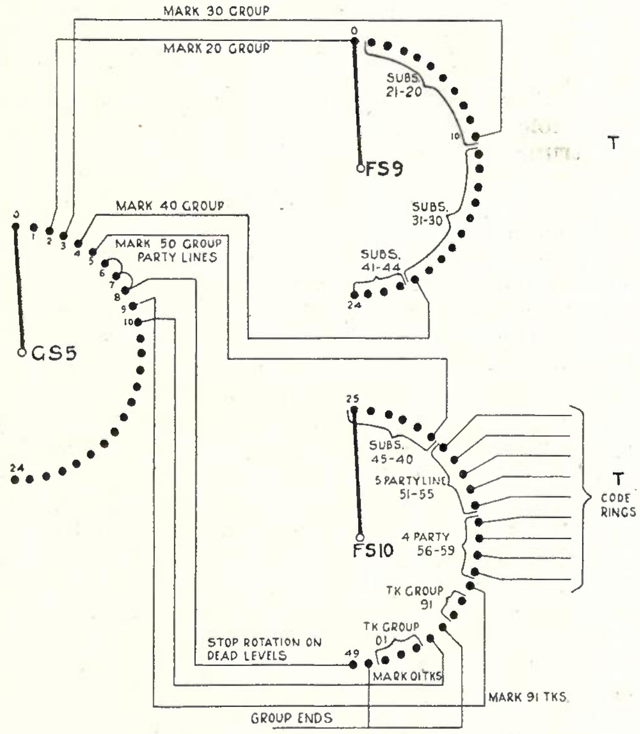


Fig. 4.—Typical jumpering, "B" type R.A.X.

an exchange having the following lines and numbering scheme:—

| | | |
|---|---|---|
| 30 exclusive services | numbered | 21–40 |
| 1/5 party line | ,, | 51–55 |
| 1/4 party line | ,, | 56–59 |
| 3 trunks to parent exchange | ,, | 01 (rotary) |
| 2 trunks to adjacent exchange | ,, | 91 (rotary) |

Considering the "T" bank of the final selector switch from the last contact, it will be noted that this contact is strapped to the dead levels on the 5th level of the group selector switch to stop the rotation of the final selector switch and provide busy tone. Contact 48 is the end of the 01 group and stops the final selector switch rotation should all trunks be busy. The overflow meter operates from the "equivalent P" wiper of this switch. The next three contacts are trunks to the 01 group, and contact 44 is the marking contact for the "0" level. Contact 43 is the end contact of the 91 group and contact 40 marks the "9" level. The strapping on the remaining contacts as shown in the diagram, is self-explanatory.

The pilot model of this unit was installed at Carrum Downs in December, 1947. Fig. 5 is a photograph of this exchange, the building of which is of the prefabricated type. This unit, and two others which were subsequently made up locally and installed at other locations, have given satisfactory service. 500 more units are on order from overseas, and delivery of these should commence very shortly. The installation of these exchanges should improve the grade of service in many country areas, as many of the localities where the R.A.X's will be installed are at present served by magneto exchanges which do not afford

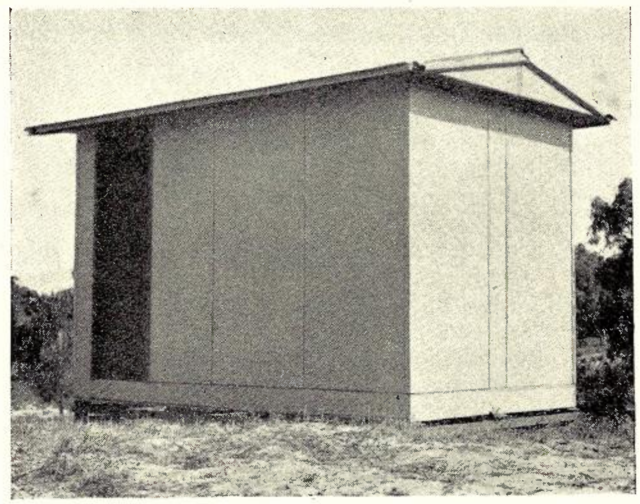

Fig. 5.—Carrum Downs R.A.X.

continuous service to the subscribers. It is hoped that, by the standardisation of the "B" type unit along the lines described, our future supply problems will be eased considerably. This in turn should help to bring us a step nearer the goal of complete automatisation of the telephonic system of the Commonwealth. In the latter regard, figures recently published by an international organisation, giving telephone statistics of various countries as at January 1, 1948, showed that one country, Switzerland, had at that date 93% of its telephones of the automatic type. At the same date Australia's percentage was about the same as that of the United States, viz., 59.5%, indicating that there is still plenty of scope for cutovers to automatic working in this country.

# DEVELOPMENTS IN THE TELEGRAPH SERVICE

J. C. Harrison

Important developments are taking place in the telegraph services of a number of countries overseas, and, when effect is given to the plans of these Administrations, telegraph users in those countries will enjoy a much speedier service than under present conditions. This desirable objective will be achieved by introducing fundamental changes in the methods of circulating telegraph traffic so that any telegram will need to be transmitted manually only once in its transit between the offices of origin and destination.

### Teleprinter Automatic Switching System

The inland telegraph service in the United Kingdom was converted exclusively to teleprinter operation in 1928, except that offices dealing with less than 80 telegrams per day utilised telephone channels. Subsequently, voice frequency telegraph carrier wave systems were introduced on a very extensive scale in Great Britain during the 1931-1934 period, resulting in a virtual conversion of the entire inland telegraph network of v.f. operation.

With the adoption of one type of equipment and one type of connecting channel a proposal was originated in 1937 by the U.K. Post Office for the design of an automatic switching scheme which would enable any telegraph office equipped with teleprinter equipment to transmit traffic direct to any other such office after any necessary switchings were made automatically. Such a scheme had been evolved prior to the outbreak of war in 1939, but the experimental equipment which had been developed was destroyed during aerial bombing raids in 1941.

Because of the damage to large telegraph establishments as a result of enemy bombing, it became necessary to disperse traffic by setting up satellite telegraph offices and, in order to obviate unnecessary re-transmission and time lag, as well as to conserve valuable manipulative labour, a teleprinter manual switching scheme was introduced as a temporary war-time measure.

The British Post Office is now proceeding to implement an automatic switching scheme around 26 switching centres. The circuit provision is being based on the peak season busy-hour requirements. Point-to-point channels will be retained between centres where the volume of traffic warrants such a course.

Each operating position associated with the automatic switching network will be provided with a teleprinter (tape printing—see Fig. 1) and a dialling unit which will include:—

- (i) A standard telephone dial.
- (ii) Switches to give facilities—
  - (a) to set up and clear a call;
  - (b) to cut off the paper failure alarm bell;
  - (c) to place the position "out of service";
  - (d) to darken the calling lamp on received calls;
  - (e) to run the teleprinter motor for test purposes while the position is "out of service."
- (iii) Lamps to indicate—
  - (a) that a call has been originated or received;
  - (b) that the operator may commence to dial;
  - (c) that a paper failure on the printer has occurred.

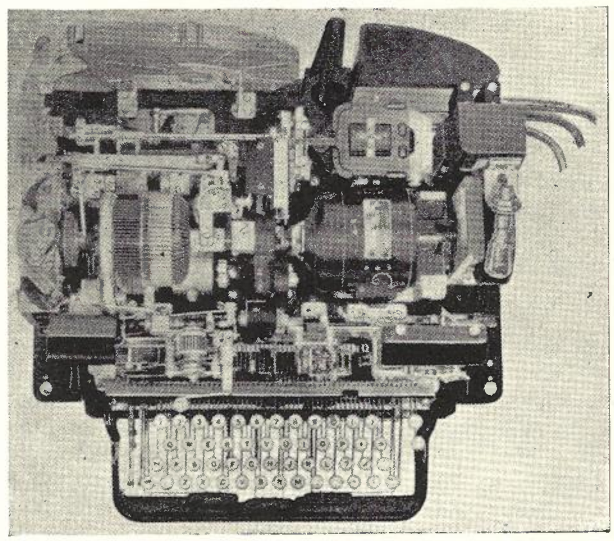

Fig. 1.—Creed & Co. model 47 tape-printing teleprinter.

The introduction of this scheme necessitates the establishment of routing lists in order to determine what signals need to be transmitted to establish communication with the office of destination. In the case of the larger telegraph offices, a "routing section" will be created and all messages for transmission, except messages for despatch over direct point-to-point channels, will be diverted to that section for insertion of the appropriate calling indications of the office of destination.

The first automatic switching centre is to be in service by the end of 1949, and the entire scheme will be implemented within about five years' time. A great improvement is expected in the grade of telegraph service when the automatic switching scheme is in operation. In addition, the scheme will enable substantial economies to be effected in manipulative labour through the elimination of intermediate re-transmissions. It is understood that the U.K. Post Office authorities propose to instal teleprinters at any office dealing with more than 50 telegrams a day. Those offices dealing with fewer than 50 messages a day will continue to utilise telephone channels for the disposal of telegraphic traffic.

Certain other European Administrations have interested themselves in the development of teleprinter automatic switching systems within their boundaries, and the May, 1948, meeting of the International Telegraph Consultative Committee (C.C.I.T.), which is an advisory body established under the provisions of the International Telecommunication Convention, discussed the question of establishing a switching network (automatic or manual) on an international basis within Europe. A recommendation that the question should be examined by a Study Group of the C.C.I.T. with the least possible delay was adopted unanimously, and the view was expressed that the European Administrations should submit, as soon as possible, the necessary detailed information to enable the matter to be explored.

Adoption of such a scheme would enable any telegraph office in one country to establish direct communication with any telegraph office in another European country, thus eliminating the intermediate re-transmission operations involved under present arrangements with their attendant additional transit times and manipulative labour costs and errors.

### The Reperforator-tape Relay System

In the United States of America, the reperforator-tape relay system is being introduced in the internal telegraph network of the Western Union Telegraph Company and on the overseas radio services of the Radio Corporation of America, as well as in the telegraph systems of the United States Army Signal Corps. This system envisages each telegram being manually transmitted only once, namely, at the point of origin and, if re-transmission be involved at any intermediate centre before the message reaches its destination, a replica of the message will be reproduced automatically in the form of perforations in the 5-unit code on a tape. Fig. 2 shows a Model 14 typing reperforator. The reperforator also prints the equivalent characters on the tape. At the repeating centres, all the equipment used for re-transmission is rack-mounted.

In the Western Union system, the messages carry a short prefix to indicate the routes they are to follow. As each message is received at a repeating centre, the operator presses a button which sets up the necessary connection to transfer the signals to the appropriate outgoing channel for onward transmission. The received tape then passes through a transmitter which relays the signals electrically across the room to the terminal of the outgoing channel concerned. In later installations, the prefixes automatically operate switches to set up the necessary connections.

The Radio Corporation of America has also adopted the reperforator-tape relay system on an extensive scale in connection with radio channels operated on a 5-unit code basis. The arrangements, however, differ in certain respects from those of the Western Union Co. For example, after reception, the reperforator tape is moved physically through pneumatic tubes to the appropriate outgoing terminal of the other circuit concerned, where re-transmission to another city is involved or, if for local delivery, to the "City Routing" section, where the appropriate indication is inserted to ensure its routing to the appropriate Branch Office or private-wire subscriber. Multiple-gang transmitters are used to obviate any loss of channel time in the insertion of tapes.

As a safeguard against loss of messages, all messages are serially numbered in re-transmission over the tape-relay system. The appropriate perforations in the tape for the next channel serial number on the outgoing circuit, however, are inserted before each message automatically by a separate machine.

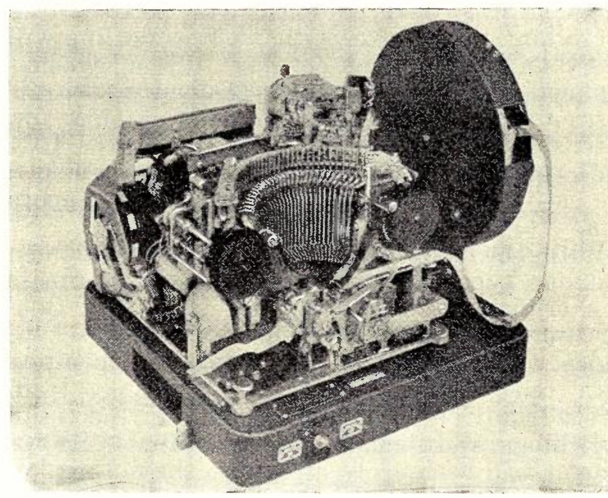

Fig. 2.—Teletype model 14—Typing reperforator (receiving only).

The reperforator-tape relay system eliminates the cost and time-lag associated with the manual reperforation of traffic at intermediate centres, as well as the costs and time-lag associated with the physical movement of documents from one position to another. It also removes the possibility of human errors in re-transmission, but there still remains a possibility of mutilations being introduced by the machines. This system has the advantage of enabling channels to be utilised to the maximum capacity, whereas, with a teleprinter automatic switching system such as that being introduced by the U.K. Post Office, channels need to be provided on a much more liberal basis than with the tape-relay method.

The Western Union Co. also makes extensive use of its varioplex system, which employs electromechanical devices to enable one long-distance channel to be utilised for the transmission of light traffic loads between a number of subsidiary offices associated with either main terminal. The subsidiary office terminals may be located either on the premises of private-wire lessees or in branch offices of the telegraph company.

Messages which are signalled by a subsidiary office are recorded at the main office, in 5-unit code, on perforated tape which is fed into its associated transmitter. Each transmitter is automatically connected in turn to the long-distance channel by a distributor, and at the distant terminal the received signals are sorted out by a synchronised distributor and relayed to a printer at the appropriate reception point.

### Other Measures to Eliminate the Need for Manual Re-transmission of Traffic

Important investigations are also being undertaken with a view to the introduction, on a world-wide basis, of measures for the reduction of manual re-transmission of telegrams between countries and systems to a minimum.

At the Bermuda Telecommunications Conference of 1945, between representatives of the Governments of British Empire countries and the U.S.A., a demonstration was given to emphasise the possibilities of speedy around-the-world communication by the use of 5-unit code teletype equipment operated over radio, landline and cable channels. The Conference discussed technical developments on the radio side which would offer a greater degree of stability in operation of machine equipment and also the question of standardisation of 5-unit code start-stop systems to enable inter-operation of the various systems to be achieved.

The R.C.A. is already utilising 5-unit code printing equipment on many of its radio circuits. Certain radio channels are not at present, however, sufficiently stable for operation on that basis and, therefore, high-speed morse and 7-unit code printing systems are employed on these. The R.C.A. 7-unit error detecting code (as distinct from the start-stop 7-unit code comprising a stop, a start and 5 intelligence pulses) requires 7 intelligence pulses. These are marking or spacing and each character or function is represented by a code having three marking and four spacing pulses. The receiving equipment is so designed that should more than three marking pulses ("extras"), or less than three marking pulses ("drop-outs") be received in the code group of a character this combination is recorded as an error, an asterisk being printed on the received copy. The 7-unit code is generally used in conjunction with time division multiplexing equipment, there being, in effect, 7 intelligence segments per channel on the distributors in lieu of the normal five segments.

Consequently, electro-mechanical devices have been evolved by the R.C.A. for automatically converting:—

(a) Wheatstone morse code tape signals to 5-unit code tape;
(b) 5-unit code tape signals to morse code tape;
(c) 7-unit code tape signals to 5-unit code tape, and
(d) 5-unit code tape signals to 7-unit code tape.

The C.C.I.T. at its May, 1948, meeting adopted certain important recommendations for the standardisation of teleprinter equipment which are designed to ensure satisfactory inter-operation between the American teletype, the English teleprinter and other European 5-unit code start-stop systems. The objective is to ensure as far as practicable that a uniform code of signals should be adopted on all circuits.

Many of the existing long submarine cables are unsuitable for the operation of 5-unit code printing systems, and the question of the evolution of machines to convert from cable code to 5-unit code, and vice versa, is, therefore, being pursued overseas. It may, therefore, be feasible, within a period of a few years, for telegrams prepared in Roman characters to be transmitted between any two telegraph offices in the world without the need for any manual re-transmissions to be undertaken.

It is also interesting to note that the International Civil Aviation Organisation is giving consideration to the adoption of a tape reperforator relay system in connection with the radio services associated with civil aviation.

### Teleprinter Subscribers' Exchange Service (Telex)

Teleprinter Subscribers' Exchange services have been in operation in a number of countries for over 16 years, and some interesting developments are now taking place with the much greater use that is being made of voice frequency telegraph carrier wave channels.

In the U.S.A. a teleprinter exchange service was first offered to the public in 1931 and now some 20,000 subscribers are using this facility.

The telex service was first provided in the United Kingdom about 1933, and up to the present time it has been operated over telephone channels. The service is not used greatly for the transmission of traffic between different cities, but more for the purpose of transmitting telegrams between the premises of the subscribers and their local telegraph offices. It is proposed, however, to vary the present arrangements and to arrange for the operation of telex services over V.F. telegraph carrier wave channels on an automatic or semi-automatic basis.

A telex service, operating on a wholly automatic switching basis, was in operation in Germany prior to the outbreak of war in 1939, and the system provided intercommunication facilities between all subscribers by dialling, calls being recorded automatically on meters on a time-zone basis.

In Denmark, a telex service over V.F. telegraph carrier wave channels was introduced in 1940, the necessary switchings being established on an automatic basis. A number of other European countries has gone ahead with the development of telex services on voice frequency telegraph carrier wave channels, and the stage has been reached where plans are being made by them to introduce an international teleprinter exchange service.

At the May, 1948, meeting, the C.C.I.T. gave consideration to proposals which had been previously prepared by a Reporters' Commission for the adoption of rules concerning an international telex service between European countries. The C.C.I.T. unanimously adopted a group of regulations, comprising 18 Articles, prescribing technical standards, operating procedure, accounting, and the general arrangements. These recommendations are being considered at the International Telegraph Conference which will be meeting at Paris this year.

**Picture Transmission Systems and Facsimile Equipment**

European administrations are taking steps to re-introduce facilities for the transmission of phototelegrams. For example, the United Kingdom Post Office has already provided an international phototelegram service for use by the public between London and Paris, Brussels, Oslo, Copenhagen, Stockholm and Rome. The equipment used is similar to that which is being installed in Australia.

International phototelegram services are also operated over radio channels between the United Kingdom, U.S.A. and a number of other countries. In the United Kingdom and U.S.A. a public phototelegram service is not available, but channels are made available to newspapers for the transmission of pictures by means of their own equipment.

The Western Union Telegraph Company has developed a facsimile system which is suitable for the transmission of telegrams. This equipment is capable of transmitting written, typewritten as well as printed matter, and a document of about 8 inches by 5 inches may be despatched over short land-line circuits (e.g., over suburban circuits in about 2 minutes). Skilled manipulative labour is not required for the operation of this equipment. This apparatus is used for the transmission of messages between a main and a branch telegraph office, as well as between the premises of a subscriber and a telegraph office, where relatively light loads are involved.

Facsimile equipment is also used in U.S.A. by railway companies for transmitting train instructions to unattended railway stations, the train crews collecting the messages on arrival. The Western Union Company is also experimenting with the use of facsimile equipment in automobiles equipped with V.H.F. radio installations, messages for delivery being transmitted to the cars from the local telegraph office.

**Development of the Commonwealth Telegraph Network**

Naturally, the foregoing developments have been noted with great interest in Australia. There might perhaps be a tendency at first for anyone to think that, although the adoption of a teleprinter automatic switching scheme or an extensive re-perforator relay system might be justified in other countries, such as the United Kingdom and U.S.A., with their much greater populations, such schemes would not be warranted in Australia, with a population of about 8 million people.

Consideration must be given, however, to the fact that Australia has a very high telegraph density compared with other countries. The number of telegrams originated in this country during 1946-47, for example, represented 4.5 per capita, as compared with 1.1 in the United Kingdom and 1.5 in U.S.A. Expressed another way, the 47 million people of the United Kingdom originate 52 million telegrams a year, while about 8 million people in Australia lodge 34 million messages in one year.

For many years past, the Department has been striving to reduce the number of transmissions in the movement of telegrams between the offices of origin and destination, recognising that unnecessary handlings not only involve higher costs but also greater transit times, as well as more potential errors due to the human factor.

During the past 23 years, much has already been accomplished in Australia in the direction of eliminating unnecessary re-transmissions. For example, a large number of provincial traffic centres has been abolished and direct channels have been provided over a number of interstate routes where formerly re-transmissions were involved. Notwithstanding the adoption of these measures, however, the present method of circulating telegraph traffic in Australia, i.e., on a manual relay basis from point to point, necessitates, on the average, each telegram being transmitted approximately twice, involving double operating costs and additional time lag, as compared with either of the proposed United Kingdom or U.S.A. procedures.

The number of telegrams lodged for transmission within the Commonwealth during 1938-39 represented 17,252,000. During the recent war period, the load expanded by 100%. The increased load has been maintained since, the corresponding figures for 1947-48 being 34,691,608, although the ornamental telegram stationery for greeting telegrams has not yet been re-introduced since the end of the war owing to production and other difficulties, while the telegraph advertising campaign, which also was suspended during the war, has not yet been resumed. Investigations are being made into the feasibility of introducing a teleprinter switching scheme, a tape reperforator-relay system, or a scheme incorporating both of these features, in the Australian telegraph network.

An essential pre-requisite to these schemes is a uniform telegraph alphabet and signalling code. Unfortunately in Australia a number of different alphabets is employed, namely, Murray multiplex, Creed & Co., and Teletype Corporation start-stop printers, as well as morse simplex and duplex apparatus. The Department is, however, proceeding with the standardisation of signalling speed, telegraph alphabet, and code of the start-stop printers which comprise the greater part of the machine systems. The existence of a number of different telegraph systems and a variety of types of transmission circuits make the problems more complicated than they would be otherwise.

It is probable that the Department may be forced to abandon the use of multiplex equipment in the next few years owing to the difficulty in obtaining further units for replacement purposes. At the present time about 50% of the total traffic load in Australia is moved over machine systems,

Fig. 3.—General view of Melbourne phonogram room.

direct printing equipment being already installed on 162 channels and a further 56 morse channels are already scheduled for conversion to machine operation (either teleprinter or teletype).

The installation of machine apparatus on circuits connected to country and suburban offices provides facilities for disposal of traffic more expeditiously than by morse, while the messages received by machine printer present a better appearance than those prepared in handwriting or by typewriter. Any plan which may be decided upon for eliminating the need to re-transmit telegraph traffic manually at intermediate centres would need to be introduced gradually, and many years might elapse before it could be implemented in its entirety. Investigations are also being made into the practicability of introducing a Teleprinter Exchange (TELEX) Service in this country, utilising V.F. telegraph carrier wave channels for inter-capital calls.

Arrangements are being made to instal a picturegram network interconnecting all the capital cities and Newcastle. The first link in this network was brought into operation on May 9, 1949, and service is being extended to the other cities in the network as soon as the equipment is delivered. It is hoped that it will be feasible eventually for the Australian picturegram network to be connected to the overseas picturegram links operated in this country by the Overseas Telecommunications Commission (Australia) by the provision of automatic relaying equipment at Mel-

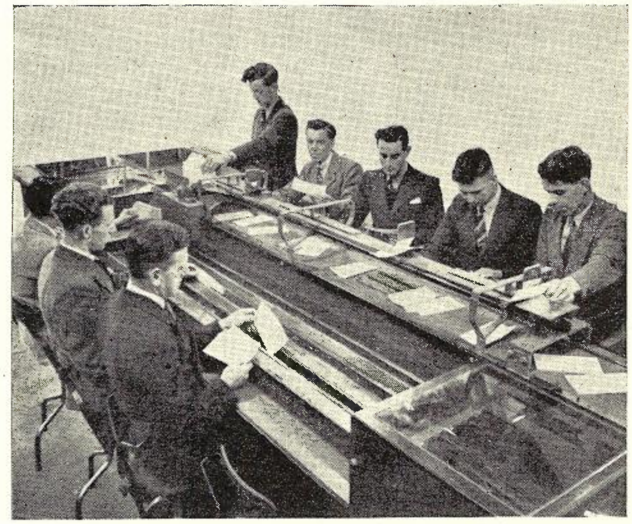

Fig. 4.—Typical primary sorting table.

bourne to enable pictures transmitted from places overseas to be received simultaneously in a number of cities throughout the Commonwealth.

Other important developments in the Australian telegraph service during recent years include:—

(a) A great expansion in the mileage of telegraph channels, which represented 300,000 miles in June, 1939, as compared with 763,000 in June, 1948.

(b) The provision of modern equipment in the Phonogram section providing for the automatic distribution of inward calls to idle operators, with facilities for storage of calls when all operators are busy, waiting calls being withdrawn from the respective queues, in the order of their arrival, as operators become disengaged.

Separate queues are provided for calls incoming from exchange subscribers and those from post offices respectively. In the larger installations, moreover, separate queues are provided for calls from post offices served by trunk line and those within the local network.

Such installations are already in operation at Sydney, Melbourne, Brisbane, Perth, Hobart and some provincial centres. Similar installations are planned for the Adelaide C.T.O., as well as at certain other provincial cities. Fig. 3 is a general view of the Melbourne phonogram room.

(c) The evolution of a belt distribution system to facilitate the internal circulation of traffic in the Chief Telegraph Offices. The first system of this kind has already been installed at Perth, and others are to be provided in the near future. A typical belt system applied to a primary sorting table is shown in Fig. 4.

(d) More extended use of motor-cycles for delivery of telegrams.

(e) A phenomenal growth in the private-wire telegraph services, the uni-directional channel mileage involved in 1948 representing 124,000 miles as compared with 10,000 miles in June, 1939. There were 167 private-wire teleprinter services in operation in June, 1948, as compared with 31 in 1939.

(f) Installation of departmental radio services for disposal of telegraph traffic during emergencies and for special purposes. For example, radio networks have been established in the North-West area of Western Australia, along the northern coastal regions of Queensland and N.S.W. for use during periods of failures of the land-line system.

## J. C. GARCIA

On 1st December, 1949, Mr. J. C. Garcia, Superintending Engineer, Postmaster-General's Department, Queensland, retired from the service. Mr. Garcia entered the Victorian State Service as a messenger in March, 1898, following this by a period as a telephonist. He was appointed to the

Engineering Branch as an instrument fitter during the early years of Federation and occupied this position until about 1910 when he was appointed as Engineer in the Telephone Equipment Section in the Engineering Branch, Victoria.

In 1912 he commenced duty as an Engineer in the Central Administration under the late John Hesketh, Chief Engineer, and this was followed by an appointment as Chief Telephone Traffic Officer in the Chief Engineer's Branch. Subsequently Mr. Garcia occupied the positions of Divisional Engineer, Telephone and Telegraph Workshops, Sydney; Divisional Engineer, Dubbo; Divisional Engineer, Transmission Section, Sydney; Assistant Superintending Engineer, Adelaide; Supervising Engineer, Lines, Sydney; Superintending Engineer, Adelaide; Supervising Engineer, Lines, Chief Engineer's Branch, and Superintending Engineer, Brisbane, which position he held at the time of his retirement. During the period as Superintending Engineer, Queensland, he was responsible for important phases of the communication network which formed a vital link in the conduct of the Pacific War.

Mr. Garcia was one of the foundation members of the Professional Officers' Association, taking part in its formation and contributing in many ways to its subsequent development. He has always taken a keen interest in the work of the Association and throughout his career has been ever ready to assist in its advancement.

Naturally, Mr. Garcia's long career in the Post Office has resulted in a wide variety of experiences and no mean contribution to the progress of the telecommunication art in Australia. In the early days of Federation he was associated with the installation of the first branching magneto multiple switchboard at Wills Street, Melbourne (as Superintending Engineer, Queensland, he was somewhat astonished in 1942 to find that the same switchboard was still functioning at Townsville). In 1912 he was associated with the installation of the first automatic exchange in Australia at Geelong and subsequently installed a branching multiple magneto lamp signalling switchboard at Bendigo, the first switchboard of that type to be installed in Australia.

Mr. Garcia leaves the Department with a knowledge of a unique period of service ranging over the whole of the Department's history as a Commonwealth undertaking. During that period the changes in telecommunication science and practice have covered a range unlikely to be reproduced in a similar period in the future. In saying farewell we wish Mr. and Mrs. Garcia many years of health and happiness in their retirement.

# PROJECTED NEW RADIO-TELEPHONE LINK FROM THE MAINLAND TO TASMANIA — PROPAGATION MEASUREMENTS

*O. M. Moriarty, B.A., A.M.I.E.E., A.M.I.E.(Aust.)*


## SUMMARY

During the period 1947-1949 a survey was made of a new route for a radio telephone link between the mainland of Australia and Tasmania, and radio propagation measurements were made over the route selected. The route was from Wilson's Promontory (Victoria) to the lower slopes of Mount Arthur, near Launceston (Tasmania), with a repeater on Flinders Island (Bass Strait). The measurements indicated that a high-grade multi-channel link could probably be provided on a frequency of about 60 Mc/s. It is likely that radio-telephone links over the route selected will be used to provide high grade Melbourne-Launceston circuits fully alternative to the existing route via Stanley.


## INTRODUCTION

A submarine cable (1, 2) laid in 1935 was the first telephone link between the mainland of Australia and Tasmania. A little later a radio-telephone link (3) on a frequency of about 40 Mc/s was established to provide emergency communication during periods of cable failure.

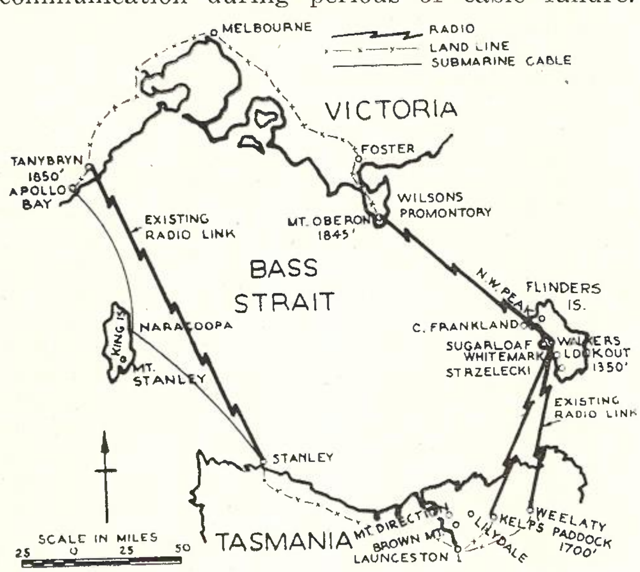


Fig. 1.—Radio paths across Bass Strait.

Fig. 1 shows the route of the first radio-telephone link, which was from Tanybryn (Victoria), at a height of 1850 feet above sea level, to Stanley (Tasmania), at a height of 400 feet above sea level. A profile of the radio path is shown on Fig. 2, where allowance is made for refraction of the radio rays by flattening the earth's surface as though the effective radius of the earth was four-thirds of the actual radius.

It is seen from Fig. 2 that the radio path between Tanybryn and Stanley is well beyond the line-of-sight between the two stations. It is, in fact, 1.9 times the radio-optical range, that

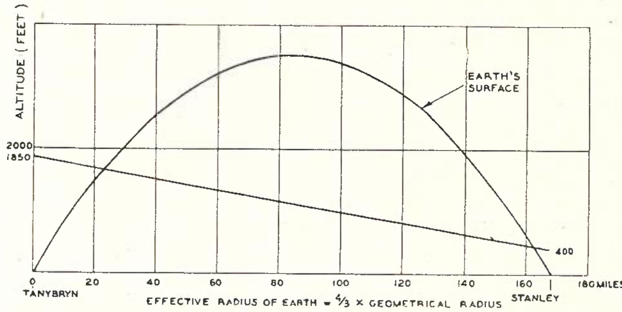


Fig. 2.—Profile of radio path between Tanybryn and Stanley.

is, the radio horizon range allowing for refraction for the heights of the two stations. The length of the radio path is 168 miles. Signals over such a long obstructed path would be expected to be

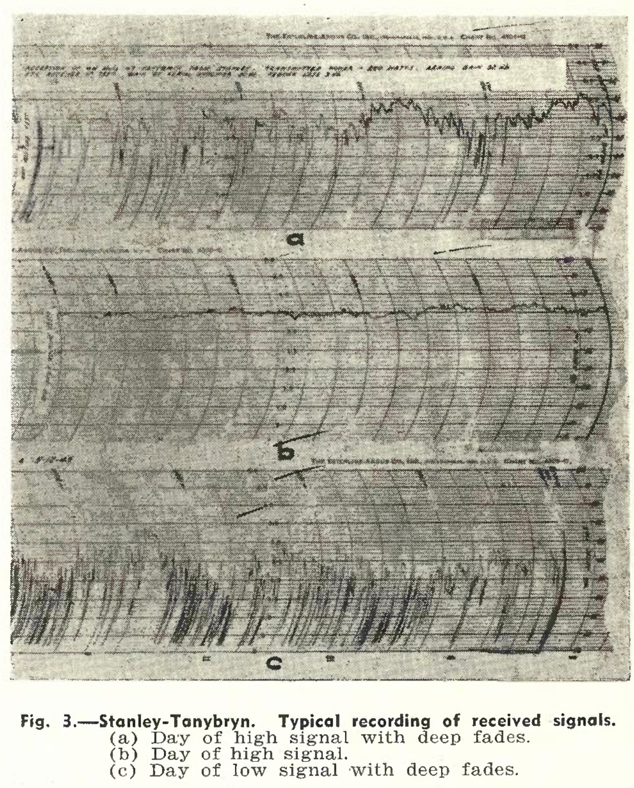


Fig. 3.—Stanley-Tanybryn. Typical recording of received signals.
(a) Day of high signal with deep fades.
(b) Day of high signal.
(c) Day of low signal with deep fades.

very variable, and to fluctuate with atmospheric conditions. This has been found to be so, and Fig. 3 shows typical records of different signal conditions. On days of low signal, the signal to noise ratio on the circuit is often very low, as it is also for short periods on days of high signal with deep fades. At such times when there is a very low signal the signal-to-noise ratio is often too low for commercial use. Fig. 4 gives typical graphs of signal strength against percentage of

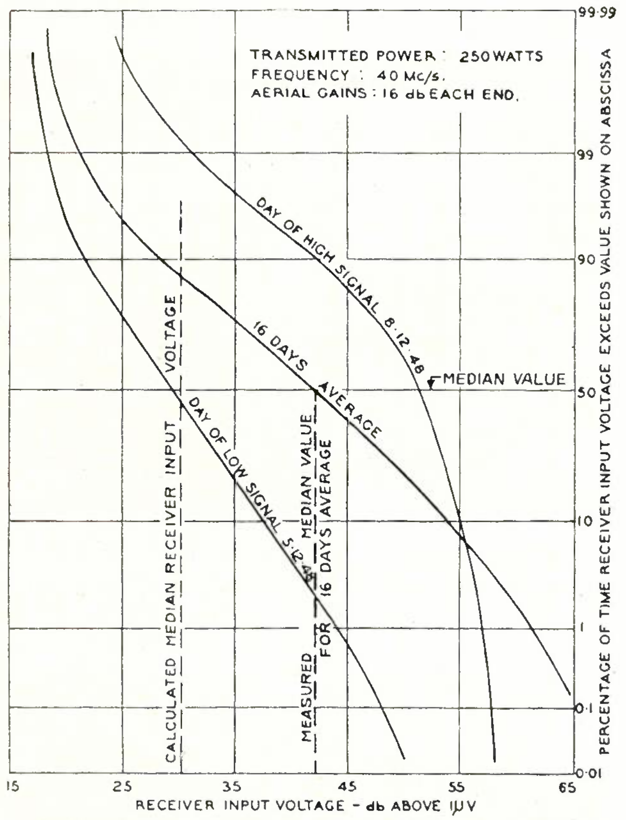


Fig. 4.—Stanley-Tanybryn. Measured receiver input voltage distribution.

the time over which the signal strength is analysed. The days of low signal correspond with weather conditions giving a turbulent well mixed atmosphere with normal radio propagation conditions. Days of prevailing high signal correspond with weather conditions producing the abnormal condition of propagation, which is called super-refraction. Reference to Fig. 4 shows that the calculated value of signal is very close to the median value for days of low signal or normal propagation. The median value is the value obtained for 50% of the time.

To improve the circuit a suggestion was made to put a repeater at King Island. Measurements were made at a low site on King Island, approximately seven miles north of the existing repeater station at Naracoopa. The measurements confirmed a calculated prediction that there would be no improvement from a repeater at such a low site. The highest available site on King Island is at Mount Stanley, 650 ft. above sea level. Calculation showed that a repeater at Mount Stanley would give two paths, one just equal to the radio-optical range, and one 1.3 times the radio-optical range. Calculations showed that a substantial improvement could be made in the circuit by a repeater at Mount Stanley if a low frequency of about 44 Mc/s, large aerials of gain 16 db, and a transmitter power of 200 watts, were used over the non-optical path.

The calculated improvement in the circuit over the western end of Bass Strait by a repeater at Mount Stanley would not, however, give a circuit as good as one calculated for the eastern end of the Strait, and described below. The latter circuit would have an advantage also in that it could be provided on higher frequencies with smaller aerials and lower power. Further, the path to be described, at the eastern end of the Strait, would end near Launceston, the telephone centre of Tasmania, and give a complete alternative to the submarine cable route. The submarine cable terminals in Victoria and Tasmania are at Apollo Bay and Stanley respectively, and the connecting land line circuits for the cable and radio channels are carried on the same pole routes and affected by the same failures. Stanley is connected to Launceston by a long pole route over difficult terrain and there has been a number of failures of this route, which completely isolated Launceston from the mainland.

## SELECTION OF SITES AT EASTERN END OF BASS STRAIT

### Selection of Site in Victoria

A map examination and calculations had indicated that the establishment of a radio circuit over paths at the eastern end of Bass Strait might provide a better service than improvement of the existing service at the western end of the

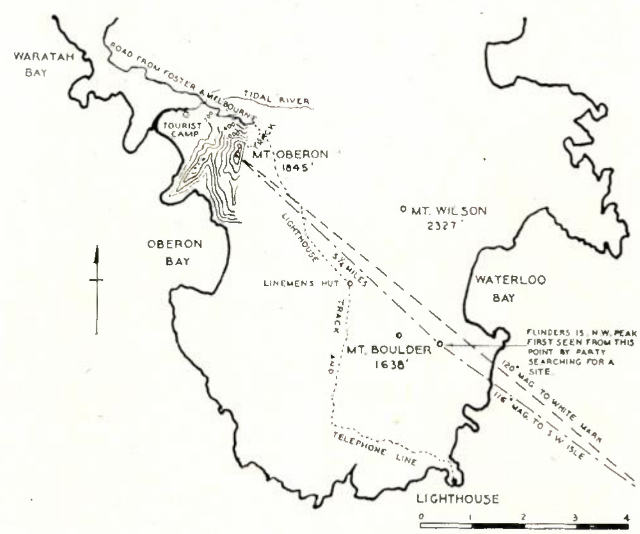


Fig. 5.—Map showing the location of the Mt. Oberon site on Wilson's Promontory.

Strait. Wilson's Promontory was the area selected for a site in Victoria. This is a large, rugged promontory with high mountains and only one road which ends some ten miles back from the southern extremity of the Promontory. Fig. 5 shows the area adjacent to the end of the road from Foster and Melbourne. Flinders Island is the only easily accessible and suitable repeater location at the eastern end of Bass Strait (see Fig. 1), and the post office and telephone exchange is located at Whitemark, near the centre of the western coast of the island. It was to be determined whether a readily accessible high site could be found on Wilson's Promontory with a clear outlook towards Whitemark.

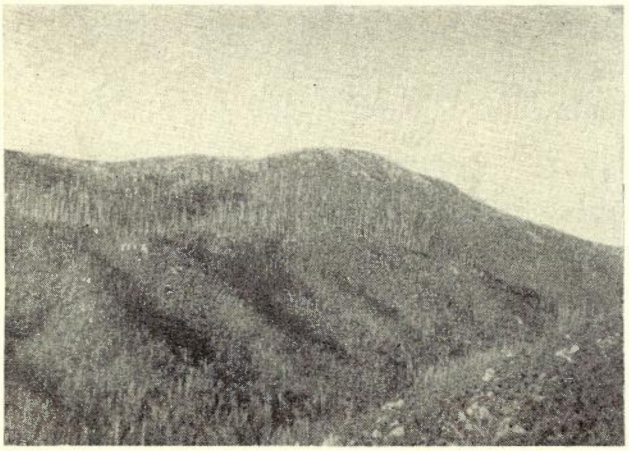

Fig. 6.—Mountainous country on Wilson's Promontory.

In November, 1947, an expedition was arranged to examine likely sites in Wilson's Promontory. Pack horses were used to transport camping gear, as a map examination and tentative profiles of paths to Flinders Island had shown that any suitable site would lie beyond the end of the road. The country was found to be very rough when off a track on the hillsides. Mount Boulder and

Fig. 7.—Some of the pleasant, low-lying country near Mt. Oberon.

Mount Oberon were investigated as the likely sites and the slopes and summit of both were trackless with tangled scrub. In places the scrub formed a solid roof, and the party had literally to crawl through in the gloom beneath. Figs. 6 and 7 are typical of some of the conditions of the search for a site. Fig. 8 shows the Lineman's hut used as a headquarters in the search. Mount Boulder had to be dismissed as impractical of access. Mount Oberon was found to be much less densely covered with scrub, and there were

Fig. 8.—The headquarters of the search. Linemen's hut built of local stones and driftwood.

several gradual grades for a track from the end of the road to the summit, and it was selected as the most suitable site. Fig. 9 is a view of the mountain. Fig. 10 is a photo of the summit. Fig. 11 shows a view from the top of the

Fig. 9.—Mt. Oberon seen from Tidal River.

mountain looking in the direction of Melbourne, while Fig. 12 is a view looking over the promontory to the sea, in the direction of Flinders Island. It is fortunate that there is a low gap in the ranges on the eastern side of the Promontory; all points on Flinders Island, as viewed from Mount Oberon, lie within the arc bounded by this gap, so that any possible path is unobstructed at the Wilson's Promontory end.

The only settlement near the road in the Promontory is at Tidal River, at the north-western base of Mount Oberon. Having decided on a site on the summit of Mount Oberon, an attempt was made by linemen from Foster to cut a track up the north-western slopes. It was found, however, that the slopes near the summit were

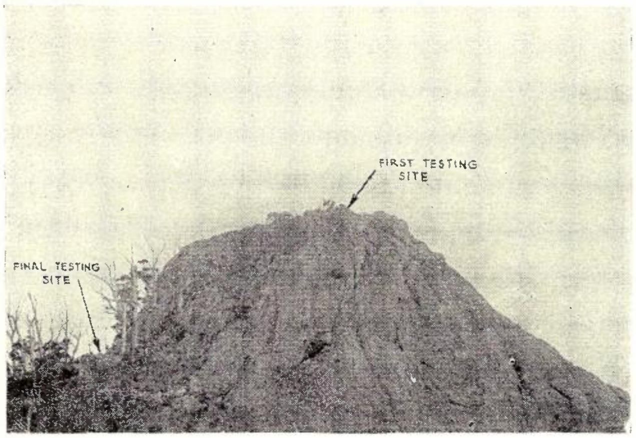


Fig. 10.—Summit of Mt. Oberon.

too steep and slippery to permit of equipment being carried up by this route. The aim was to make a track to take up equipment to make radio propagation tests with Flinders Island. A new track was then cut up a long ridge from the end of the road on the eastern side of the mountain.

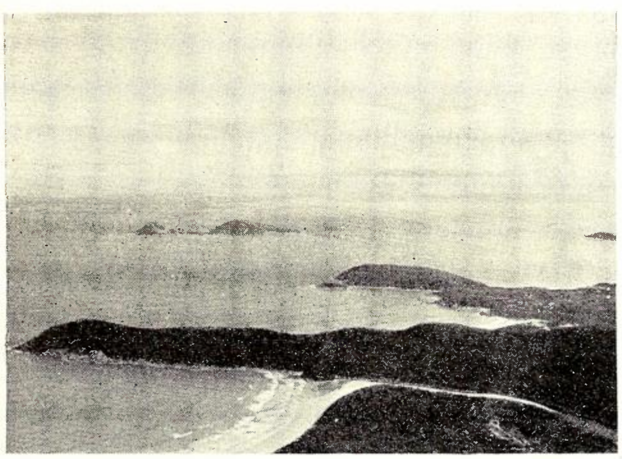

Fig. 11.—View from Mt. Oberon looking over Tidal River in the direction of Melbourne.

It had been intended that this track be wide enough for the use of a horse and sledge or a pack horse. It was difficult enough, however, to make a narrow foot track, and it was obvious that all equipment would have to be carried by men up the 900 feet of ascent between the end of the road and the summit. As will be described later, the considerable amount of equipment required was carried up the mountain by members of the testing parties assisted by local linemen.

**Visibility of Flinders Island from Mount Oberon.** The north-western side of Flinders Island is the closest to Wilson's Promontory. While examining the summit of Mount Boulder two high peaks, about one degree apart, were observed on Flinders Island. The same peaks would be in unobstructed range from Mount Oberon, and only about another four miles further away. The bearing from Mount Boulder on the more southerly and more visible peak was 116° which, on the map, passed through North

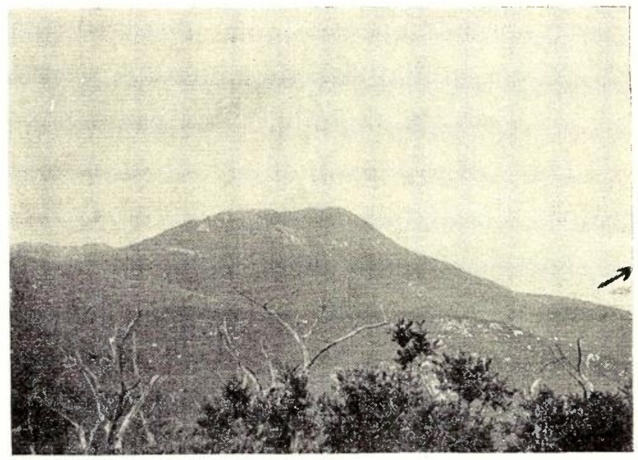

Fig. 12.—View from Mt. Oberon. Flinders Island lies in the direction of the arrow.

West Peak in Flinders Island. The other visible peak was presumed to be Mount Killecrankie, slightly to the north of North West Peak on Flinders Island.

The distance from Mount Boulder to North West Peak is 93 miles. The height of the peak is given as 1080 feet. The geometrical limit of the horizon between heights of 1650 feet, the height of Mount Boulder, and 1080 feet, the height of North West Peak, is 90 miles, which is less than the distance between the two points. If allowance is made for refraction of optical waves in the atmosphere (see Admiralty Navigation Manual, 1938, Volume III, pages 219-223) the distance to the horizon is 1.08 times the distance to the geometrical horizon. With this allowance a height of 870 feet at North West Peak would reach the horizon from a site at 1650 feet at a distance of 93 miles. With the allowance for visual refraction, therefore, North West Peak should have projected about 210 feet above the horizon, as was observed.

During several series of inspections and measurements it was only on about three occasions that the atmosphere was free enough from haze to allow of visibility from Mount Oberon to Flinders Island.

### Selection of Site on Flinders Island

An inspection was made of Flinders Island to find an accessible site from which to work to Mount Oberon. The highest sites, namely Strzelecki Peaks, the Sugarloaf, North West Peak and

Mount Killecrankie, were found to be too inaccessible, although they would have given paths within the radio horizon from Mount Oberon. A site at Walker's Lookout, in the Darling Ranges, was finally selected.

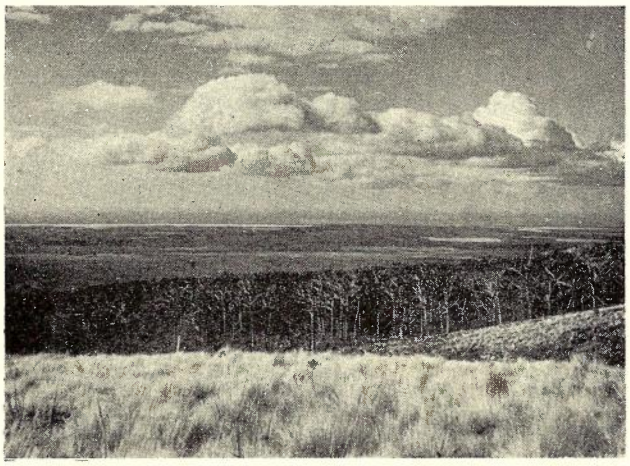

Fig. 13.—Walker's Lookout, Flinders Island.

The site at Walker's Lookout is on a clear, grassy hill (see Fig. 13), close to the end of a road from Whitemark, which is the post office centre of the island. The distance from Whitemark is 7 miles, and the grade of the road is gradual. The slope from the site to the end of the road was, however, steep without a road being cut, but it was possible to negotiate it with four-wheel drive vehicles, and this was done during the subsequent measurements.

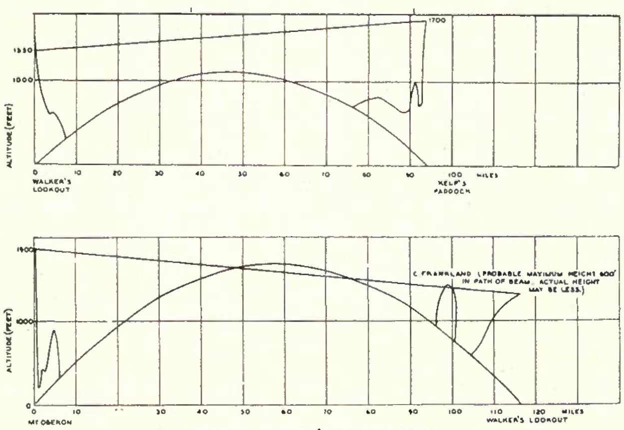


Fig. 14.—Profile of radio paths from Walker's Lookout to Kelp's Paddock, and from Mt. Oberon to Walker's Lookout.

The height of the site at Walker's Lookout is 1350 feet above sea level. A profile of the path to Mount Oberon is shown in Fig. 14. The path length is 1.03 times the radio-optical range for the heights of the sites. There might be an additional slight obstruction in the path at Cape Frankland, about 17 miles from Walker's Lookout. It was difficult to obtain the height of this obstruction, but the maximum height was estimated to be 600 feet.

### Selection of Site in Tasmania

A number of sites in the vicinity of Launceston were investigated for the Tasmanian end of the circuit. The sites examined were:—

(a) Mount Barrow which was rejected because of the nature of the road leading to the summit. In some weather conditions this road would be very unsafe and could lead to a fatality among maintenance staff.

(b) Brown Mountain, near Lilydale, which had no road to the possible site.

(c) Mount Direction, which is not readily accessible, and is remote from power.

(d) Weelaty, the existing terminal of a link from Flinders Island. This site is farther from Launceston and more remote from power supply than the site finally selected.

(e) A site on the lower slopes of Mount Arthur, at what is known as Kelp's Paddock. This site was considered suitable.

The site at Kelp's Paddock is at a height of 1700 feet above sea level. It is 2½ miles from the township of Lilydale, and about 14 miles from the outskirts of Launceston. The road to the site was good and low tension power supply was being extended along the road from Lilydale towards the site.

A profile of the path between Kelp's Paddock and Walker's Lookout is shown in Fig. 14, where the path is seen to be well within the radio-optical range for the heights of the sites.

## CALCULATION OF SIGNAL STRENGTH AND SIGNAL-TO-NOISE RATIO

### Reference Radio System

The strength of the received signals over the paths selected was calculated early in 1948 for several frequencies. The calculated signal strengths were then used to estimate the signal-to-noise ratio, which would be obtained with a multi-channel radio-telephone system.

An actual radio system which was developed and proven for long paths is that operated by the British Post Office between England and the Channel Islands, and is known as the Guernsey-Chaldon Link (4). This link is of length 85 miles, and its length is 1.51 times the radio-optical range for the heights of the sites. The system used on this link is taken as a reference for performance of a system over the Bass Strait paths.

Six channels are operated with modulating frequencies between 60 and 85 kc/s. The carrier frequencies are about 45 Mc/s, and frequency modulation with a maximum deviation of 300 kc/s is used. The deviation per channel is about 20% of the maximum deviation.

For a check on the methods of calculating the signal-to-noise ratio for the Bass Strait paths, the signal-to-noise ratio of the Guernsey-Chaldon link was calculated by the same methods to be 56 db. The performance analysis of the circuit published by the British Post Office (4) shows that the median value of signal-to-noise ratio for days of low signal is 54 db, and for an average over 8 weeks the median value is 59 db. The methods of calculation were, therefore, considered to be sufficiently accurate for the present purpose. The evidence of all the measurements which were made on the long paths across Bass Strait was that the calculated value of signal corresponded

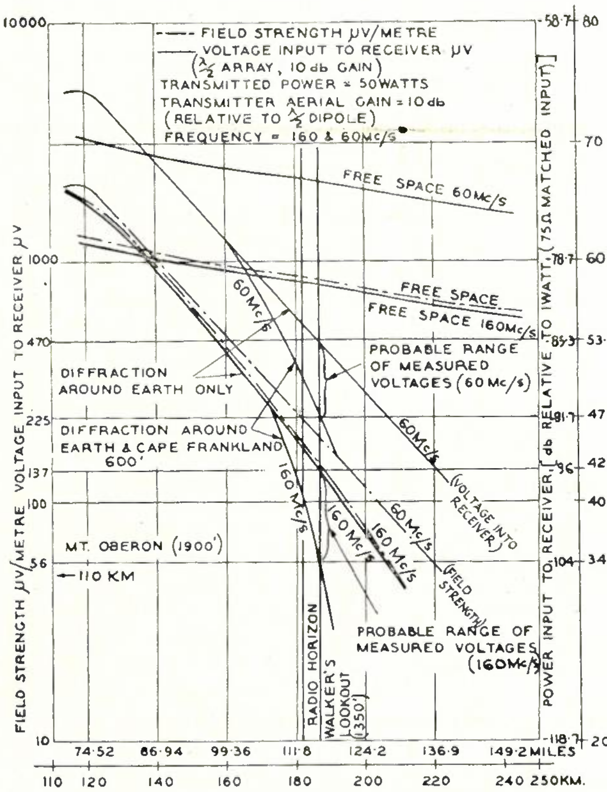


Fig. 15.—Calculated median field strengths at Walker's Lookout from transmitters at Mt. Oberon.

closely with the median value on days of low signal, which are taken to be days of normal propagation in a well-mixed atmosphere. The days of high signal are considered to be days on which there is abnormal propagation produced by a strong bending downwards of the radio rays, this condition being known as super-refraction. Apparently on the Guernsey-Chaldon link also the calculated value of signal is the median value on days of low signal, while days of high signal correspond to super-refraction conditions.

It is of interest to note that for 99% of the time on the Guernsey-Chaldon link, when signal strengths were averaged over eight weeks, the signal-to-noise ratio was not more than 18.5 db below the value calculated here, and for not more than 1% of the time was the signal-to-noise ratio more than 10 db above the value calculated here.

## Calculation of Signal Strength Paths, Wilson's Promontory-Flinders Island-Tasmania

As the Bass Strait paths were within, or close to, the radio-optical range, it was decided to measure with and plan for the use of the highest frequencies with which a high-grade signal-to-noise ratio could be obtained. The Mount Oberon-Walker's Lookout path was the one which would give the lowest signal strength and calculations were made for frequencies of 160 Mc/s and 60 Mc/s. Measurements were made on frequencies within 2 Mc/s of those used in the calculations. The use of the highest possible frequency had the advantage that the size of aerials would be smaller for the same gain.

Horizontal polarization of the radiation was assumed because reflected components from the sea would be less and because the aerials would be easier to mount. The method of calculation of signal strength used was that due to Domb and Pryce (5), which is simpler than other methods in common use. The method of allowing for the diffraction loss of obstructions in the path was taken from the work of McPetrie and Ford (6). The method of calculation of signal-to-noise ratio was one devised by the author (7, 8). The calculations were made for the channel having the highest modulating frequency, which would give the lowest signal-to-noise ratio.

For the Mount Oberon-Walker's Lookout route calculations of signal strength were made with and without allowing for diffraction over Cape

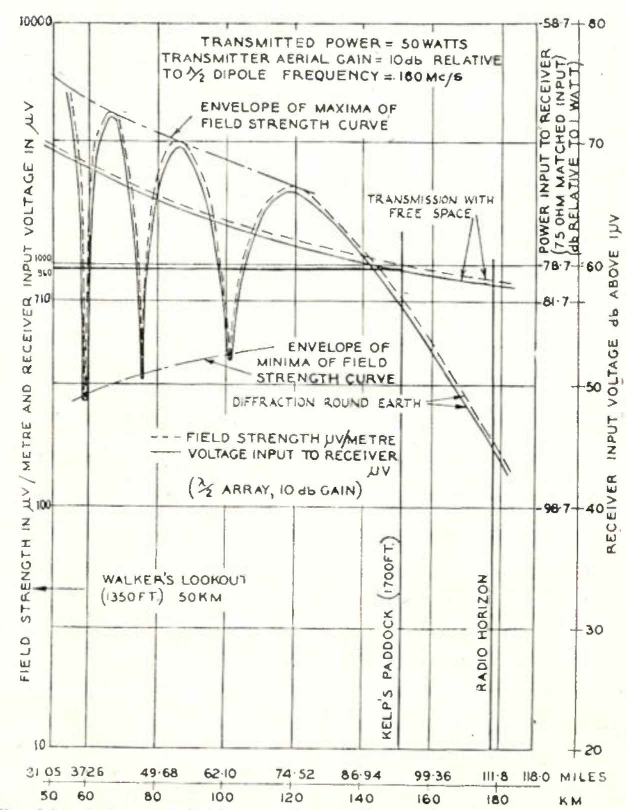


Fig. 16.—Calculated field strength at Kelp's Paddock from transmitter at Walker's Lookout—160 Mc/s.

Frankland. The results of the calculations are shown in Fig. 15. It is obvious from Fig. 15 that the diffraction loss at 160 Mc/s, due either to the approach to the radio-horizon or to the probable effect of the obstruction of Cape Frankland, is appreciably greater than at 60 Mc/s. The probable ranges of measured voltages shown in Fig. 15 referred to variations of mean signal due to diffraction with and without an obstacle at Cape Frankland and not to fluctuations due to variable refraction.

As the path from Walker's Lookout to Kelp's Paddock is clear of the earth's surface, there is no diffraction loss except that due to the approach to the radio-horizon. The results of the calculations on 160 Mc/s and 60 Mc/s are shown in Figs. 16 and 17 respectively.

### Calculated Signal-to-Noise Ratio on Bass Strait Paths

In order to indicate the likelihood of a multi-channel V.H.F. radio system being satisfactory on this route an estimate of the probable overall performance was made, based on current English (British Post Office) designs. Using the calcu-

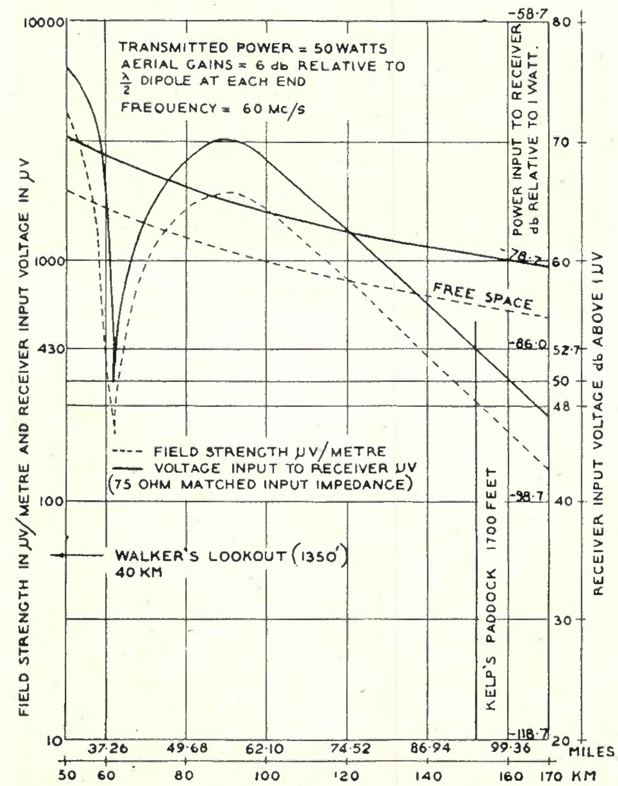


**Fig. 17.—Calculated field strength at Kelp's Paddock from transmitter at Walker's Lookout—60 Mc/s.**

lated field strengths obtained in the foregoing, the values given below of calculated signal-to-noise ratio were assessed for a system similar to the reference British Post Office system described previously, but with aerial gains and transmitted powers as assumed for the calculations of field strength:

(a) **Carrier Frequency 60 Mc/s.**

(i) **Mount Oberon-Walker's Lookout.** With the diffraction around the earth and Cape Frankland, and without fading due to variable refraction, the calculated signal-to-noise ratio was 59 db.

(ii) **Walker's Lookout-Kelp's Paddock.** The aerial gain for which the calculation of field strength was made on this path was 6 db, whereas it was 10 db on the Mount Oberon path. With this aerial gain, and without fading due to variable refraction, the calculated signal-to-noise ratio was 65 db.

(b) **Carrier Frequency 160 Mc/s.**

(i) **Mount Oberon-Walker's Lookout.** With diffraction around the earth and Cape Frankland, and without fading due to variable refraction, the calculated signal-to-noise ratio was 47 db.

(ii) **Walker's Lookout-Kelp's Paddock.** With aerial gains of 10 db as on the Mount Oberon-Walker's Lookout path, and without fading due to variable refraction, the calculated signal-to-noise ratio was 70 db.

From these calculations it was decided that propagation measurements should be made on 60 and 160 Mc/s to verify the calculated median received signal strengths and to permit an estimate of probable fading to be made. With this information it would be possible to carry out a detailed design of the radio equipment aspects of the complete system. The criterion for a satisfactory circuit was one that would give a signal-to-noise ratio above at least 50 db.

## ESTABLISHMENT OF TESTING STATIONS

### Testing Station at Mount Oberon

Severe physical difficulties faced the parties setting up and maintaining the test site at Mount Oberon. The linemen from Foster had cut a foot-track up the eastern ridge of the mountain from the end of the road (see Fig. 5). This track was very steep in places, and climbed 900 feet in a little more than a mile, which was the distance to the summit from the end of the road. The grade of the ridge was suitable for the formation of a road but, as Wilson's Promontory is a National Park, permission was not likely to be given for a wide track to be cleared unless the case for establishing a station were proved.

It was necessary to carry all the testing gear by manpower to the summit. It is a great tribute to an enthusiastic staff that the gear was carried and a substantial test station was set up. Figs. 18 and 19 show some of the gear being carried up in the more open parts of the track at the beginning and end of the ascent. The last one hundred feet of the ascent to the summit was up a rock wall, and one part of this climb was usually negotiated with the help of a rope.

**First Test Station at Mount Oberon.** The first test station on Mount Oberon was on the highest point of the mountain, with the equipment housed in tents. Figs. 20 and 21 show this station, which was for testing on 160 Mc/s only. Recordings for seven days were made at this site and then the aerial mast and tents were blown over in a heavy gale. The radio gear was salvaged and carried down the mountain to the accommodation centre in the tourist camp below.

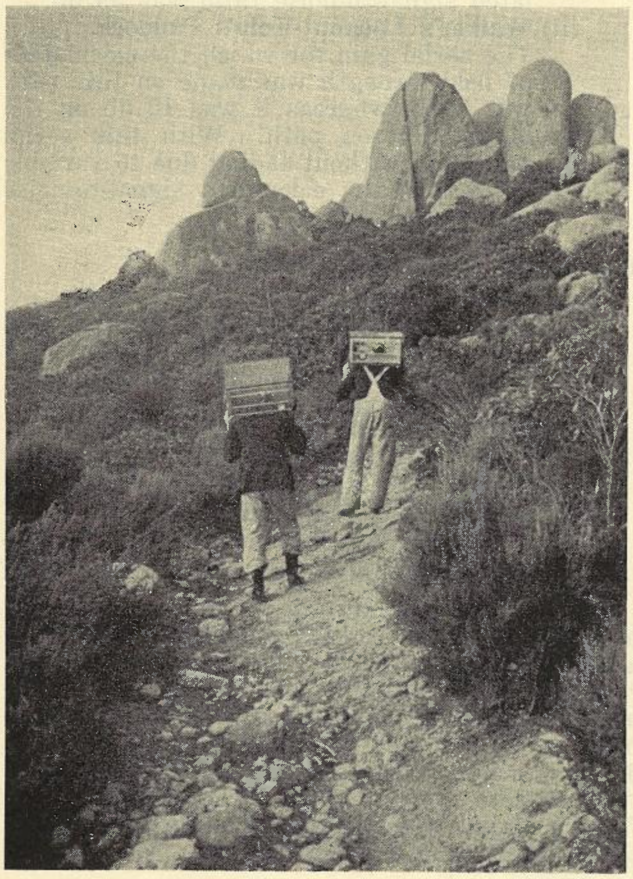

Fig. 18.—Carrying a receiver and power supply on the lighthouse track before turning off on new track to the summit of Mt. Oberon.

Fig. 19.—Petrol electric generating set weighing 120 lbs. being carried near the summit of Mt. Oberon.

Fig. 20.—First test station on Mt. Oberon—August, 1948.

Fig. 21.—Tent protection for equipment—first test station on Mt. Oberon.

**Second and Final Test Station at Mount Oberon.** A second series of measurements was planned for November-December, 1948. Experience had shown that the summit of Mount Oberon was too difficult of access and too exposed. It was estimated that there would be no serious loss of signal if the aerials were erected a little below the summit. Aerials were erected both on the summit and about 70 feet below it. Both sets were connected by concentric cables to receivers about 100 feet below the summit. The difference in signal level between the two sets of aerials appeared to be accounted for chiefly by the different lengths of cable connecting them to the receivers, the lower aerials giving the higher signals. The upper aerials were then dismantled and re-erected lower down, to serve in an emergency as spare aerials. Although there was now a rock wall some thirty feet behind the aerials, no evidence of troublesome reflections could be found.

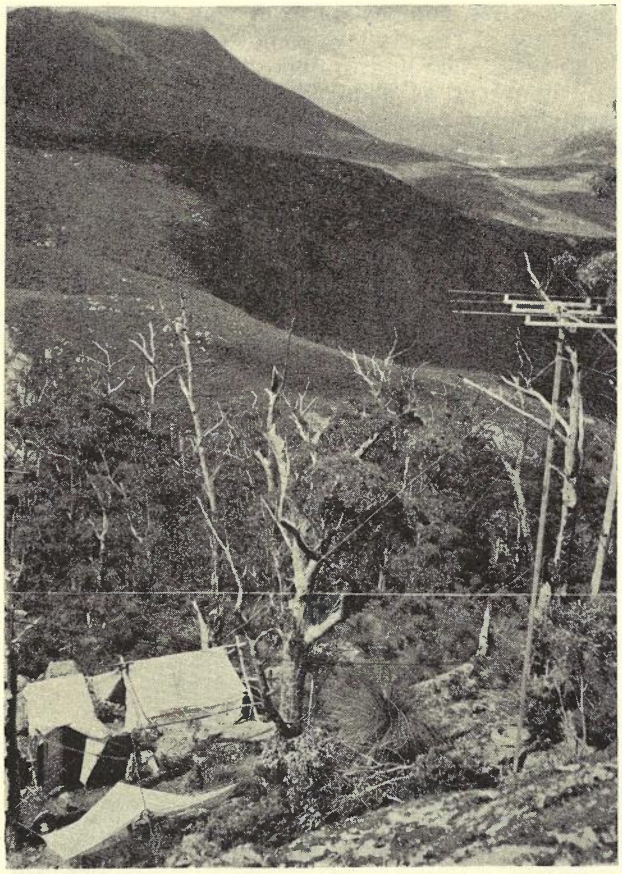

Fig. 22.—Final test station on Mt. Oberon—60 Mc/s aerial is shown pointing to Flinders Island.

As tents had been shown by experience to give insufficient protection to the radio equipment, light huts had been made up with a covering of composition board. These huts were in small sections which bolted and hinged together when erected. The floor space was about 6 feet by 3 feet. One of these huts was carried in sections to the top of Mount Oberon for the second and final test station. Figs. 22 to 26 show the final test station, which was probably unique for the difficult conditions in which it was set up. Fig. 22 shows the 60 Mc/s aerial, a 3-element Yagi, pointing through the gap in the ranges to Waterloo Bay and Flinders Island. Fig. 23 shows a 160 Mc/s aerial, a six-element Yagi. Fig. 24 shows a communication aerial which was a six-

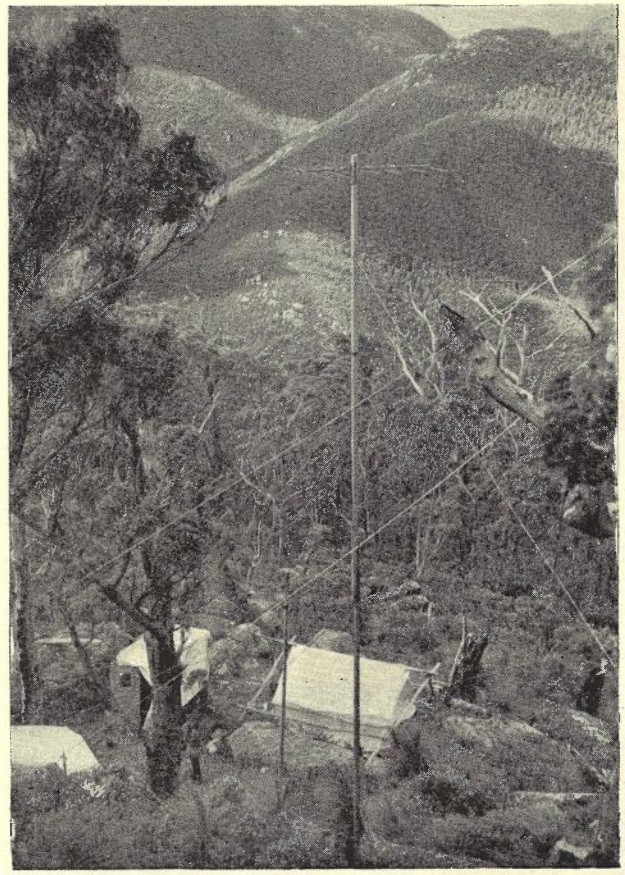

Fig. 23.—160 Mc/s aerial at final test site, Mt. Oberon.

Fig. 24.—A communication aerial at final test site, Mt. Oberon.

element Yagi on 104 Mc/s. Fig. 25 shows the location of three of the six aerials which were erected on one or two pieces of 3 by 2 inch softwood bolted together if two were used, each piece being twenty feet long. Fig. 26 shows

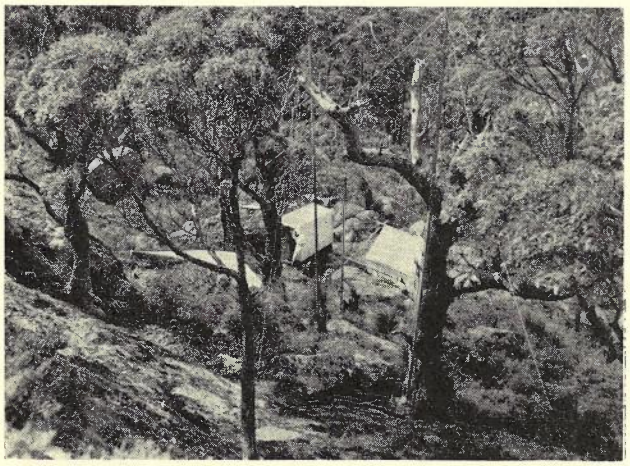

Fig. 25.—Three of the six aerial masts at final test site, Mt. Oberon.

the location of the test station, this being also the recommended location for the terminal of the projected new radio link. The hut is shown in Figs. 22 to 26 with a tarpaulin draped over it

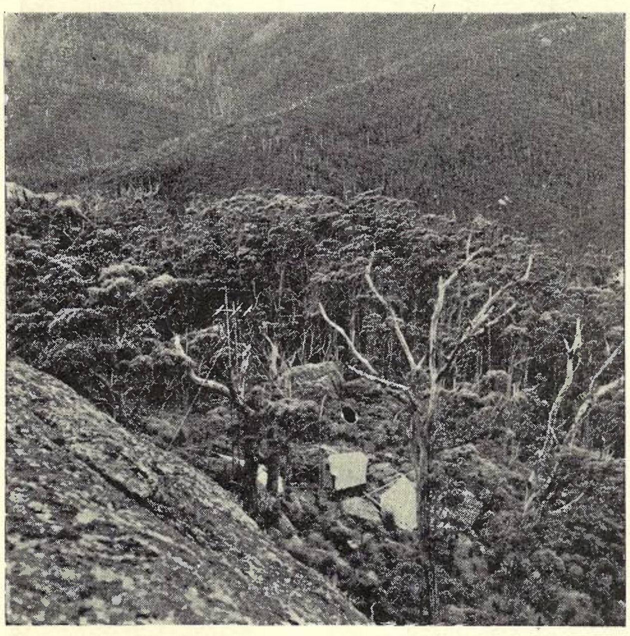

Fig. 26.—View of final test site at Mt. Oberon. Recommended site for terminal of a link to Tasmania.

for additional protection in wet weather, particularly for the opened doorways.

Because of the difficulty of carrying the gear up Mount Oberon it was used as a receiving station. When completed it had receivers for 60 Mc/s and 160 Mc/s and a spare for each, a calibrating signal generator for each of these two frequencies, a transceiver for communication, an electronic voltage stabiliser, three petrol generator sets of 250 watt, 230 volt output, and six aerials. For ventilation purposes the petrol-electric sets were operated in a large tent.

Even when the test station was completed the difficulties of the staff were not over, for each day of the tests they had to make the long climb from their quarters at Tidal River up the steep and often slippery track, carrying with them food and water and the daily supply of petrol for the generating sets.

### Test Station at Walker's Lookout

The obstacle to access to the site at Walker's Lookout was the last steep climb up the grassy hill. This was overcome by shipping into the island a small four-wheel-drive vehicle. As shipping to the island is spasmodic by small vessels, there was much trouble in getting this vehicle shipped. The vehicle is shown in Fig. 27 arriving on the site with timber with which to erect a


Fig. 27.—Four-wheel drive vehicle on the site at Walker's Lookout, Flinders Island. The arrow shows the direction to Kelp's Paddock site in Tasmania.

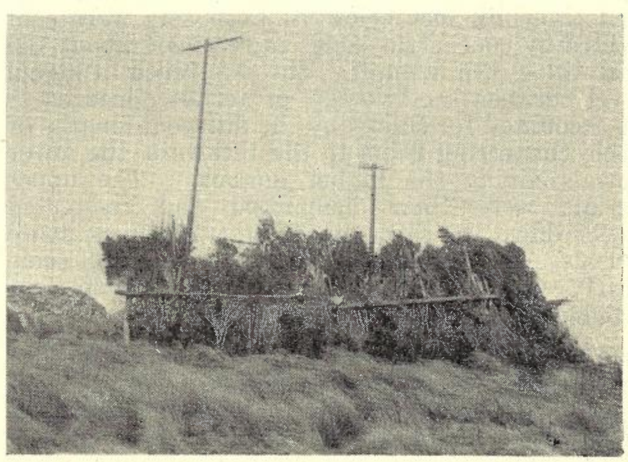

Fig. 28.—Site at Walker's Lookout. Testing installation in early stages. A brushwood windbreak was required as protection against strong winds.

breakwind. The wind on the exposed site was often so strong that tents could not be held up without a breakwind. Fig. 28 shows the breakwind sheltering the station. Two tents for the equipment were supplemented by a sectional hut bolted together, similar to the one on Mount Oberon.

The equipment at Flinders Island came near to being lost in a bushfire which burnt the surrounding country during a week-end. When it reached the station it stopped at the places where the grass had been trampled down and the earth dug in establishing the breakwind.

### Test Station at Kelp's Paddock

The testing site at Kelp's Paddock was in a large clear area beside the road from Launceston. A sectional hut similar to that at the other stations was used for the equipment, and a tent for the petrol generating sets.

## MEASUREMENTS AND RESULTS

### Measurements at Western End of Bass Strait

In January and February, 1948, measurements were made between Tanybryn and the site seven miles north of Naracoopa, and from the latter to Stanley, in Tasmania. The former path was 1.15 times the radio-optical range and the latter 1.9 times the radio-optical range. King Island was the receiving station in both cases.

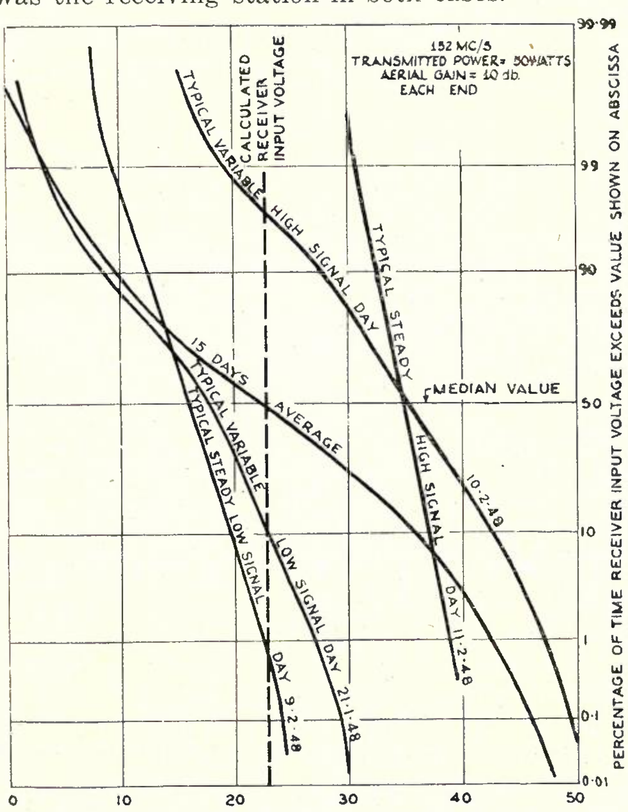


Fig. 29.—Tanybryn-King Island (site seven miles north of Naracoopa) Measured receiver input voltage distribution.

The measurements from Tanybryn were made on 152 Mc/s with a transmitter power of 50 watts and aerial gains of 10 db at each end. The transmission from Stanley was on 44 Mc/s, with 200 watts into an aerial of gain 11 db. The receiving aerial had a gain of 5 db. Both paths had slight obstructions over that of spherical earth, and an allowance for diffraction over these obstructions was made in the calculations of received field strength. Figs. 29 and 30 show the results of

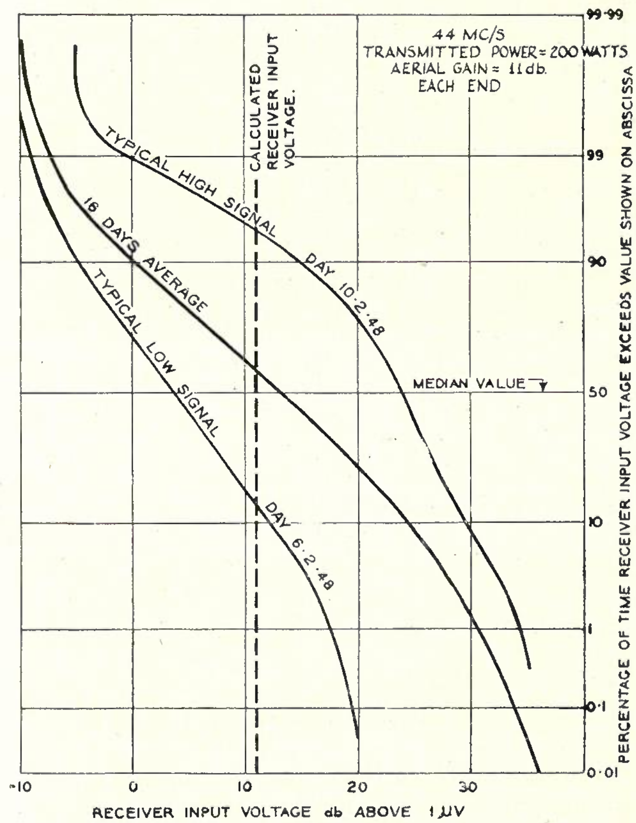


Fig. 30.—Stanley-King Island (site seven miles north of Naracoopa). Measured receiver input voltage distribution.

the measurements, and in each case there is close agreement between the calculated and median value of the measurements when the median value is taken over a period of about a fortnight. This was found to be a general result for all the series of measurements.

As previously stated calculations of signal-to-noise ratio for paths at the western end of Bass Strait showed that these paths were inferior to those at the eastern end of the Strait.

### Measurements at Eastern End of Bass Strait

**First Series of Measurements.** The first measurements between Mount Oberon and Walker's Lookout and Kelp's Paddock and Walker's Lookout were made in August, 1948, on 160 Mc/s. It was found that signals were variable, but there was good agreement between the calculated value of signal strength on both paths. The calculated value with which agreement was obtained on the Mount Oberon-Walker's Lookout path was that with the full allowance for diffraction over Cape Frankland. The types of signals obtained were similar to those obtained in later series of tests and described below.

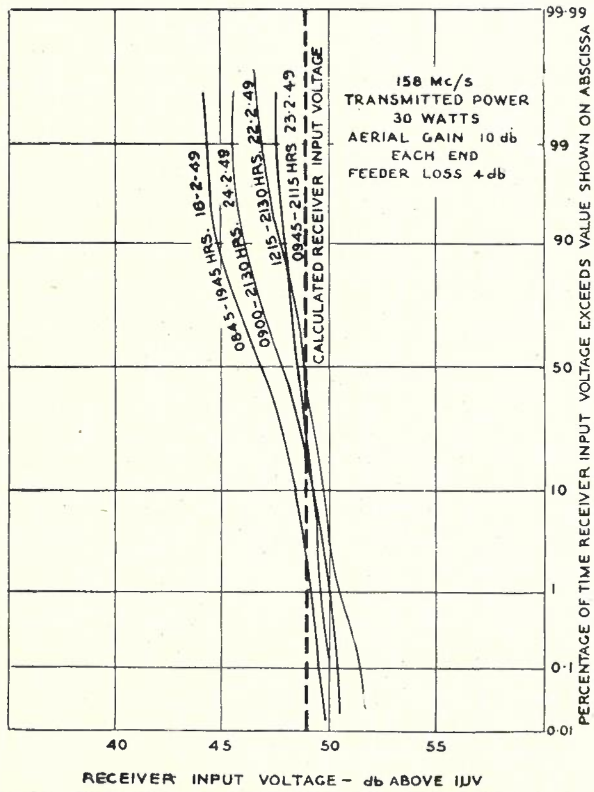


Fig. 31.—Walker's Lookout-Kelp's Paddock. Measured receiver input voltage distribution—158 Mc/s.

**Second and Third Series of Measurements.** The second series of measurements were made between 26th November and 15th December, 1948. The third series of measurements were made for

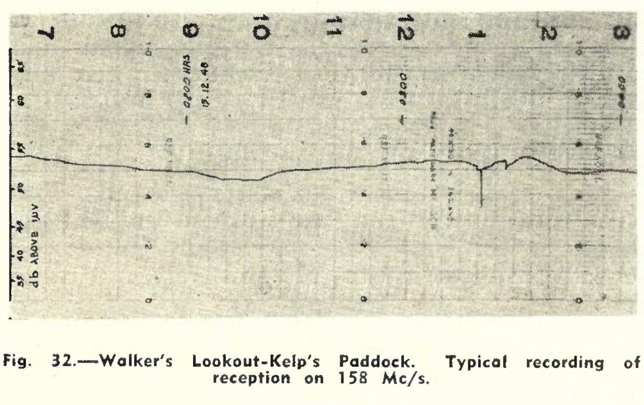


Fig. 32.—Walker's Lookout-Kelp's Paddock. Typical recording of reception on 158 Mc/s.

eight days in February, 1949, on both paths from Walker's Lookout, and on 12 days in March on the Walker's Lookout-Mount Oberon path only.

(a) **Results on 158 Mc/s on Kelp's Paddock Path.** Fig. 31 shows graphs of an analysis of the records for some representative days of recording on

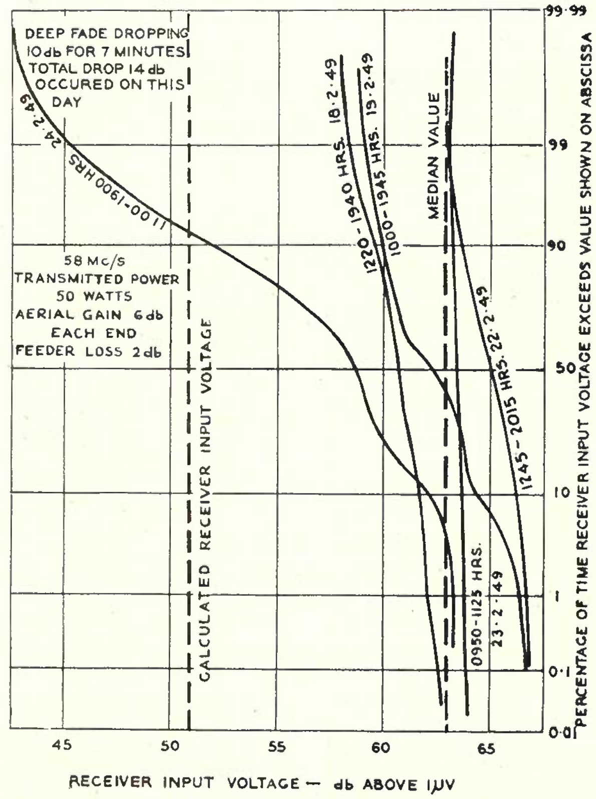


Fig. 33.—Walker's Lookout-Kelp's Paddock. Measured receiver input voltage distribution—58 Mc/s.

158 Mc/s on the Kelp's Paddock path. From that figure it is seen that the variations of input voltage to the receiver extended over about 8 db only, and were distributed close to the calculated value. Fig. 32 is a copy of a typical recording of reception of 158 Mc/s on this path.

Only one very deep fade was recorded on 158 Mc/s on the Kelp's Paddock path. A copy of the recording is shown on Fig. 35 and it is described later.

(b) **Results on 58 Mc/s on Kelp's Paddock Path.** Fig. 33 shows graphs of an analysis of the recording of 58 Mc/s on typical days, and Fig. 34 is a copy of a typical recording, except for one unusual fade of about 20 db depth from the estimated median value.

From Fig. 33 it will be seen that the median value of the measurements is some 12 db above the calculated value. This was found to be due to the signal generator used for calibration being faulty and giving a low output, thus apparently making the readings of received signal seem about 10 db high.

The only very deep fade recorded on 58 Mc/s on the Kelp's Paddock path is shown on a copy of a recording on Fig. 35. This was during the second series of tests, and throughout that series the median value of received signal on 58 Mc/s was about 10 db below the calculated value due

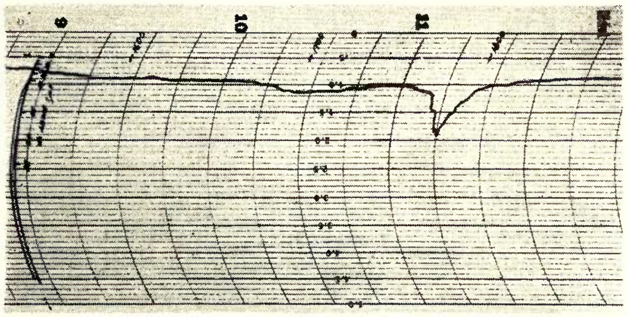

Fig. 34.—Walker's Lookout-Kelp's Paddock. Typical recording of reception on 58 Mc/s.

to a lower transmitted power being used than assumed in the calculations.

(c) **Deep Fade on 158 Mc/s and 58 Mc/s on the Kelp's Paddock Path.** A copy of the recording is shown in Fig. 35 of a deep fade occurring at about the same time on 158 Mc/s and 58 Mc/s on the Kelp's Paddock path on 13th December, 1948.

The signal level was high before the fades occurred shortly after 1300 hours. The weather was fine over Tasmania to the south of the path, except for a thick bank of nimbus cloud at a height of several thousand feet, which was moving northwards towards the path. When the boundary of this bank of cloud came near the path, the fade occurred.

On 158 Mc/s the signal began to drop at about 1305 hours, and was oscillating at levels between 10 and 8 db below the level at 1305 hours, when a sudden sharp drop occurred at 1400 hours. This drop in signal was at least 30 db below the signal level at 1305 hours, and it may have been as much as 60 db. As such deep fades had not been expected on this path, the recorder had not been set to measure fades deeper than 20 db. The signal rose sharply about six minutes later to the same level as at 1400 hours, and thereafter rose slowly over an hour and half by some 5 db to a value a little higher than the median value for the path.

On 58 Mc/s the signal began to drop slowly at about 1320 hours, and had dropped about 7 db at 1400 hours. It then began to drop more rapidly and had dropped 11 db at about the time the 158 Mc/s signal had recovered from its sharp drop. The 58 Mc/s signal then dropped at least 20 db in five minutes. By 1412 hours the drop may have been as much as 40 db, but the recorder had not been set up to measure fades of more than 20 db. By 1420 hours the signal had risen sharply to a value about 12 db below the value at 1320 hours. The signal then rose slowly over an hour and a half to a value a little greater than the median value for the path.

As the fades on the two frequencies were not simultaneous, but the fades on 58 Mc/s followed that on 158 Mc/s, it is reasonable to conclude that it was due to reflection at the boundary of a moving air mass. A calculation was made of the distances which would be needed between the direct path and the reflecting boundary to bring about a reduction of the direct received signal by reflected signals.

The result of the calculation was that a boundary of a layer in the atmosphere would cause

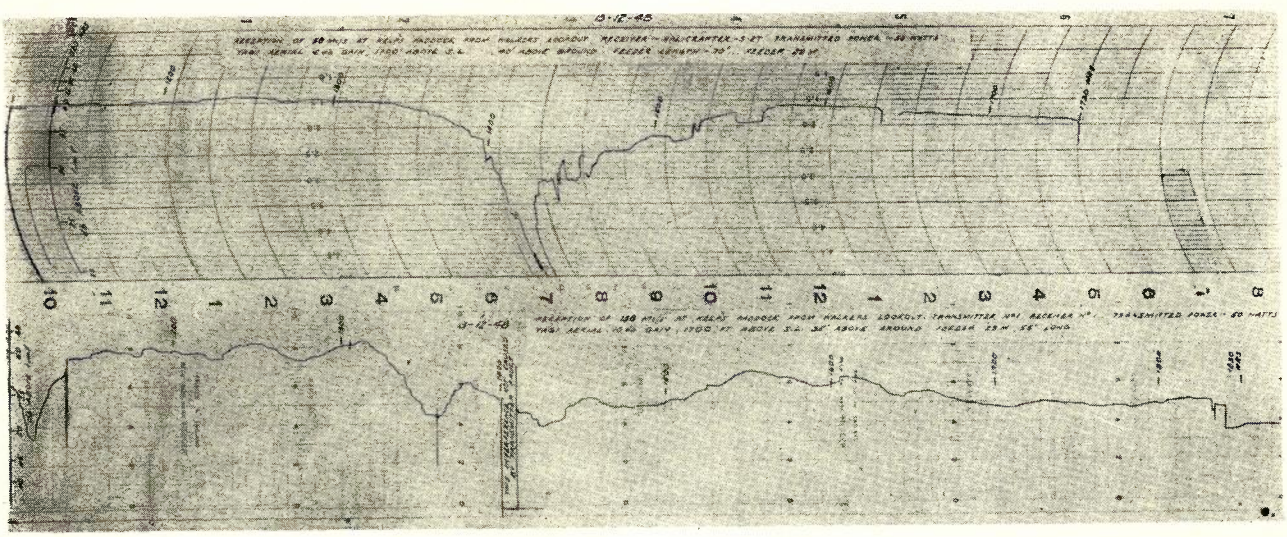

Fig. 35.—Walker's Lookout-Kelp's Paddock. Recording of reception on 58 and 158 Mc/s, showing a deep fade.

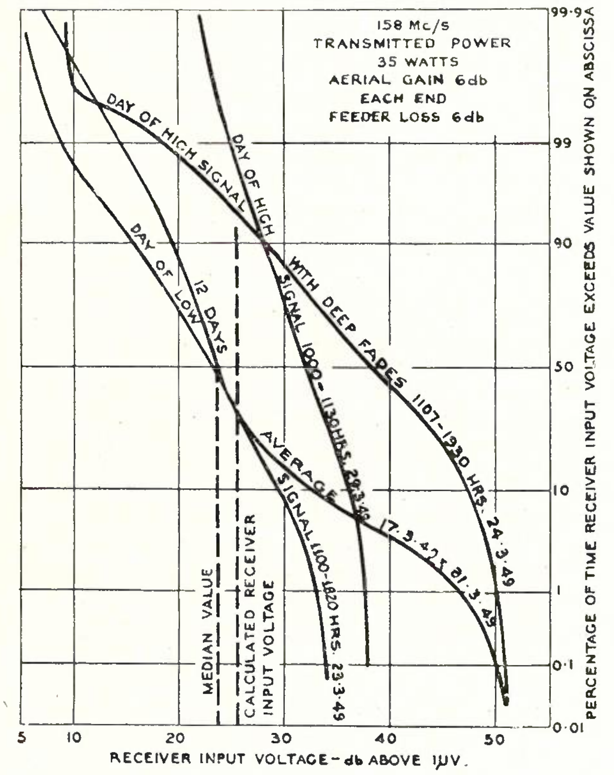


Fig. 36.—Mt. Oberon-Walker's Lookout. Measured receiver input voltage distribution—158 Mc/s.

reflections in phase opposition with the direct signal if the height of the boundary above the earth were 2120 feet for 158 Mc/s and 2550 feet for 58 Mc/s. These figures would be apparently in accordance with the observation of the height

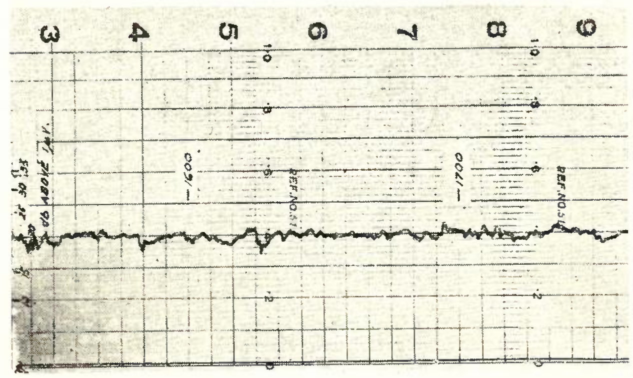

Fig. 37.—Mt. Oberon-Walker's Lookout. Typical recording of reception on 158 Mc/s. Day of normal signal.

of the nimbus cloud and could fit in with the interval of six to twelve minutes by which the fade on 58 Mc/s followed that on 158 Mc/s. The distance from the receiver to the reflective point was

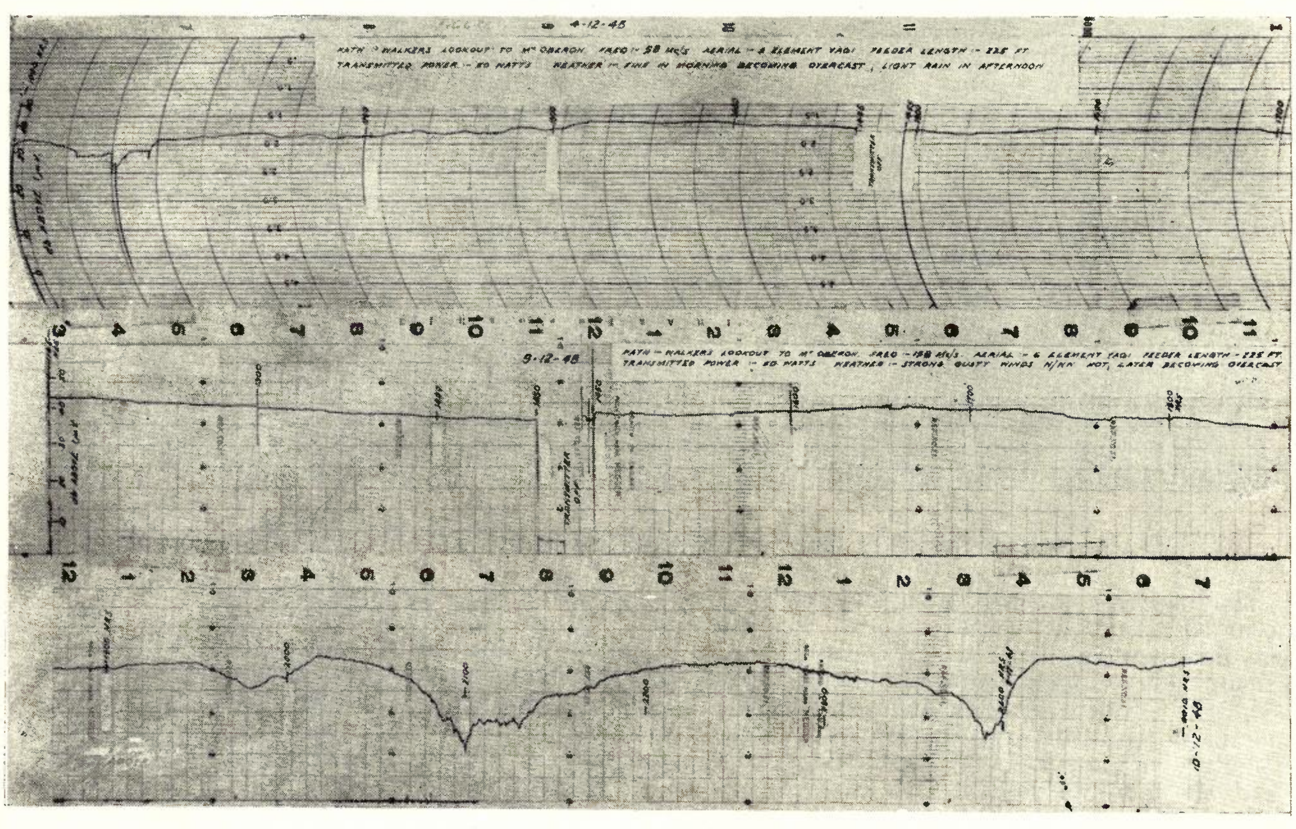

Fig. 38.—Mt. Oberon-Walker's Lookout. Typical recording of reception on 58 and 158 Mc/s. Day of high signal.

found to be 2.6 miles for 58 Mc/s and 8.6 miles for 158 Mc/s.

From the unique conditions found for the height and distance of the boundary required to give a signal causing cancellation, it is expected that such deep fades will be rare. A similar fade was not experienced on the Mount Oberon path on this day.

level. During the night time the level began to drop and slow fading occurred.

Fig. 39 shows a record of a day of high signal strength, with several sharp deep fades of depth about 20 db and duration less than two minutes at the greatest depth. As the fades were from a comparatively high level, the lowest signal

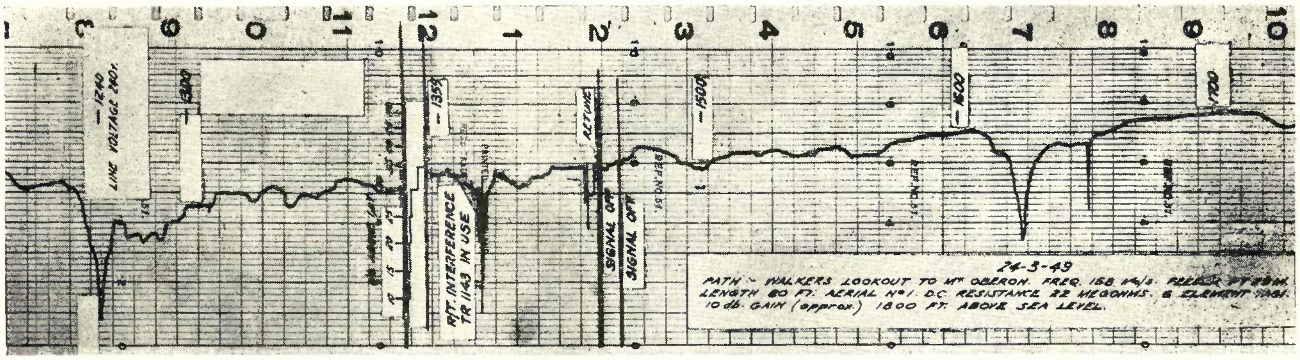


Fig. 39.—Mt. Oberon-Walker's Lookout. Typical recording of reception on 158 Mc/s. Day of high signal with several sharp deep fades.

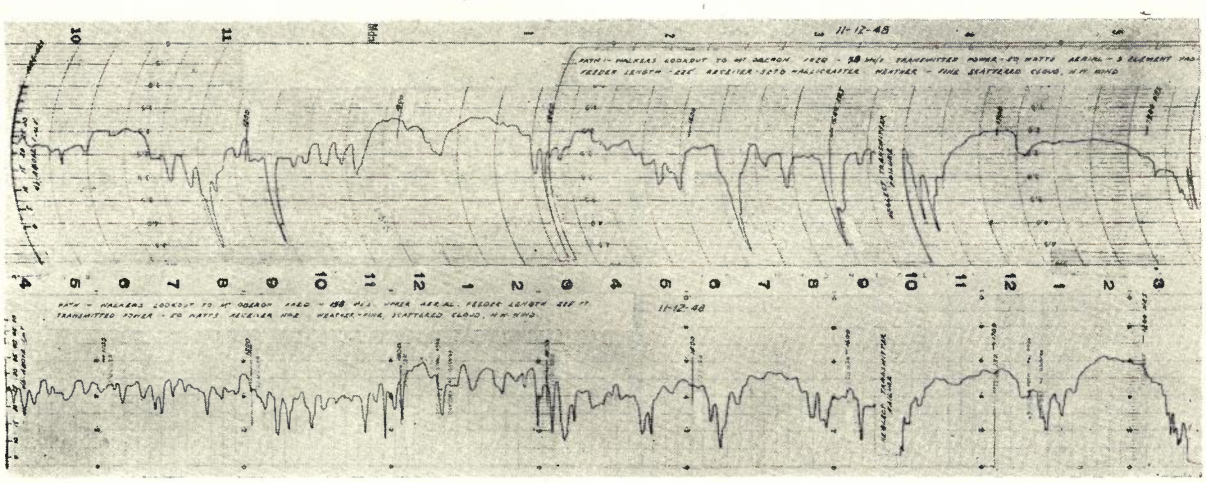


Fig. 40.—Mt. Oberon-Walker's Lookout. Typical recording of reception on 58 and 158 Mc/s. Day of low signal.

(d) **Results of 158 Mc/s on Mount Oberon Path.** Fig. 36 shows typical graphs of the distribution in time of received signals on 158 Mc/s on the Mount Oberon path. Figs. 37, 38, 39, 40 and 41 show copies of records for typical days.

Fig. 37 shows a record on a day of normal signal, when the variations from the median or calculated values did not exceed a few decibels throughout the day.

Fig. 38 shows a day of high signal, the general level being more than 15 db above the normal recorded on this day was not more than about 15 db below the median or calculated value for the path. The signal on this day rose as high as 25 db above the median value for the whole period of measurements.

Fig. 40 is a copy of the record for the day on which low signal strength was obtained for the greatest percentage of the time during the tests. This applied to 58 Mc/s as well as 158 Mc/s. The record is further described later.

Fig. 41 is a record of deep fading on both 158 and 58 Mc/s, and is further described later.

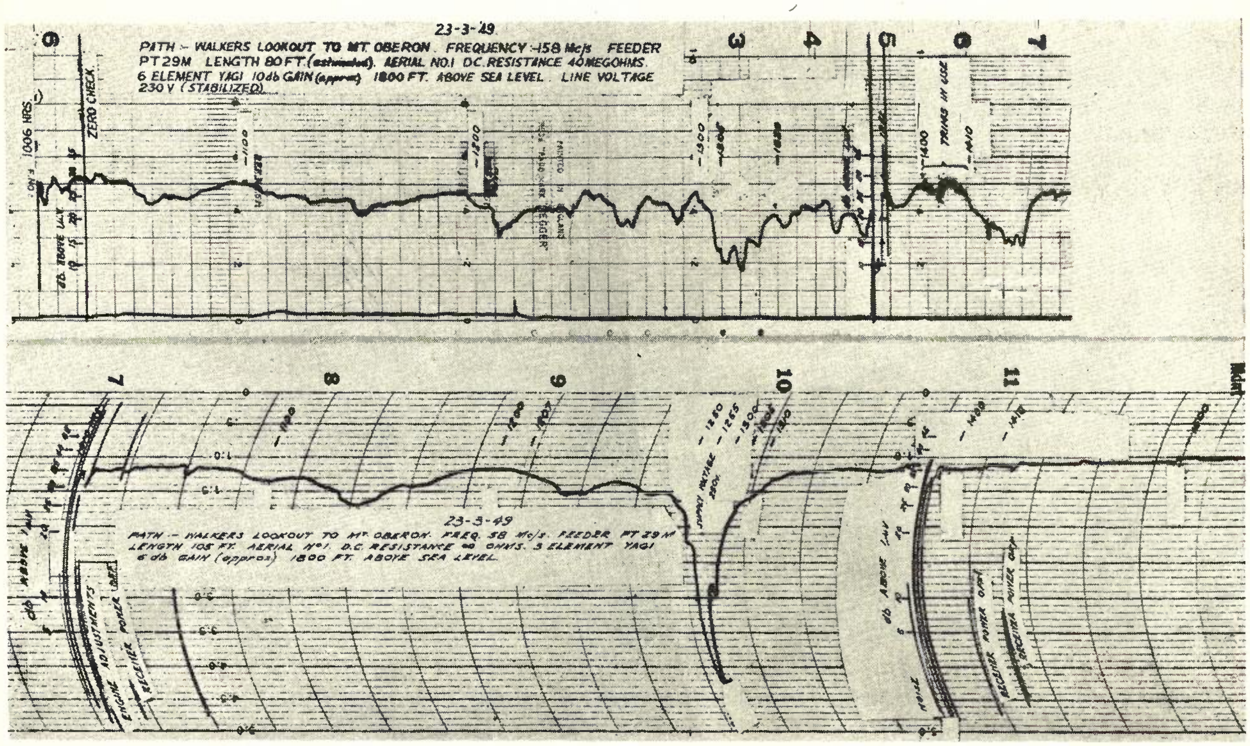


Fig. 41.—Mt. Oberon-Walker's Lookout. Typical recording of reception on 58 and 158 Mc/s. Deep fading.

(e) **Results on 58 Mc/s on Mount Oberon Path.** Graphs are shown on Fig. 42 of an analysis of the distribution in time of the values of received signal on 58 Mc/s on the Mount Oberon path. For the period of 11 days analysed on Fig. 42 the median value of the average of each day's recording was very close to the calculated value.

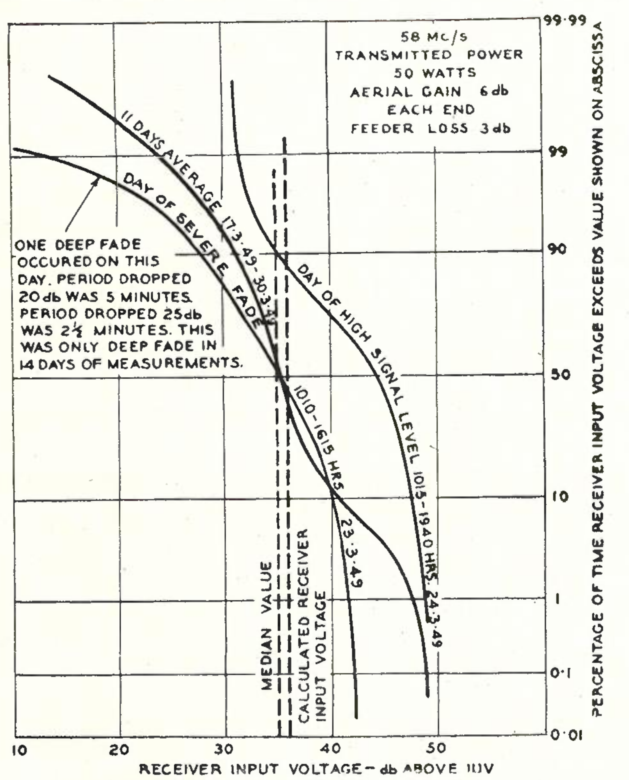


Fig. 42.—Mt. Oberon-Walker's Lookout. Measured receiver input voltage distribution—58 Mc/s.

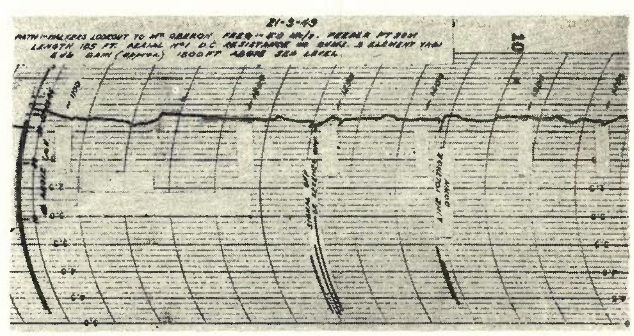

Fig. 43.—Mt. Oberon-Walker's Lookout. Typical recording of reception on 58 Mc/s. Steady normal signal.

Fig. 43 is a copy of a recording on a day of steady normal signal, which was usually a day with cold, disturbed weather conditions. As shown in Fig. 37, the recording on 158 Mc/s was also steady on this day.

Fig. 38 shows a record of a day of high signal on 58 Mc/s. The level on this day rose to about 15 db above the median value for the second series of tests of which this record formed part. For this series of tests the median value was about 10 db below the calculated value due to the transmitted power being lower than assumed in the calculations.

Fig. 44 shows a record of a day on which the 58 Mc/s signal remained fairly steady at values 10 to 15 db above the median value, while the 158 Mc/s signal (see Fig. 39) was also generally high, but subject to deep fades.

**TABLE I**

**Duration of Periods of Low Signal at Mount Oberon on 11th December, 1948**

**Period of Recording, 7 hrs. 50 minutes**

| Time hrs. | 58 Mc/s Duration of drop in signal | | 158 Mc/s Duration of drop in signal | |
|---|---|---|---|---|
| | No. of minutes 17 db below median value | No. of minutes 22 db below median value | No. of minutes 14 db below calculated value | No. of minutes 19 db below calculated value |
| 1143 | 4 | 2 | | |
| 1210 | 3 | 2½ | 1½ | |
| 1225 | | | ½ | |
| 1246 | | | ½ | |
| 1254 | | | ½ | |
| 1359 | ½ | ¼ | | |
| 1401 | | | ½ | |
| 1406 | | | 2½ | |
| 1438 | | | ½ | |
| 1442 | | | ½ | |
| 1511 | | | 3 | |
| 1518 | 4 | 2½ | | ½ |
| 1553 | | | 3 | |
| 1600 | 7 | 1 | 1 | |
| 1634 | 1½ | | | |
| 1638 | 3½ | | | |
| 1720 | | | 1½ | |
| Total | 23½ minutes | 8¼ minutes | 15½ minutes | ½ minute |

(f) **Day of Lowest Average Signal Strength on Mount Oberon path.** A copy of the recordings for the day of lowest average signal strength, 11th December, 1948, is shown on Fig. 40. The 23 largest falls in signal strength were of short duration, of the order of a half minute to two and half minutes, but they were separated by considerable intervals. Table 1 above is an analysis of the periods of low signals.

Reference to Table 1 shows that a radio-telephone system over this path would give almost 100% service if the signal-to-noise ratio obtained for the median or calculated value of signal strength was about 20 db above the minimum acceptable ratio.

(g) **Deep Fades on 58 and 158 Mc/s on Mount Oberon Path, Diversity Reception.** Fig. 41 is a record of the deepest fade measured on 58 Mc/s on the Mount Oberon path. This fade occurred at 1250 hours, and was of depth about 33 db below the calculated value of the path. It lasted almost two minutes at its greatest depth and about ten minutes at a depth of 15 db. At about 1303 hours, when the 58 Mc/s signal had almost recovered from the fade, the signal on 158 Mc/s, also shown in Fig. 41, faded sharply and reached a lowest level of about 15 db below the calculated

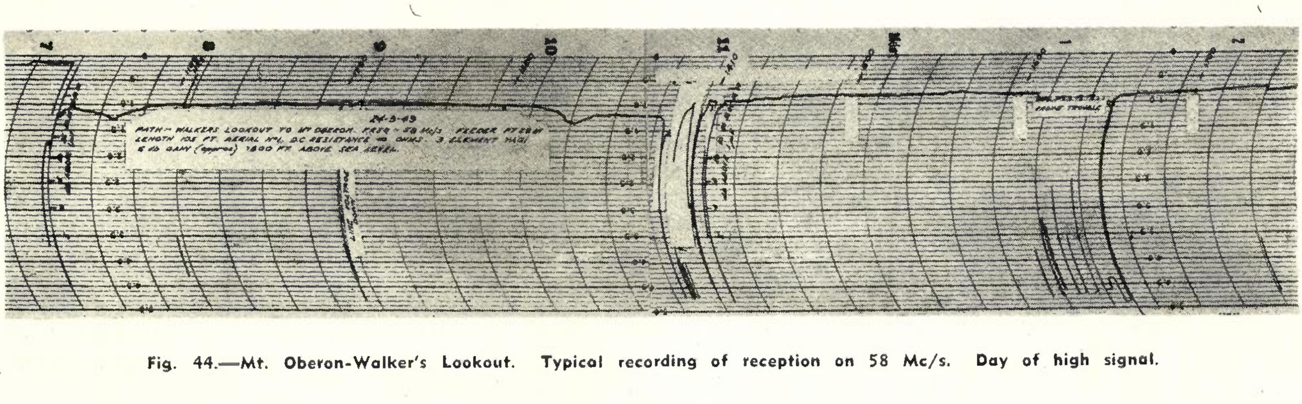

Fig. 44.—Mt. Oberon-Walker's Lookout. Typical recording of reception on 58 Mc/s. Day of high signal.

value. The signal then took about thirty minutes to recover from this fade.

The similarity between these fades and those shown on Fig. 35 for the Kelp's Paddock path is evident, and it is seen that a radio system using diversity reception from two transmitters on different frequencies could correct for these deep fades.

## COMMUNICATION OVER TEST PATHS

In the first two series of tests communication between the transmitting and receiving stations was carried out on Transceivers, Type SCR522, with 10 watts output on about 154 Mc/s, and with aerials of some 6 db gain at each end. Communication on the Kelp's Paddock path was satisfactory, but on the Mount Oberon path communication was good only when the recorded signal strength on 158 Mc/s was high. When the recorded signal strength on 158 Mc/s was normal or low, communication over the Mount Oberon path was not possible.

It was calculated that by using Transceivers, Type TR1143, with 7 watts output on 104 Mc/s, and aerials of 10 db gain, it should be possible to communicate at all times over the Mount Oberon path. This installation was made for the third series of tests and, in spite of the noticeable noise level, the communication was practicable at all times, the volume control having to be turned right down for comfortable hearing on days of high signal on 58 or 158 Mc/s.

## CONCLUSION

Calculations have been made of the median values of the attenuation at 60 and 160 Mc/s on paths across Bass Strait at the eastern and western ends. These showed that paths at the eastern end, namely Wilson's Promontory-Flinders Island-Lilydale, were superior to those at the western end, namely Tanybryn-King Island-Stanley. Propagation measurements, made at appropriate frequencies during several seasons, showed the choice of paths to be correct; the median value of the received signals indicated that in most cases the path attenuations were within a few db of the calculated values. In addition the measurements enabled the fading ranges to be estimated. By way of illustration, some figures are given to indicate, in broad terms, the signal-to-noise ratio which might be obtained when a frequency division multiplex system is used on radio bearers on the eastern path.

The measurements have shown that, when frequency diversity is not used, an allowance of 20 db for fading will cover all likely fades except a deep fade which occurs on the average less than once a fortnight and lasts for a period of about two to five minutes at a depth greater than 20 db. A further allowance of 20 db would probably be sufficient to account also for the very deep fades except for momentary periods.

If, therefore, a circuit over these paths were required to have a minimum acceptable signal-to-noise ratio of, say, 40 db, the circuit should give 60 db signal-to-noise with the calculated (median) value of signal to allow for all but the occasional very deep fades, and it should give 80 db to allow probably for the deepest fades.

To attain something like these allowances, the operating conditions used in the foregoing in this paper would have to be varied in some instances by the use of greater aerial gain or greater power. In this way the following calculated values of signal-to-noise ratio are obtained for the highest frequency channel of a 6-channel system similar to the British Post Office system used between Guernsey and Chaldon, but with a power of 50 watts and a receiver noise factor of 9 db:—

### Mount Oberon-Walker's Lookout

(a) **Carrier Frequency 60 Mc/s.** With aerial gains of 16 db each end, and aerial feeder losses of 2 db, the signal-to-noise ratio is 69 db.

(b) **Carrier Frequency 160 Mc/s.** With aerial gains of 16 db each end and aerial feeder losses of 4 db, the signal-to-noise ratio will be 55 db.

### Walker's Lookout-Kelp's Paddock

(c) **Carrier Frequency 160 Mc/s.** With aerial gains of 16 db each end and aerial feeder losses of 4 db, the signal-to-noise ratio will be 78 db.

(d) **Carrier Frequency 60 Mc/s.** With aerial gains of 16 db each end and aerial feeder losses of 2 db, the signal-to-noise ratio will be 83 db.

The above results are those without the allowance for fading. As stated in the foregoing, this allowance should be at least 20 db and 40 db if possible. As it is possible to get a higher signal-to-noise ratio with a frequency in the vicinity of 60 Mc/s than it is with a frequency in the vicinity of 160 Mc/s, and, as the higher ratio of signal-to-noise is required at times of fading to keep a high grade circuit, it was recommended that the lower order of frequency be used. This applies particularly to the Mount Oberon path, which is the critical one.

The tests indicated that a high grade multi-channel radio-telephone circuit could be established between Wilson's Promontory and Tasmania with a repeater at Flinders Island.

### Acknowledgments

The investigation described was carried out as part of the programme of the Research Laboratories, Chief Engineer's Branch, Postmaster-General's Department, Australia.

Some special acknowledgments are due to the staff who carried out the project in difficult and unusual conditions. Of the staff of the Research Laboratories, Mr. C. Rollan was in charge of the provision and construction of the special equipment used for the measurements, and took an active part in all the field work, Mr. H. Hyamson

made most of the calculations and analyses reported in this paper, and took part in the field work. Arduous work in establishing the stations at Mount Oberon fell on Mr. A. Irving, Line Foreman at Foster, and his staff. The hardest part of the assignment fell on the technicians of the Research Laboratories, who manned the stations, and of these Mr. H. Ternes, Senior Technician, was on the project throughout.

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[**Note**: In a subsequent issue of the Journal a further article will deal with the radio equipment aspects of this project.]

# THE MANUFACTURE OF THE PLASTIC ARRESTER PROTECTOR

*A. Scarfe*

The Arrester Protector, Serial 11, Items 40 and 41, consists essentially of four parts:—

(1) The plastic moulded block ⎫
(2) The discharge piece (blade) ⎬ Item 40
(3) The cap ⎭
(4) The carbon block Item 41

The carbon block (Item 41) is made by a commercial manufacturing firm under contract, and the "upper assembly," i.e., plastic block, blade and cap, is manufactured in the Sydney Workshops and by other contractors under separate contracts, the two "halves" then forming the complete Arrester Protector.

The quantities requisitioned to date on the Sydney Workshops are of the order of 500,000, and at a production rate of 4000-5000 per week this furnishes a steady production job which once set up is easily maintained and supervised. In other words, it is the type of job dear to the heart of the production engineer.

It will be seen from Fig. 1 that the most critical dimension is that of the air gap between the blade and the carbon block, and this is obtained in two ways: by the dimensional stability of the plastic moulded block and by the careful machining of the discharge edge of the blade after assembly. The gap of .004" with tolerances of ± .00075" required careful planning, accurate tooling and setting up to achieve on a mass production basis, and suitable gauging for the check of this vital dimension has been devised which enables the assembled product to be handled speedily. The principal items of tooling are:—

(a) The moulding die for the block.
(b) The blanking die for the blade.
(c) The forming and guillotining tool for the cap.
(d) The piercing die for slot in cap.
(e) The staking tool for assembly of blade to cap in block.
(f) The machining fixture for the blade after assembly.
(g) Various gauges and gauging fixtures.

The thermo-setting moulding die (see Fig. 2) has 10 cavities but is being replaced by a larger one having 24 cavities. The use of black mica-filled bakelite moulding powder, which was found to be more abrasive than the usual wood-filled powders, has caused considerable wear on this die. The frequency of maintenance inspection of moulding dies in which this powder was used had to be doubled to ensure that wear on dies, particularly the upper force, did not exceed permissible limits. Investigation disclosed that the colouring pigment was mainly responsible for the rapid deterioration of the die, not the mica filling, which was originally blamed. The moulding cycle for the arrester block is seven minutes, and with the new die in service the production rate will be more than doubled, although not increased in the ratio of 24 to 10 as might appear at first sight. This is due to the longer time necessary to handle the heavier die between fills and the slightly greater loss of heat during cleaning, etc. Filling the die with moulding powder is effected by means of a loading fixture. Supplies of the moulded block in polystyrene, injection moulded, have been made by other manufacturers and should give a satisfactory performance.

The blanking die for the discharge piece, or blade, is a pillar type lever pin locating die fed by hand with phosphor bronze strip guillotined to the correct dimensions (see Fig. 3). Advancement of the strip is made on the up stroke of the ram, and the strip is located by a lever pin for the next down stroke, the pin engaging in the cavity made by the previous blank. In the figure the lower die is obscured by the stripper plate, but the locating mechanism is clearly shown.

The cap is made from coiled phosphor bronze strip, which is annealed before passing through the press. The width of the strip is identical with the length dimension of the finished cap, and the die for this piece part performs two operations almost simultaneously (see Fig. 4). The first operation is that of guillotining the strip to the correct width, and this is followed on the last part of the down stroke by the forming operation, the guillotined portion of the strip being retained in situ by the two stop pins (P) and the face of the guillotine bar (G). Ejection is effected by small spring-loaded pins, one of which is in the upper force and two in the lower force of the die. A jet of air is also directed on to the die to aid ejection. The next operation on the cap is the piercing of the slot through which the blade ultimately fits. This is performed in a small hand press by a normal piercing tool, the formed cap being nested by hand for the job. Removing flash from the moulded block is done by forcing each block through a small die plate, and the metal parts are dipped for removal of grease and other

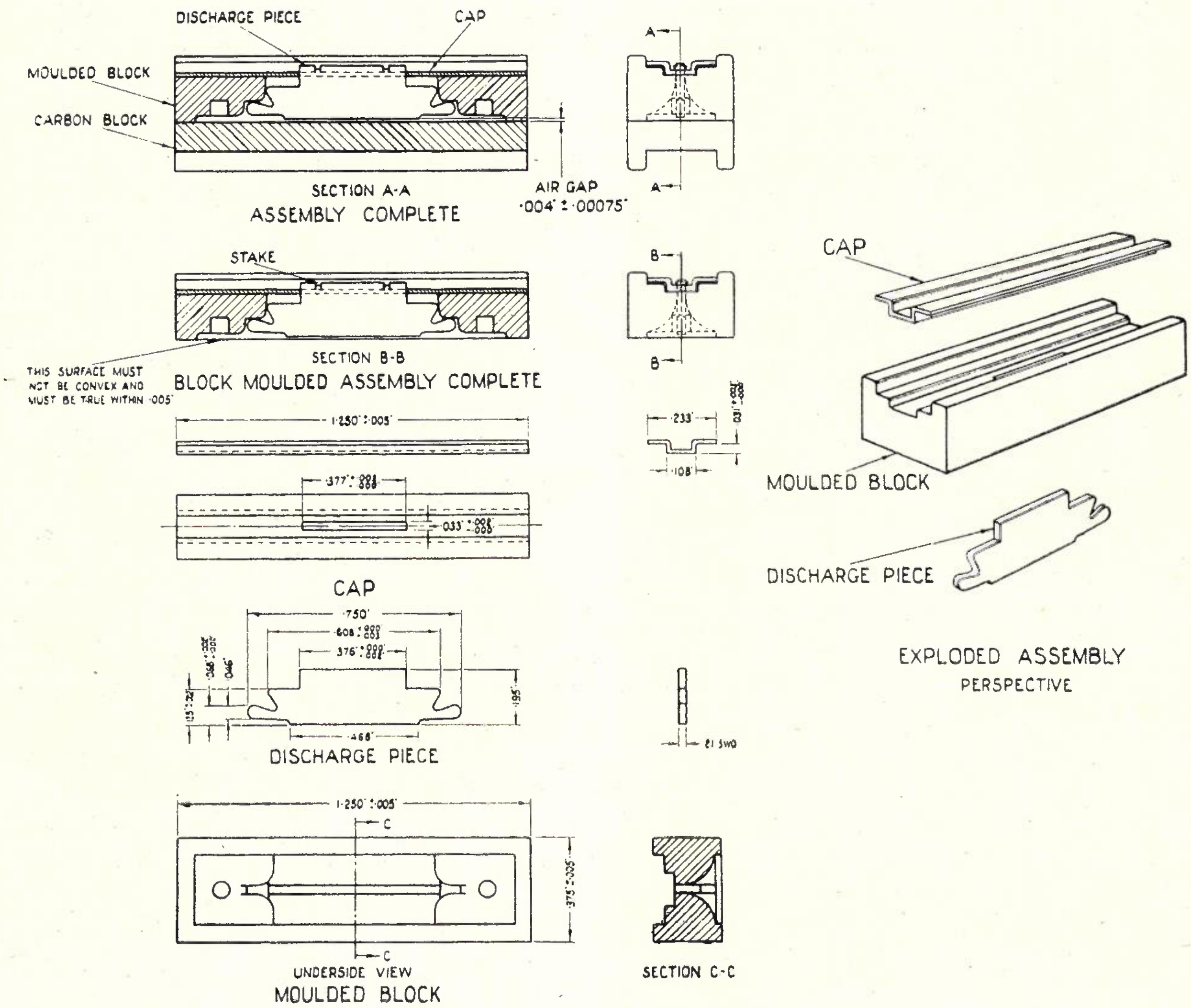



**Fig. 1.—Principal dimensions of the arrester.**

adhering matter. During production a percentage of each of the parts is taken from each day's press or machine operation, and close checks are made to ensure that piece parts conform to specification requirements.

For final assembly the blade is inserted in the block from the under-side and the cap placed in position over the top of the blade. The staking operation is then performed by hand press, using a spring-loaded pressure pad on the punch to avoid distortion of either blade or cap, but to ensure a stable adherence between these parts with no movement in the block. The assembly is then checked by a dial indicator gauge for correctness of the air gap. The ideal condition of having a large percentage satisfactory immediately on assembly has not materialised, and further operations are necessary before the final acceptance test is applied. Methods of improving the percentage having the correct air gap on assembly are being investigated, but, although some progress has been made, a real solution has not yet been achieved.

The dial indicator gauge is shown in Fig. 5, with an assembled protector in position for checking the air gap. Longitudinal movement of the protector covering slightly more than the full length of the discharge piece is provided for, and the hinged cylindrical weight at the top serves to simulate the pressure of the springs in which the protector is placed when in use.

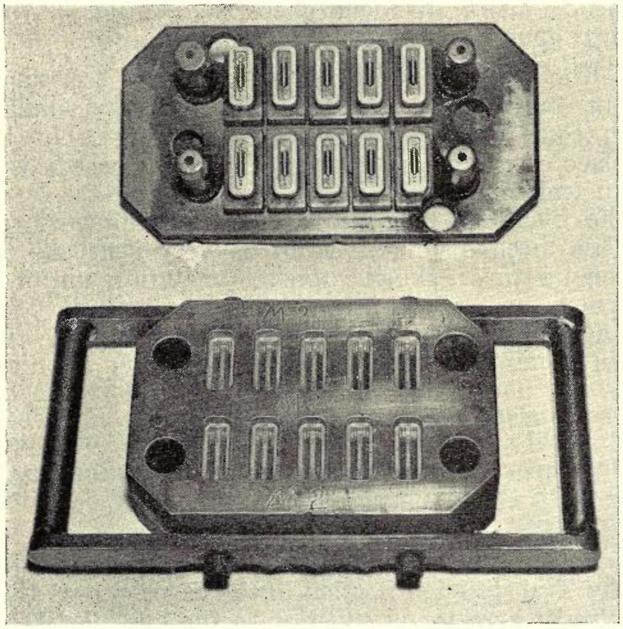


Fig. 2.—Thermosetting moulding die.

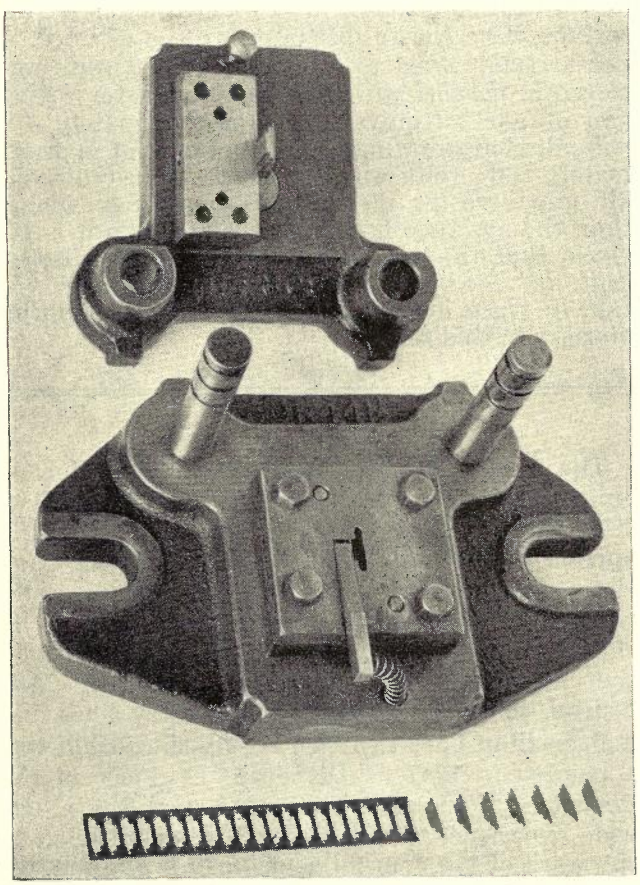


Fig. 3.—Blanking die for discharge blade.

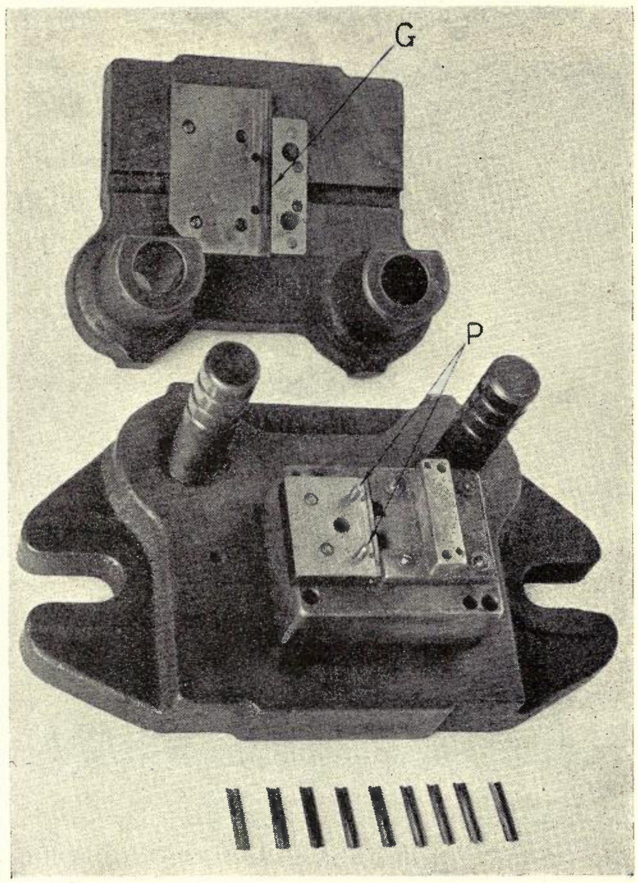



Fig. 4.—Die for forming cap.

By movement of the article from left to right and back again, the actual gap clearance can be read on the dial. The upper and lower limits of permissible gap are marked in distinguishing colours on the dial, and when gauged after assembly the protectors are sorted into three bins: (a) O.K.; (b) gap over tolerance; (c) gap under tolerance.

Those assemblies having the gap over tolerance are very lightly finished on the face of the moulding, and with practice the operator becomes very adept at reducing the gap to correct proportions quickly. After some experience has been gained, seldom more than one check in addition to the final gauging is required.

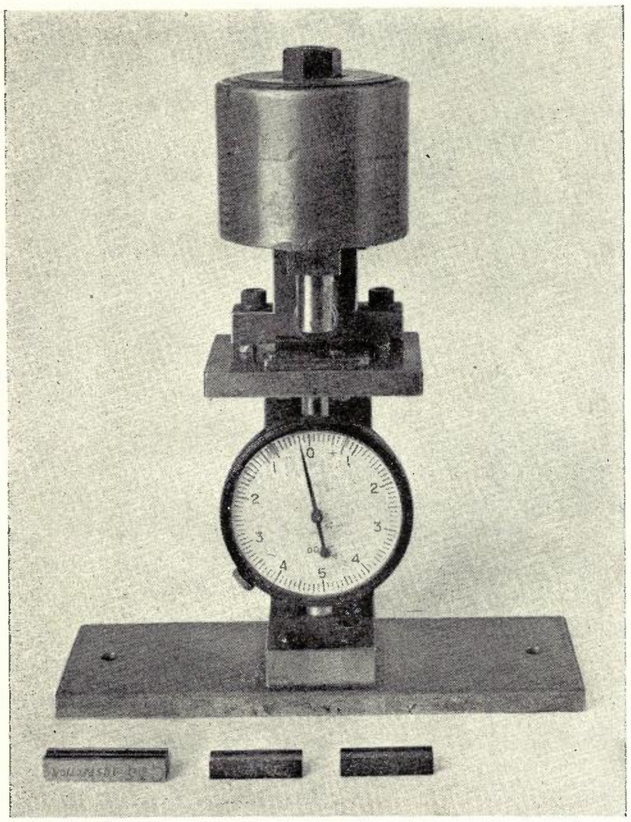


Fig. 5.—Dial indicator gauge.

The assemblies with the gap under tolerance are corrected by means of a fixture very similar in construction to the indicator gauge, but in place of the gauge stem the blade is passed over an end mill, which is set to remove metal from the blade to give the correct gap dimensions. This mechanism proved to be very sensitive to temperature changes, and to maintain uniform dimensions in the assembly it was necessary to have the miller running for at least thirty to forty minutes before use, and continue running during meal breaks. Variations of as much as one-thousandth of an inch were noticed between the cold and warm conditions of the miller. These final operations are followed by final acceptance tests by the Material Testing Section and despatch to Stores.

Some interesting experiments carried out by the Transmission Section have disclosed that this type of arrester is superior to the gas-filled tube type, in that discharge takes place faster through the air gap than through the tube which has a delayed action due to ionisation of the gas having to take place before discharge can be effected. A gas arrester rated to discharge at 350 volts was placed in parallel with the plastic arrester with a gap of .004" (equivalent to approximately 800 volts discharge rating). When a surge of approximately 2000 volts was applied to the circuit, the air gap arrester discharged appreciably sooner than the gas tube type. For this reason it is believed that the gas arrester will become obsolescent, and the blade to carbon discharge piece will take its place, at least until some new development appears in this field.

## MR. S. T. WEBSTER: MR. N. M. MACDONALD

It is with considerable regret that the Postal Electrical Society records the resignation, in September, 1949, of Mr. S. T. Webster as a member of the Board of Editors. Since his appointment in 1946, Mr. Webster has rendered sterling service to the Society by his contribution to the Telecommunication Journal. His wide experience and ability to assess the requirements of the reader have been invaluable to his co-editors. We all hope that he will fully recover from the ill-health which has brought about his retirement from the Board of Editors, and that at some future date he will once again be able to take a full and active part in the work of the Society.

The regret at Mr. Webster's resignation is tempered by the pleasure that the Postal Electrical Society has in being able to record the appointment of Mr. N. M. Macdonald to the position vacated by Mr. Webster. The co-editors join with the Society in welcoming Mr. Macdonald to the Board. Following 5½ years as Engineer in the Superintending Engineer's Branch, Melbourne, covering transmission, country lines and metropolitan lines experience, Mr. Macdonald was appointed in 1947 as Divisional Engineer in the Long Line Equipment Section, Central Office. His wide experience, coupled with his contribution to the work of the Journal as sub-editor and author, fits him well for his new position.

# THE INSTALLATION OF THE RADIO TELEGRAPH NETWORK IN NORTH-WEST WESTERN AUSTRALIA

*J. Mead*, Dip.E.E., A.M.I.E.(Aust.)

The section of Australia known as the "North-West" covers an area of approximately 500,000 square miles, representing nearly half of the total area of Western Australia, and is sparsely populated with a number of small, scattered communities. The long distances involved (Geraldton to Wyndham is 1500 miles "as the crow flies") and the very low traffic density has to date precluded the installation of a telephone service connecting centres in the area to the rest of the continent. As a result, considerable reliance has had to be placed upon telegraph communications. The route

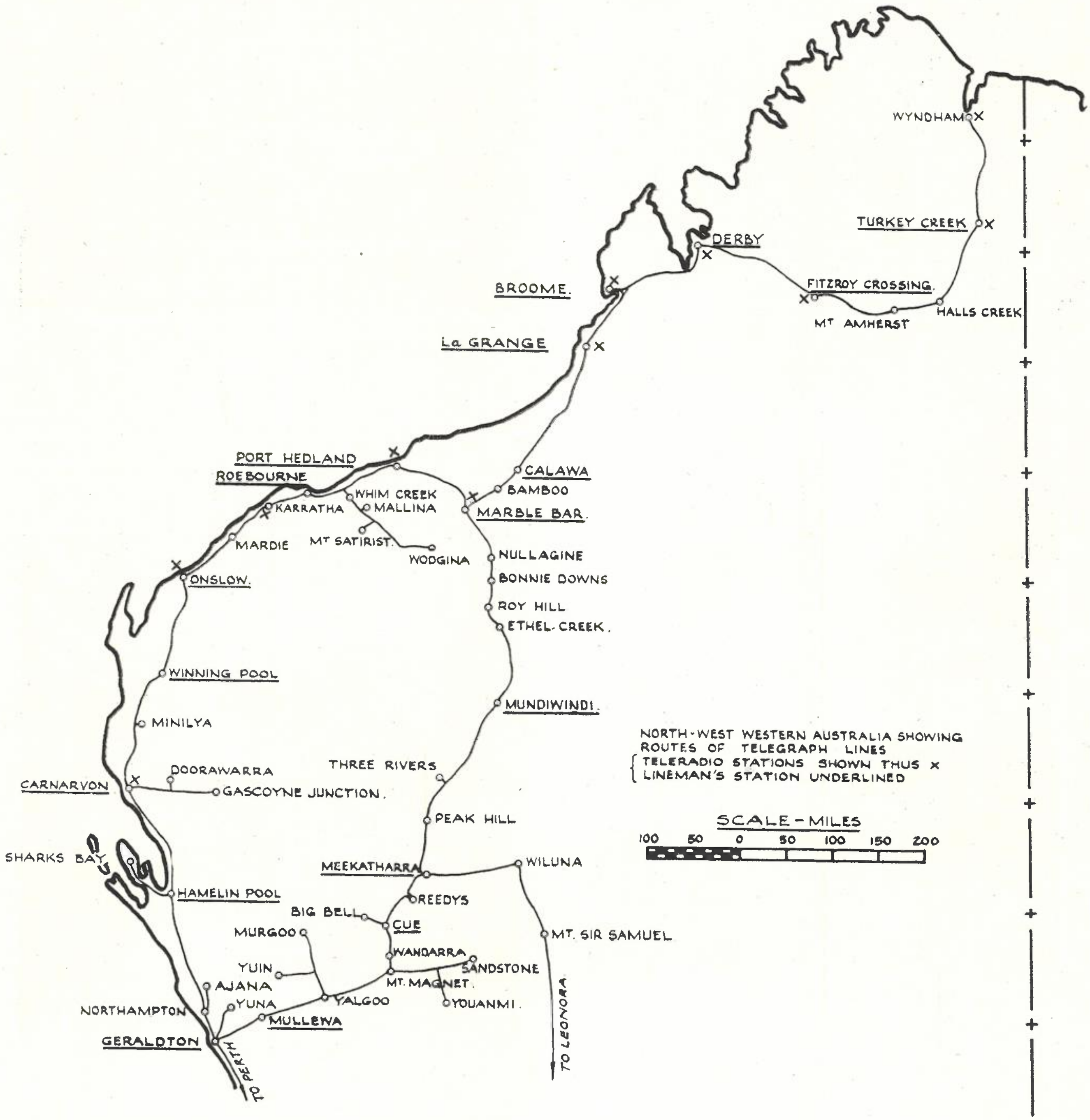



Fig. 1.—North-West Western Australia Teleradio Stations.

and extent of this network are shown in Fig. 1, while Figs. 2, 3 and 4 show typical pole line construction and road conditions. Of the two routes between Geraldton and Marble Bar, the inland route, via Mundiwindi, is more important, as the coastal route is more subject to leakage trouble from sea mists and to coastal storms, and is generally more difficult to maintain.

The importance of maintaining communications was emphasised during the recent war and the close proximity of the Japanese forces to the mainland stressed the need to ensure the security of the land line system connecting this area to the remainder of the network. Approximately 1800 miles are involved in the circuit from Geraldton to Wyndham, and as the area is subject periodically to floods and cyclones it follows that at times serious interruptions have occurred to the service. Such interruptions in many cases are difficult to repair because of the lack of suitable roads, the obstruction of rivers during times of flood and the long distances between lineman's stations. In the worst cases, several days may elapse before circuits are restored, causing serious accumulation of traffic.

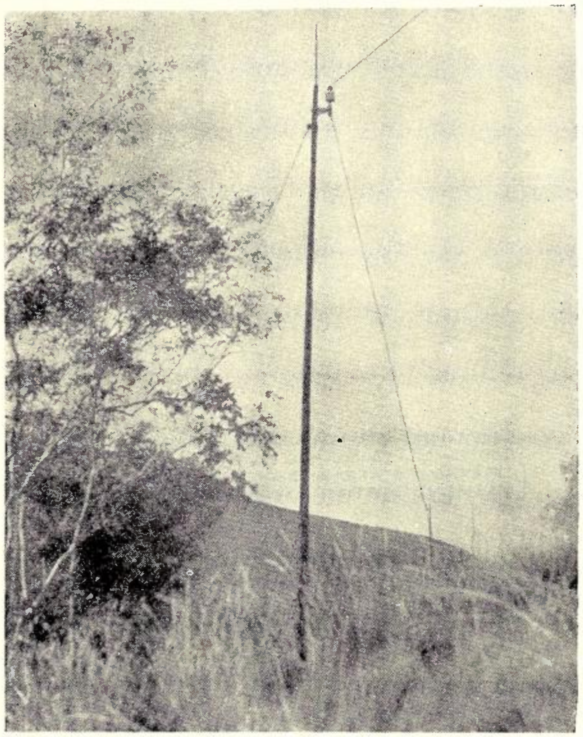


Fig. 2.—Typical section of pole line.

As a result, it was decided to provide a radio network linking all of the main post offices on the route, to enable a faulty section of line to be bridged. The location of the units is shown in Fig. 1. The most desirable features of the equipment are:—

(i) Portability.
(ii) Simplicity.
(iii) Operation from batteries.

Portability was necessary to conserve space, as the Post Offices in the district concerned were restricted for space. Simplicity is vital to ensure continuous service, as the operating personnel

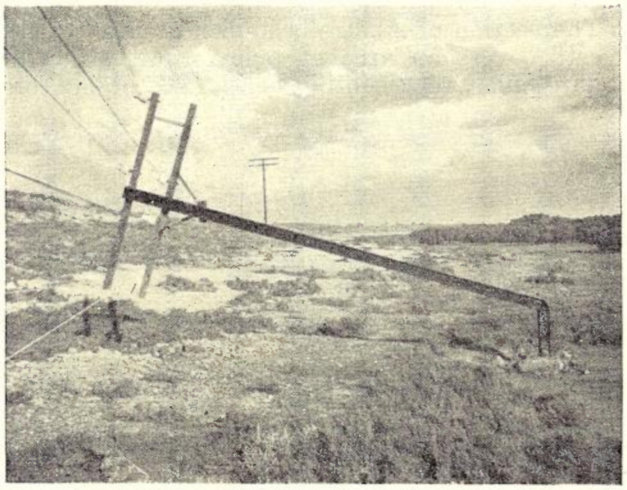


Fig. 3.—Storm damage after a "Nor'-West Blow."

are not technically-minded, although very keen to learn. Operation from batteries was an essential feature, as power supplies in the towns concerned are, in most cases, non-existent, and even where available are unreliable. The installation of prime movers and alternator sets was not

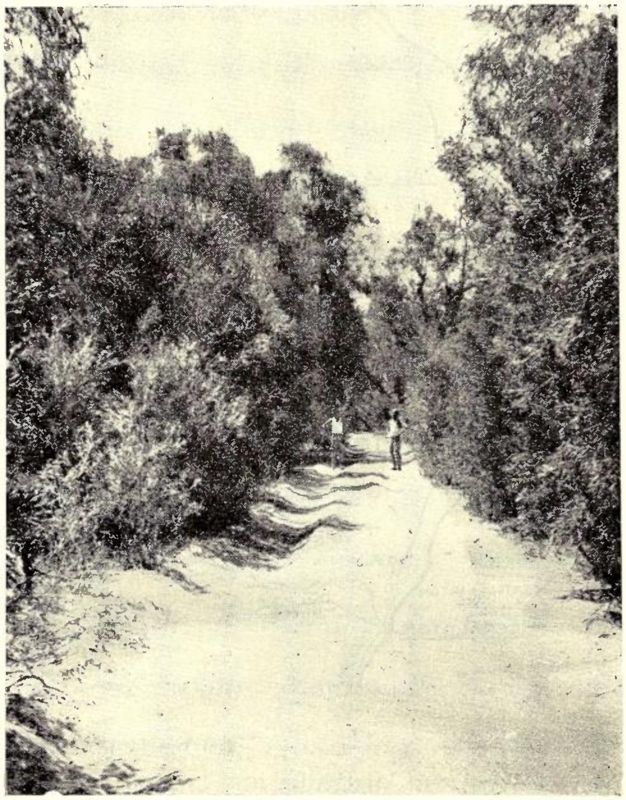


Fig. 4.—Main Broome-Marble Bar Road.

attempted as the power required was not sufficient to warrant such an installation and the lack of trained staff was a serious objection.

The equipment selected was the "Teleradio 3BZ" combination, manufactured by Amalgamated Wireless (A/asia) Ltd., and illustrated in Fig. 5. The complete installation comprises transmitter, receiver and speaker and the power supply.

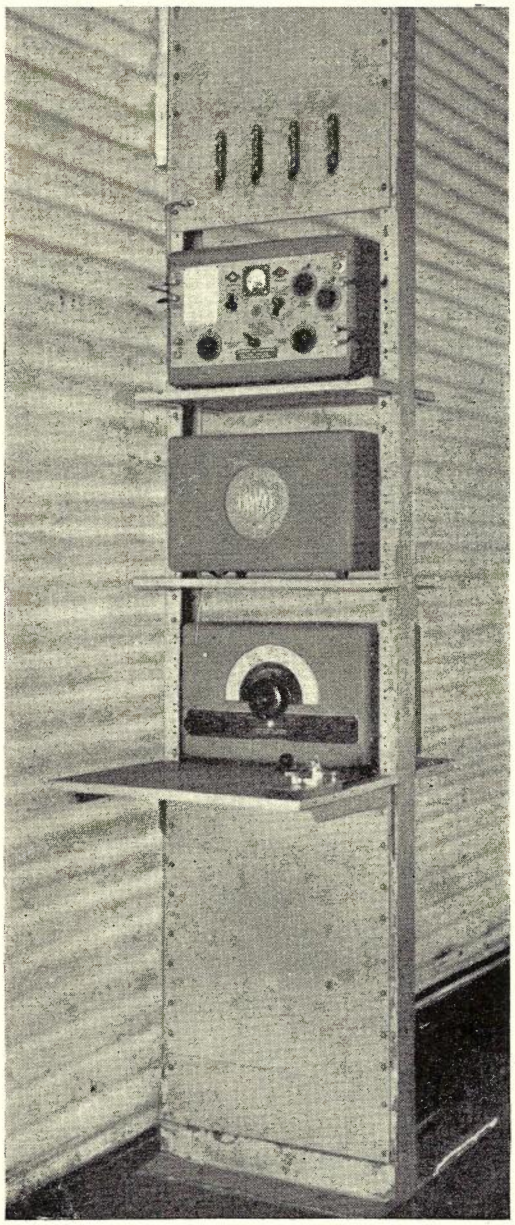


Fig. 5.—Complete "Teleradio" installation.

**Transmitter:** The transmitter is a crystal controlled, two-stage unit using a pentode type 6V6G valve as oscillator, and a beam type 807 valve as either power amplifier or frequency doubler, its operation being dependent on the required frequency output. The coverage is from 2.5 Mc/s to 10.0 Mc/s, in two ranges, 2.5 to 5.0 and 5.0 to 10.0, the latter range using the 807 stage as a frequency doubler. Modulation, applied to both anode and screen of the 807, is obtained from a pair of type 6V6G tubes in parallel as a modulator, driven by a single 6V6G, all used as class "A" pentodes. The microphone is a standard telephone handset with the earpiece removed, thus giving a carbon microphone with hand grip. The modulated output is from 8 to 12 watts, the lower output being due to the inefficiency of modulating frequency doubler stage.

Power is obtained from a 12 volt battery supply, and a synchronous vibrator developing 350 volts for the high tension. The total input is approximately 90 watts with the transmitter giving an output of 11 watts to an artificial load of 600 ohms on a frequency of 2.5 Mc/s. Provision is made for the use of two types of aerial; a high impedance of 600 ohm and a low impedance or grounded Marconi type. Switching is arranged so that the one aerial is used for both transmitting or receiving, the change being completed upon the operation of the **Transmitter-Standby** switch.

**Receiver:** The receiver is a five-valve vibrator operated super-heterodyne, and covers a frequency range of from 200 kc/s to 30 Mc/s, with a small gap at 535 kc/s due to the intermediate frequency. It employs one R.F. stage, one I.F. combined beat frequency oscillator, and the normal converter, second detector and audio stages. The loudspeaker is an 8″ permanent magnet type with a dust-proof silk across the cone throat, and the complete unit is mounted in a pressed mild steel cabinet of similar dimensions to the other two units.

**Antenna:** The aerials were subject to a great deal of consideration before it was finally decided to use the high impedance type. Firstly, the advantages were towards a low impedance vertical type because of its simplicity of erection, cheapness of installation, and conservation of space; but its very serious disadvantage was the tuning necessary to load up the aerial when a frequency change was effected. Artificial loading is employed, consisting of a variable inductance in series with the aerial, and, although this in itself is very simple to a person of slight technical knowledge, it would cause considerable trouble to unskilled personnel, without using any aerial indicating device. Thus, the high impedance single wire feeder type of aerial was used, one for each frequency of which there were four, viz., 2585, 3970, 5555, 9230 kc/s. The impedance of the feeder is adjusted to appear as near to 600 ohms as practicable by variation of its point of application to the radiator itself. This point is approximately 37% from either end of a half-wave aerial. The four radiators were suspended between three 40 ft. masts arranged in the form of a triangle, the dimensions of which were dependent upon local conditions.

The masts were made of 4″ x 4″ dressed jarrah in three sections jointed by scarf joints and assisted by two side plates and three bolts. Figs. 6 and 7 show details of the aerial mast.

Pole steps are provided to facilitate climbing for the attachment of aerials and to allow for periodical inspection. Three sets of three guys are provided at the top and each joint, and are spaced 120°, and attached to reinforced star stakes 6 ft. long, with a further star stake behind. The mast is mounted by two channel iron shoes bolted to a concrete block which is fitted with a galvanised iron ant cap.

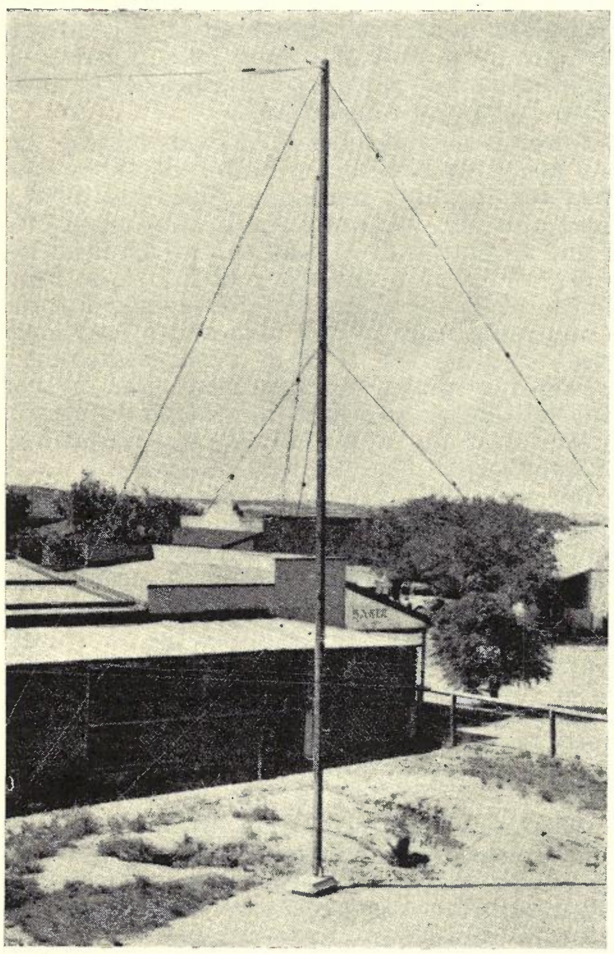


Fig. 6.—Aerial mast.

It will be noticed that the two shoes are mounted off centre to allow for a portable base for the jury mast to be placed on the concrete foundation during the mast erection. The jury mast used consisted of 12 feet, in two 6 ft. sections, of 3″ x 3″ oregon, selected from light-weight timber because of strength and portability. As all the travelling throughout the installations was by aeroplane, and the jury mast, erecting block and tackle, together with tools, had to be transported likewise, the weight of these items was of some importance.

**Power Supply:** The power supply consists of two 6-volt motor vehicle type 15 plate batteries stored behind the rack on a lead base. The charging set originally supplied was a petrol-driven Cooper 4-stroke engine directly coupled to a 300-watt 12-volt generator, fitted with ammeter, variable charging resistance and cut-out. The original intention was to have this motor mounted close by and to provide a switching arrangement and enable a charge/discharge sequence to be obtained. However, the mechanical noise was too great and so the machines were removed to a distant spot, and carrying handles provided for battery transportation. Within a few months these small motor generator sets have been replaced by petrol-driven Ronaldson-Tippett 2 h.p. type N vertical engines coupled by a single vee belt to a 300-watt generator.

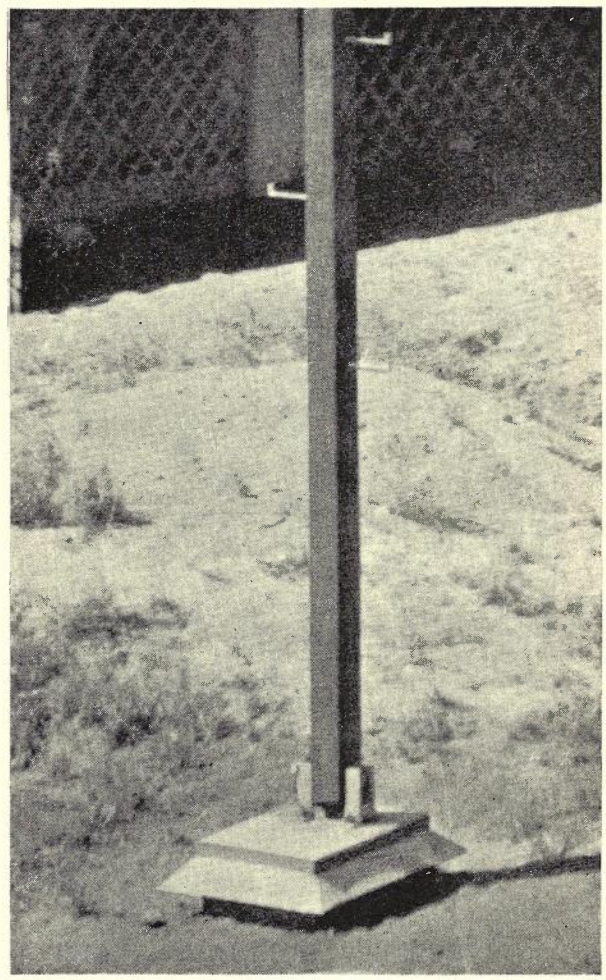


Fig. 7.—Mast mounting.

**Installation:** The installation was simplified somewhat by having all the mast stays constructed in Perth before despatch, with the ground ends long enough for termination with the mast in situ. As will be seen from Fig. 5, the equipment was mounted on a 10′ 6″ standard rack, with a writing shelf at table height holding the receiver. The speaker is directly above the receiver, and the third unit, the transmitter, higher still. All these units have wooden shelves screwed on to iron brackets fitted to the bay, and are all removable by plug-in type connectors. Inter-unit wiring is fitted inside the channel iron and the battery supply leads are connected to a small connecting block at the rear of the bay. An aerial panel is mounted above the transmitter, using single-pole-double-throw knife switches with the centres commoned and connected to the transmitter, bottom contacts earthed, and the top contacts connected to their respective aerials. In this manner selection to individual aerials can be obtained as required. All the apparatus was assembled on the rack, completely wired and tested, and then stripped for despatch and shipped to the port nearest its final destination. From this point overland transport was used and the gear then stored pending the arrival of the installation staff.

Considerable differences in types of ground were experienced, from loamy material at Derby, soft sand at Fitzroy Crossing, to real hard iron stone at Hall's Creek and Marble Bar. On this account, the depth to which the anchor stakes were driven was dependent upon the type of ground, and it is pleasing to note that only one mast has been in trouble and that due to the softening of the ground due to an abnormally high tide. The earth connection for the apparatus was taken to a group of galvanised star earth stakes driven two feet into the ground and connected together by several strands of 200 H.D.C. The aerials were constructed of 200 H.D.C. and the down leads of 200 H.D.C. or 7/.029 bare copper, depending upon supplies.

The apparatus rack was installed within reasonable reach of the usual telegraph operating position, so that access could be made to the filing facilities when the radio gear was in use. Telegraphy is the normal mode of communication, the transmitter oscillator being keyed with the modulator stages switched off and headphones or loudspeaker being used for reception. Where a lineman only is stationed, telephony is used in both directions.

**Conclusion:** With the units installed at the locations shown in Fig. 1, it is practicable to maintain reliable communication at all times between each adjacent station, although at times appreciably greater distances have been operated. For example, during the initial tests communication was established between Wyndham and Broome and between Hall's Creek and Marble Bar. When a break occurs in the line between two centres equipped with radio the telegraph messages are repeated from the land-line sections through the radio link, via the operators normally stationed at these centres for telegraph purposes. Apart from the clearance of traffic during the fault condition, the radio link is of considerable value in co-ordinating the efforts of the linemen operating from each end of the faulty section.

It is estimated that since the tele-radio system was installed 5000 telegrams, which would otherwise have been delayed until the land-line was restored, have passed over the various channels. As an example of a particular failure, the telegraph line serving Port Hedland was interrupted at both sides of that station from the 7th to the 19th February, 1946, and during this period the teleradio links handled practically all of Port Hedland's telegraph traffic, involving a total of 1405 telegrams.

**Reference**

"Lines and Networks of the North-West Coast," C. F. Cook, Telecommunication Journal, Vol. 1, No. 3, Page 89, June, 1936.

# A MECHANICAL ANNOUNCER FOR THE PUBLIC TELEPHONE SYSTEM

A. H. Baddeley, B.Mech.E., B.E.E.

**Summary:** A machine has been developed at the Research Laboratories for the purpose of introducing recorded announcements into the public telephone system, the recording medium being 35 m.m. sound film. Provision is made for two separate announcements in the prototype machine, each sound channel using its own exciter lamp, optical system, phototube and audio amplifier. The need for a machine of the type described herein for use in the public telephone system was originally appreciated by the Circuit Laboratories during the progress of development work directed to the simplification of the public telephone instrument. Subsequently, the design and construction of the prototype machine was undertaken by the Research Laboratories. The purpose of this article is to describe the construction of the machine itself rather than the method of switching the announcements produced by it into the telephone network.

**Proposed Announcement:** For use in the public telephone circuits, the proposed announcements would be:—

(a) "Please insert two pennies," directed to the calling party when the called party has lifted the receiver.

(b) "Public telephone calling," directed to the called party as a warning to wait until the coins have been inserted by the calling party.

**Previous and Contemporary Mechanical Announcers:** The idea of a machine for producing simple announcements is not new.

In the past, automatically-produced messages have been used for such purposes as telling the time of day, directing pedestrian traffic in railway stations or at highway intersections, and informing telephone operators of the anticipated delay times on trunk lines. In cases where several announcements are required, it has been the practice to record them as concentric optical sound tracks on a glass disc. The arrangement of the exciters and photo-sensitive devices is largely influenced by whether one only or more than one of the recorded announcements are to be used at any particular time.

While the machine herein described was being built, a British Post Office Report (1) was received containing a description of a machine developed in England for generating announcements of trunk line delay times. Although the duration of each announcement is shorter and the number of announcements greater than in the machine discussed herein, a comparison is interesting in view of the fact that both machines are rack-mounted, both use photographic methods of recording and both use A.C. mains power supply. Apart from these aspects, two entirely different approaches to the problem were made.

## General Features of Design

**Recording Medium:** The principal available methods of recording the announcements were sound-on-film, glass discs, magnetic wires (or tapes) and phonograph type disc recordings. The process of recording on glass discs would have required the construction of special apparatus, which was unwarranted in view of the ready supply of sound-on-film recordings. Phonograph discs, although easily procured, were considered unsuitable for this purpose because of the relatively rapid deterioration of the recording under conditions of continuous operation.

During the initial design stage, serious consideration was given to the possible use of magnetic wires or tapes. There were two main disadvantages. First, the wires or tapes were not in good supply in Australia at the time. Secondly, even with an endless wire or tape, the recording would probably have had to run between two pulleys, in order to accommodate the pick-up head, and the flexing and slip of the recording so produced would have been undesirable.

Sound-on-film recordings were therefore the only ones which were:—

(a) readily available without the provision of special equipment, and

(b) able to be mounted in a manner involving no mechanical wearing effects.

**Choice of Film Size:** Selection of the most suitable size of film was influenced by three main considerations.

(i) The drum upon which the film is mounted had to fit within the confines of a standard 19 inch rack and, in order to eliminate cyclic speed variations due to static unbalance, rotation about a vertical axis was considered desirable.

(ii) The only available electric motors suitable for driving the film drum were four-pole synchronous motors, running at 1500 r.p.m. in the case of 50 c/s mains frequency.

(iii) Because of the possibility that belts, chain-drives or gears would introduce "wow," i.e., regular fluctuations in film speed producing audibly noticeable effects, a direct friction drive from motor spindle on to a rubber tyre on the film drum assembly was needed. The largest suitable available tyre was 15" outside diameter.

Two alternative designs were possible if one considered the use of either 35 m.m. or 16 m.m. film. Since these films are designed to run at different speeds (viz., 90 ft. per min. and 36 ft. per min. respectively), it will be apparent that, for a tyre diameter of 15" and a motor speed of 1500 r.p.m., the motor spindle diameter will depend upon the choice of film size. The two alternative designs are summarised in Table 1.

**Table I**

| Film Size | 16 m.m. | 35 m.m. |
|---|---|---|
| Film speed | 36 ft./min. | 90 ft./min. |
| Motor spindle diameter | 0.0982 in. | 0.245 in. |
| Duration of one revolution of film wheel | 6.12 secs. | 2.44 secs. |

In view of the very small spindle diameter involved, the 16 m.m. system could not be considered. The only disadvantage possessed by the 35 m.m. design, apart from the inflammable nature of the film, is the relatively short time available (approximately two seconds) for accommodating the announcements. This time interval was considered adequate for the proposed announcements and, therefore, the use of the 35 m.m. design was favoured.

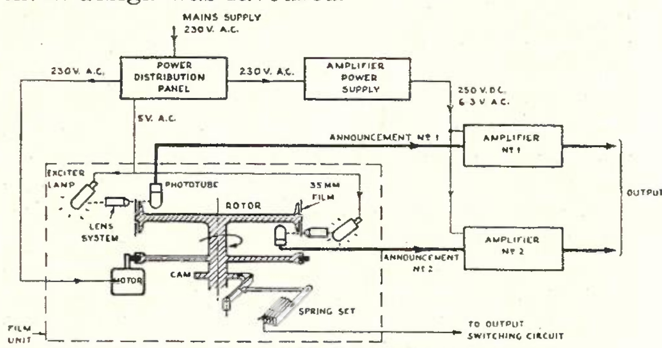


Fig. 1.—Block schematic.

**Arrangement of Equipment:** The equipment is mounted on a standard 19″ rack and for that reason, during the preliminary design stage, a decision had to be made in regard to sub-division of the apparatus into rack-mounted units. Fig. 1 illustrates in diagrammatic form the layout which was finally employed. Fig. 2 is a photograph of the complete unit, and Fig. 3 shows a close-up of the film unit. The section of the apparatus comprising exciter lamps, lens systems, film drum and driving motor, phototubes and output switching mechanism was combined into a single unit to which the name "Film Unit" was applied.

Separate audio amplifier units are used for the two output channels, the connections from the phototube bases in the Film Unit to the appropriate amplifiers being made with low-capacity beaded coaxial cable in order to reduce attenuation of the high-frequency signals. The two amplifiers derive their A.C. filament and D.C. high tension supplies from a common power supply unit which was purchasable, in a form requiring minor circuit alterations only, from a commercial manufacturer. Another unit, containing switching facilities for the A.C. input and step-down transformer for the exciter lamp supply, was built up and called the "Power Distribution Panel."

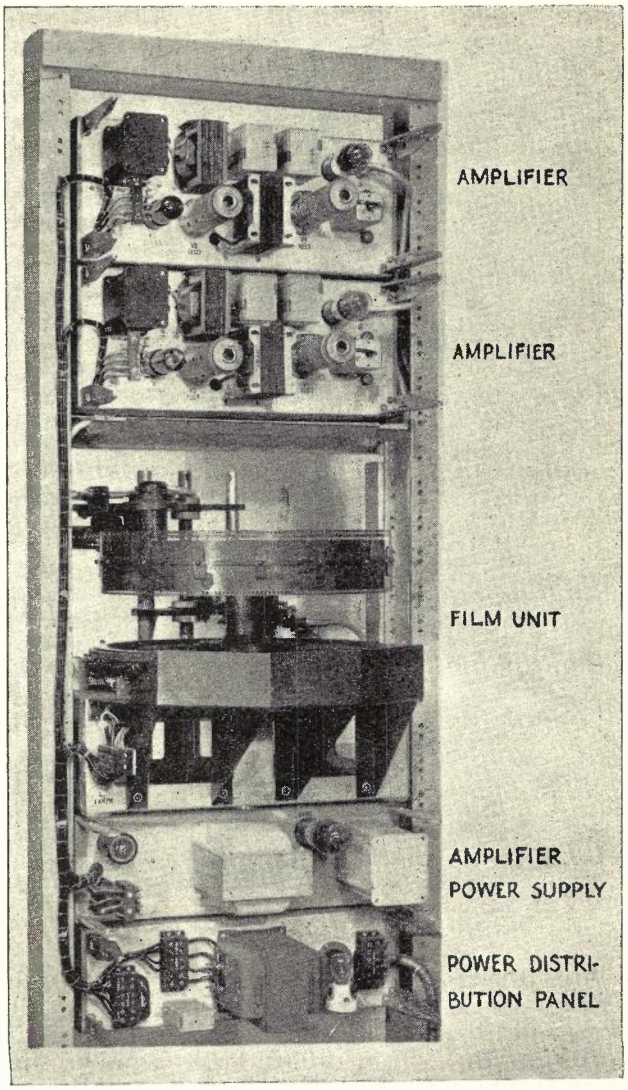


Fig. 2.—Rear view of complete installation with covers removed.

## Film Unit

**Optical System:** The optical systems, of which there are two in the prototype machine, use standard 35 m.m. sound-track equipment. The exciter lamps are rated at a supply voltage of 10 but, in this installation, are supplied at 5 volts in order to obtain long life, reliability and freedom from deterioration caused by blackening of the envelopes. Alternating current at mains frequency is supplied to the lamps and, in consequence, special precautions were needed to limit the gain of the audio amplifiers at a frequency equal to twice the mains frequency.

The condensing lens system and slit which produce a light beam of the correct dimensions through the sound track are combined in a commercially obtainable unit as supplied for motion picture apparatus. The light sensitive elements are type 930 gas phototubes fitted in shock-mounted octal sockets to reduce microphonic effects.

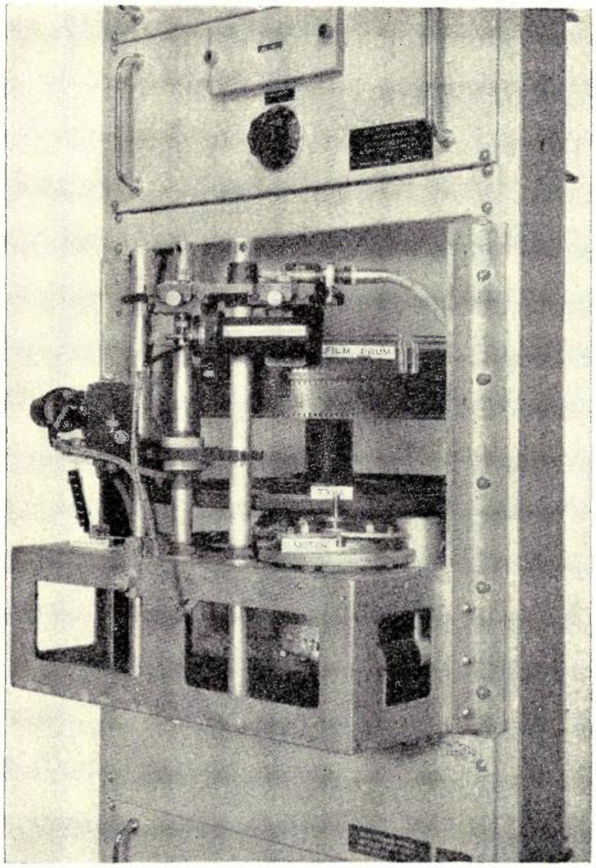


Fig. 3.—Film unit, front view (cover removed)

**Film Drum Assembly:** The rotor of the Film Unit comprises the drum on which the film strips are mounted and the wheel which carries at its periphery the driven rubber tyre, together with a tubular spacer connecting these two. All three components are machined from castings—the first two aluminium and the last gunmetal. Two angular-contact ball bearings of $\frac{1}{2}''$ shaft diameter

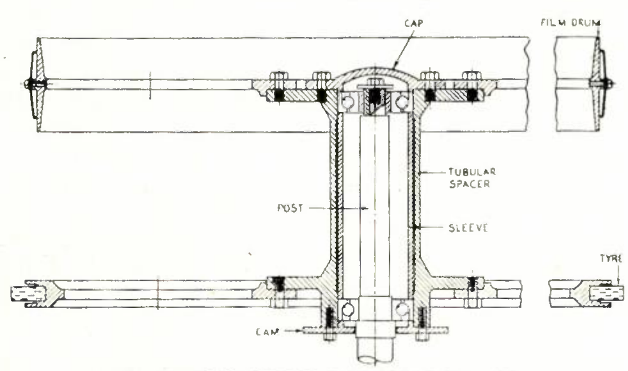



Fig. 4.—Rotor bearing assembly of film unit.

support the rotor. Fig. 4 shows the bearing installation. An advantage which this assembly possesses over the ordinary turntable bearing as used in broadcasting studios is that, even when the unit is inverted as, for instance, in transportation or packing, the rotor cannot become detached.

Special care was taken during machining to ensure that the film wheel and tyre would run "true," since accurate location of the sound track was an important requirement. The mating faces of the three castings described above were machined and fitted accurately before finishing cuts were taken on the film drum and tyre groove. The final cuts on these surfaces were taken while the whole rotor was assembled and mounted on a mandrel in the lathe. The rubber tyre was rolled into the groove provided for it and the periphery of the tyre was finally ground in order to remove irregularities.

**Attachment of Film:** The two strips of 35 m.m. film upon which the desired announcements are recorded are held in place by sixteen phosphor-bronze leaf springs spaced at equal intervals around the drum. In order to eliminate bulges in the film which might otherwise be caused by temperature and humidity changes, a small tensioner on each film strip is used to exert a tangential load on the film.

**Driving Motor:** The electric motor which drives the main rotor is a four-pole synchronous motor running with its shaft extension in direct contact with the rubber tyre on the rotor. This contact is maintained by means of a spring, the motor being suspended on rubber vibration dampeners in a pivoted aluminium mounting ring. A slinger ring attached to the motor spindle between the end bearing and the tyre reduces the possibility of the rubber tyre becoming contaminated with oil.

**Frame of Film Unit:** The film unit is assembled on a box frame fabricated by oxy-acetylene welding from 10 gauge steel sheet. Four vertical shafts carry the rotor and all gear associated with the exciter lamps and phototubes. These shafts are located in the top and bottom faces of the box frame in gunmetal bushes which were bored out after assembly of the box. This method of construction enables one to remove the complete rotor assembly without dismantling the bearings. A fabricated steel guard is bolted to the rear of the box to protect the projecting portion of the rotor. The box frame is held in place on the rack by means of two rolled steel angles screwed to its sides.

### Audio Amplifiers

The two audio amplifiers used in the equipment are identical in all respects. Fig. 5 shows the circuit diagram of one amplifier. It consists of three stages, resistance-capacitance coupled. The stages are: (a) pre-amplifier, (b) voltage amplifier, (c) output. Feedback is used between the last two stages, the final stage being shunt-fed

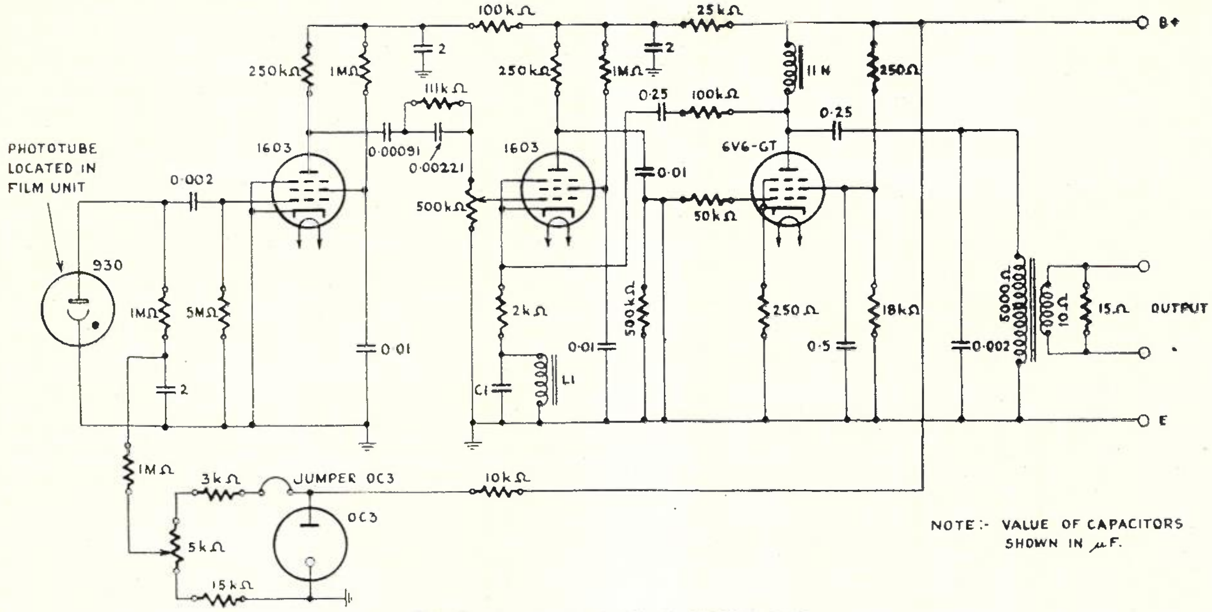



Fig. 5.—Schematic circuit of amplifier unit.

from the power supply. The circuit is designed to produce substantially constant output voltage over a large range of output impedances. This is necessary to avoid a noticeable decrease in level of the output as an increasing number of subscribers is connected.

A parallel tuned circuit ($C_1$, $L_1$) in the feedback system acts as a band-rejection filter and is designed to reduce the gain of the amplifier for a frequency corresponding to twice the mains frequency. This precaution is occasioned by the use of alternating current supply to the exciter lamps.

The network inserted in the output circuit of the pre-amplifier is an equaliser designed to correct the distortion occurring when a subscriber's telephone is connected to a low sending impedance.

## Bibliography

(1) "A Machine for Generating Verbal Announcements," B.P.O. Report, No. 11593.

# ANSWERS TO EXAMINATION PAPERS

*The following answers generally give more detail than would be expected in the time available under examination conditions. The additional information should be helpful to students.*

## EXAMINATION No. 2823—SENIOR TECHNICIAN—BROADCASTING

N. S. Smith, A.M.I.R.E.

### RADIO II

**Q.3.—Describe briefly the operation of—**
**(a) A moving coil pick-up.**
**(b) A piezo-electric (crystal) pick-up.**
**Indicate the differences between the two as regards output voltage and impedance.**

**A gramophone pick-up suitable for reproduction of high quality disc recordings usually has an equaliser associated with it. What is the function of the equaliser and in what part of the circuit would it be connected?**

**A.**—(a) A moving coil pick-up consists of a permanent magnet having a small coil of wire pivoted between the poles. A needle is attached to the coil and as the needle vibrates laterally on the disc the coil moves in the magnetic field, and E.M.F's are set up in the coil corresponding to the movement of the needle.

(b) A crystal pick-up operates on the principle that certain crystals under strain will produce opposite electric charges between the crystal faces. The strain is transmitted to the crystal from the needle as it vibrates on the disc.

Fig. 3 illustrates a typical crystal unit such as used in broadcast recording centres. The rear end of the crystal is securely fastened and the needle applies a bending motion to the free end (the required strain). Rubber damping blocks are mounted on each side, and serve to position the crystal as well as control the frequency response.

| | Crystal | Moving-coil |
|---|---|---|
| **Output voltage** | Relatively high | Low |
| **Impedance** | High (250,000 ohms) | Low (requires matching transformer close to source.) |

The equaliser associated with the gramophone pick-up is for the purpose of correcting the low frequency attenuation introduced by the constant amplitude characteristic of the recording equipment below 250 cps. (6 db per octave).

In the case of a crystal pick-up the record-equaliser is placed between the gramo-fader and the pre-amplifier.

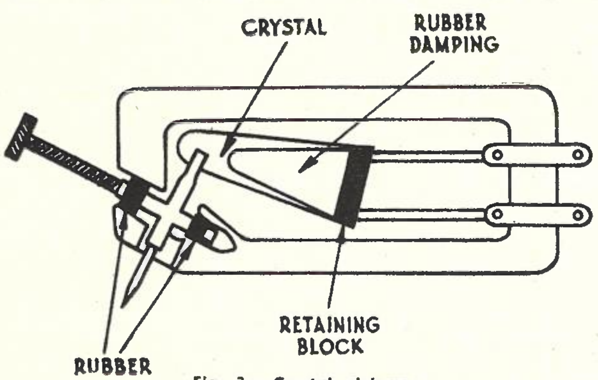



Fig. 3.—Crystal pick-up.

Due to the low level output of the moving-coil pick-up, however, it is necessary to place the equaliser after the pre-amplifier in order to preserve as high a signal-to-noise ratio as possible.

**Q. 4.—Explain the operation of a moving coil loud speaker. Give a diagram showing the magnetic circuit and indicate clearly the direction of the magnetic flux.**

**What is the function of the baffle used with a loud speaker?**

**A.**—The operation of a moving coil speaker will be best understood by referring first to Figure 4, which is an elementary sketch of this type.

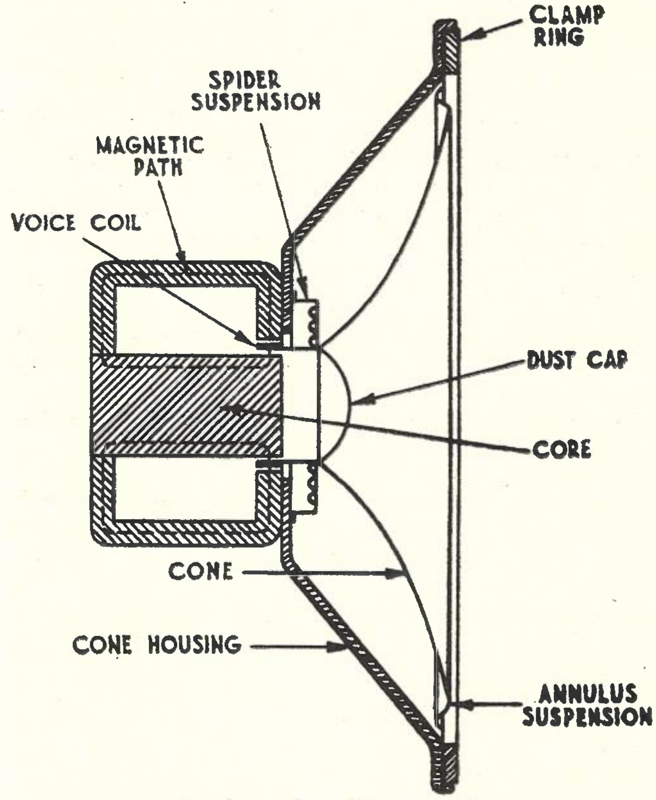



Fig. 4.—Moving-coil loud speaker.

The unit consists of a paper cone, to the apex of which is fastened a coil (commonly called the "voice coil") located in a strong magnetic field and carrying the audio-frequency currents to be transformed into sound waves. In such an arrangement, the action of the magnetic field of the coil current produces a mechanical force that vibrates the paper cone and causes radiation of sound waves. The cone is supported in a metal frame around its outer edge, while the coil is held in position and supported by means of a flexible spider, or a corrugated disc where dust proofing is essential. The entire coil is, therefore, free to move as a unit and, under ordinary conditions, is proportioned in such a manner as to have a resonant frequency at the lower end of the frequency range to be reproduced.

**Operation.**—The operation of a moving-coil loud speaker can be understood by considering the basic theory of its operation. Assume a straight conductor carrying current is placed between two large plane pole faces of a permanent magnet. The component fluxes are as shown in Fig. 5a. The flux due to the magnet is uniform in the gap between the poles, as shown by the equally-spaced parallel straight lines. The conductor lies in a plane parallel to the pole faces, and current is flowing through it into the paper. The lines of flux are concentric circles.

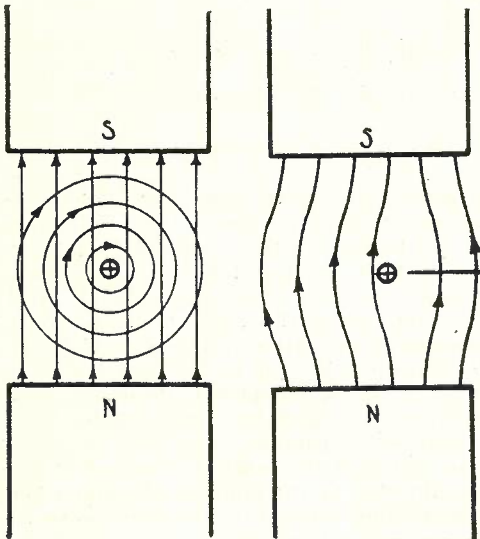



Fig. 5.—Illustrating the distribution of flux lines in the magnetic field of a moving-coil speaker

The resultant distribution of flux lines is shown in Fig. 5b. On one side of the conductor, the component flux lines run in the same direction, and so the field is strengthened as shown by the packing of lines. The resultant field is weak on the other side, and the lines are comparatively far apart. This condition forces the conductor to the right in a plane parallel to the pole faces.

If the direction of the current in the conductor is reversed, it will be seen that the conductor will move in the opposite direction, that is, to the left. The force obtained in a moving coil is given by

$$\frac{B\ I\ L}{10} \text{ dynes}$$

where B = the flux density due to the magnet in lines per square centimetre,

I = the current in amperes flowing in the conductor, and

L = the length in centimetres of the conductor which is the region of uniform flux density B.

It will be apparent that, as the conductor moves in the magnetic field, it is cutting lines of force and will then follow Lenz's Law:

"The direction of the induced e.m.f. produced by the motion of a conductor in a magnetic field is such that, if induced current could flow, it would produce a force opposing the motion."

This law is important as it explains the behaviour of the cone in respect to transient response, for, if a large induced current could flow, a large force would oppose the motion and the cone would lose its momentum quickly when the voice currents cease to flow.

A baffle or box is used in order to prevent the radiation from the front and back of the speaker from cancelling at low frequencies.

**Q. 5.—What do you understand by the term "undistorted power output" as applied to an audio amplifier? Indicate possible causes of distortion occurring in an audio amplifier.**

**A two-stage amplifier having a gain of 30 db. and input impedance of 600 ohms is delivering an undistorted power of 5 watts to a 600 ohm load. What is the voltage applied to the input to produce full output? Assuming that the output transformer has a step down impedance ratio of 7 : 1, what is the maximum voltage appearing on the grid of the final valve if its amplification factor is 3 and plate resistance 2000 ohms?**

A.—The undistorted power output of an audio amplifier is that output which contains less than a specified content of harmonic, phase, or frequency distortion. The allowable content may be arbitrarily specified at values between 1% and 10% depending on particular requirements.

Distortion in an audio amplifier could be due to:—
- (a) Incorrect choice of valves.
- (b) Incorrect load impedance.
- (c) Incorrect electrode voltages.
- (d) Overloading of valves.
- (e) Incorrect values of components such as condensers, resistances, inductances and/or transformers.
- (f) Faulty component in amplifier or other fault condition.

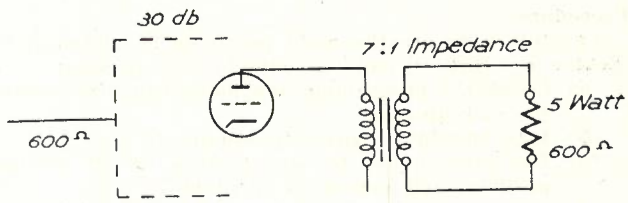



Fig. 6.

Gain = 30 db, $P_o$ = 5 watts, 5, $P_1$ = ?
gain, db, = 10 log $P_o/P_1$
30 = 10 log $5/P_1$
log $5/P_1$ = 3
$5/P_1$ = 1000
$P_1$ = .005 watts Input
W = $E^2/R$ ∴ E = $(WR)^{1/2}$
= 1.732 volts applied to input
$Z_{Pr}$ = Impedance of primary = 600 × 7 = 4200 ohms.
$E_o$ = Voltage across primary = $(WR)^{1/2}$ = $(5 \times 4200)^{1/2}$
= 145 volts (approx.)

Assume a triode,
then output voltage, $E_o = \mu Eg\ Z_{Pr}/(R_p + Z_{Pr})$
where $\mu$ = amplification factor
Eg = grid voltage
$Z_{Pr}$ = impedance of primary
$R_p$ = anode impedance
Rearranging, Eg = $[E_o\ (R_p + Z_{Pr})]/\mu Z_{Pr}$
Substituting, Eg = (145 × 6200)/(3 × 4200)
= (145 × 6200)/12600
= 71.3 volts rms.
= 100.8 volts peak.

Ans. Input voltage 1.732 volts
Max. grid voltage 100.8 volts peak.

**Q. 6.—Describe briefly the principle of operation and construction of a disc recording machine suitable for high quality studio recording.**

**What procedure would be followed in making a disc recording of a programme item transmitted to the recording centre from an outside pick-up point?**

**A.—Operation.** The principle of operation of a disc recording machine is the conversion of electrical vibrations into mechanical vibrations, the latter actuating a cutting stylus which cuts an undulating groove on a suitable wax disc. The electrical vibrations are in the form of audio frequency currents and are brought to the required level by high quality amplifiers.

A heavy turntable acts as a flywheel and assists in maintaining a constant speed when cutting. The weight of the cutting head on the disc is approximately 3 ounces and is adjustable. The cutting head is propelled across the disc by a feed mechanism which is operated by worm gears driven by the rotating turntable.

**Construction.**

The principal items of a recorder are:—

(a) Heavy cast-iron frame.
(b) Heavy cast-iron turntable carefully balanced and accurately machined.
(c) Motor and two-speed change mechanism ($33\frac{1}{3}$ r.p.m. and 78 r.p.m.).
(d) Traversing screw. This is a worm-driven threaded shaft which moves the recording head across the disc at a predetermined number of lines-per-inch.
(e) The recording head, which carries a sapphire-pointed cutting stylus.
(f) A microscope for examining "test cuts" and completed recordings.
(g) Automatic equalizer driving mechanism.

**Procedure.**

The following are the main points to be observed in making a recording from an outside pick-up point:—

(a) Check the programme and monitoring lines from the pick-up point.
(b) Line should be correctly equalised.
(c) The disc should be wiped clean of all foreign particles and placed on turntable.
(d) A sapphire cutter is selected and placed in cutting head.
(e) Overhead mechanism is lowered and the cutting head angles checked.
(f) A test cut is made without modulation and examined under microscope for depth and appearance of grooves.
(g) Modulation level is checked on associated level indicator and the recording is commenced.
(h) The swarf should be kept clear of cutter and placed in a fireproof receptacle.
(i) At the conclusion of recording the disc is examined under the microscope and then disc preservative is applied.
(j) The disc is now replayed to ensure satisfactory technical standard.

**Q. 7.—Describe the principle of operation of a power inverter for supplying A.C. power at 230 volts 50 cycles per second from a 6 volt accumulator.**

**How can the frequency of such an inverter be adjusted accurately to 50 cycles?**

**For what types of service is such equipment suitable?**

**A.**—Figure 7 illustrates an inverter circuit suitable for supplying 230 volts, 50 c.p.s. A.C. at an output of 50 to 100 watts.

A vibrating reed, "R," driven from the 6 volt battery has its contacts C1 and C2 so arranged that the battery voltage is first applied across one-half of the primary winding of the transformer, T1, and then in the opposite direction across the other half. This induces an alternating voltage in the secondary having a value determined by the battery voltage and the transformer ratio. The reed is kept in vibration at its mechanical resonance frequency by the electro magnet M, which is so arranged that, when the reed is drawn to the magnet, the circuit of the latter is interrupted at contact "X." This causes the reed to fly back when the operating circuit is again completed through contact "X." The reed possesses sufficient mass, however, to enable it to "bounce" to contact "C2" before responding again to the action of the magnet. The reed is thus kept constantly vibrating by the familiar "Trembler-bell" action. The transformer primary is therefore energised alternately via contacts C1 and C2.

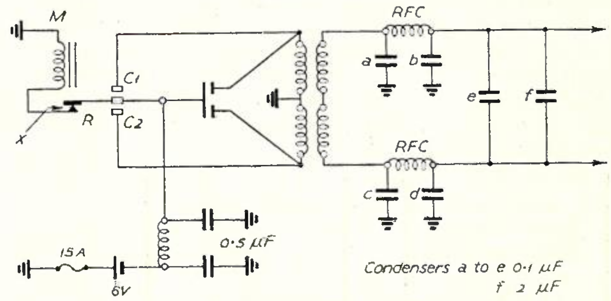


Fig. 7.—Typical power inverter.

The mechanical resonant frequency of the reed, which governs the A.C. frequency, may be adjusted by varying the weight with solder.

The frequency may be checked on a reed-type frequency meter having a range of about 47 to 52 cycles, this meter having been calibrated against a known standard; or against a cathode ray oscilloscope using the 50 cycle mains as sweep voltage.

Typical uses for vibrator power inverters are:—

(i) Driving portable recording equipment.
(ii) Driving portable reproducing equipment.
(iii) In conjunction with electron tube rectifiers, for the supply of power to radio receivers, transceivers, low power transmitters, portable measuring instruments such as field intensity measuring sets, etc.

**Q. 8.—Describe with the aid of schematic diagrams how the following performance characteristics of an audio frequency amplifier can be measured:—**

**(a) Overall gain.**
**(b) Frequency response.**
**(c) Harmonic content.**
**(d) Noise.**

**A.**—(a) A method of measuring gain is illustrated in Fig. 8.

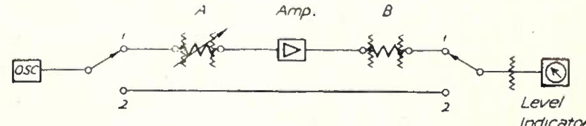


Fig. 8.

Fig. 8 shows a set-up which consists of an oscillator, attenuator "A," an amplifier, attenuator "B," and an output measuring meter, such as a level-indicator, voltmeter or power-output meter.

Attenuator "A" is to enable input to be adjusted to avoid overloading, and should be set at a value to ensure correct input to amplifier (measure if necessary).

The oscillator is fed straight to indicating meter and adjusted to give a convenient deflection, with switch at position 2.

Attenuator "B" is set at maximum attenuation and then oscillator and meter are switched to position 1. Attenuator "B" is then decreased until meter reads same as in position 2. The gain of the amplifier is then the sum of the amounts of attenuation in A and B.

Correct impedance matching of all units is necessary. Overload condition may be checked by, say, decreasing "B" by 3 db. An increase of "A" by 3 db should bring meter to same position as before. If this is not so, overloading is occurring.

(b) **Frequency response.**

Assuming a constant output oscillator (or one having a level indicator and adjustment), the set-up as in position 1 of Fig. 8 is suitable.

"A" is adjusted to prevent overload as before.

Tone at 1 kc is fed from oscillator and meter is adjusted for convenient deflection which is noted.

The oscillator frequency is varied over the desired range and attenuator "B" adjusted to give the same reading on meter for each frequency. The variation of "B" from the 1 kc reading is noted, and then, regarding 1 kc as reference level, the other frequencies may be expressed as db above or below (plus or minus) this level.

(c) **Harmonic distortion.**

Fig. 9 illustrates a method for measuring distortion.

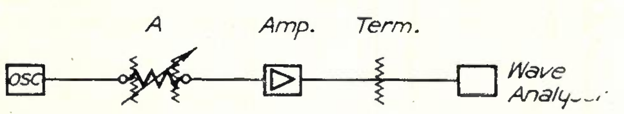



Fig. 9.

The oscillator is set to the desired frequency and connected to the amplifier through attenuator "A" which serves to enable specified input or output levels to be obtained, and/or guard against overloading of amplifier. Two types of measuring instruments are:—

(a) One which gives total distortion.
(b) One which gives individual harmonic levels (wave analyser).

In the case of (a), the output of the correctly terminated amplifier is supplied to the instrument and adjusted to a given reference level. A turn of a switch introduces a filter which eliminates the fundamental component and the total harmonic distortion is read directly on the instrument scale. This measurement is usually limited to one fundamental frequency for which the unit is designed.

In the case of (b), the fundamental frequency may be varied over a fairly wide range, enabling the harmonics of many fundamental frequencies to be measured. The fundamental frequency is tuned in on the analyser and adjusted to a given level. The instrument is now tuned to the 2nd, 3rd, 4th, etc., harmonics of the frequency being measured and each level recorded. For example, if the fundamental were 500 cycles, the 2nd, 3rd and 4th harmonics would be 1000, 1500 and 2000 c.p.s. respectively. If the scale chosen represented 100% for the 500 cycle deflection, then the readings of the other frequencies would be in direct percentages of the fundamental frequency. The total distortion is **not** the sum of the harmonic percentages, but approximates closely the square root of the sum of their squares.

i.e., Total per cent. distortion =

$$\sqrt{\frac{\text{Sum of squares of amplitudes of harmonics}}{\text{Square of amplitude of fundamental}}} \times 100$$

(d) **Noise.**

Fig. 10 shows a method of measuring noise.

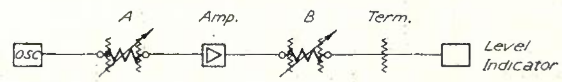



Fig. 10.

(i) Attenuator "A" is to adjust for correct input level.
(ii) Attenuator "B" should have a total attenuation greater than the expected signal-to-noise ratio.
(iii) Tone is fed to amplifier and meter reading noted.
(iv) Oscillator disconnected and amplifier input is terminated in its characteristic impedance at "X."
(v) Attenuator "B" is now reduced until meter gives same reading as in (iii). The amount of reduction is the signal-to-noise ratio in db.
(vi) If the amplifier has adjustable gain, the noise measurement should be made at the specified amplifier output.

**Note.**—In all tests and measurements described above, it is necessary to preserve correct impedance matching throughout.

## EXAMINATION No. 2817—ENGINEER—TRANSMISSION

**E. J. Wilkinson, A.M.I.R.E.**

### SECTION I—LONG LINE EQUIPMENT

**Q. 4.—Compare the advantages and disadvantages of a ring (lattice) type rectifier modulator with a vacuum tube when used in a carrier telephone system. Give the essential theory of the ring (lattice) type rectifier modulator.**

**A.**—The advantages to be gained by using metal rectifier units in the modulator of a carrier telephone system, instead of vacuum tubes, include the following:—

(a) more reliable operation of the modulator with less need for frequent maintenance;
(b) saving in space; since no auxiliary circuits (filaments, bias, high tension) are needed, the space saving is not only that due to the smaller size of the rectifier elements;
(c) circuit simplicity; coupled with the absence of additional wiring makes for a circuit which is easier to wire and to maintain;
(d) with single sideband transmission a greater degree of carrier suppression is possible with rectifier modulators than can be obtained with vacuum tube modulators.

Chief disadvantages inherent with the use of metal rectifier modulators are:—

(a) the input levels permissible with rectifier units are low compared with those used with the vacuum tube circuits. The rectifier modulator must, therefore, be followed by a valve amplifier. Vacuum tube modulators, however, usually have an amplifier associated with them also, and there is thus no great economical disadvantage in its use with the rectifier units;

(b) to obtain the best results from a modulator using rectifier elements, the elements must be carefully selected and "matched" for identical characteristics. This matching is vital if large values of carrier suppression are required, but may be achieved by using elements previously selected and tested by the manufacturers.

Fig. 1 shows the circuit arrangement of a ring (lattice) modulator. The essential theory of operation of such a circuit is as follows (see Course of Technical Instruction, Long Line Equipment, Paper No. 7, pp. 21, 22, 23).

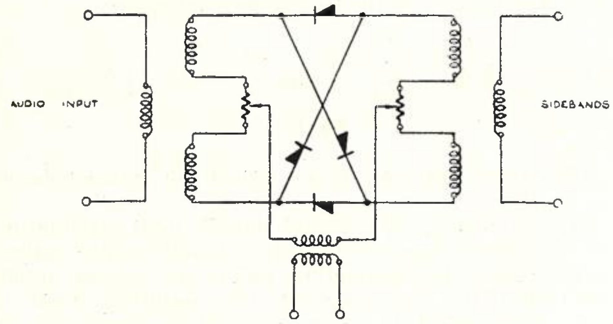


Fig. 1.

Considering the value of the input carrier voltage to be high compared with the input audio voltage, and that the rectifier elements act as resistances, the values of which depend upon the polarity and amplitude of applied potential, the rectifiers may be replaced by resistances whose values are changed from high (non-conducting) to low (conducting) values by the action of the carrier voltage. When the carrier voltage is high compared with the audio voltage, the resistance of the rectifiers will be controlled by the carrier voltage. During one cycle of the carrier voltage, pairs of rectifiers become alternately conducting and non-conducting. The audio input is thus switched or "commutated" from one pair to the opposite pair at the frequency of the carrier voltage and the output voltage from the modulator has a wave form which contains the major sum and difference components of the carrier and voice frequencies, the upper and lower sidebands.

**Q. 5.—State the frequency spacings used in the P.M.G. standard types of voice frequency multichannel carrier telegraph systems and discuss the factors which govern the number of channels which can be derived on a carrier telephone channel with particular reference to the transmitted band width.**

A.—The frequency spacings used with voice frequency multichannel carrier telegraph systems vary with the type of system in question. The 18 channel system employing the frequency range 420-2460 cycles per second has a channel spacing of 120 cycles per second, permitting a signalling speed of 50 bauds.

The A.P.O. 9-channel system uses the frequency range 540-2460 cycles per second and has a channel spacing of 240 cycles per second with signalling speed of 100 bauds.

The factors which govern the number of channels which may be derived on a carrier telephone channel are:—

(a) The effective bandwidth required for the satisfactory operation of the telegraph equipment to be employed.

(b) The efficiency of the filters in use. Adequate discrimination between adjacent channels must be provided, and this depends on the characteristics of the filters and the spacing between adjacent nominal channel frequencies.

From (b), and with the normally available filter characteristics, the effective bandwidth available for the transmission of telegraph signals is less than the nominal spacing between adjacent carrier frequencies. In practice the reduction in transmitted bandwidth may be 66%, or 80 cycles for a nominal 120 cycle channel spacing.

For very complete information leading up to and covering the above points the reader is referred to Messrs. R. E. Page, J. L. Skerrett and S. T. Webster's articles, "Developments in Carrier Telegraph Transmission in Australia," Parts 1, 2, 3, Telecommunication Journal, Vol. 5, Nos. 1, 2, 3, June, 1944, October, 1944 and February, 1945. The latter issue, pp. 129, 130, should be particularly noted with regard to the above question.

## SECTION 2—RADIO AND BROADCASTING

**Q. 6 (i) A tuned circuit consists of two arms in parallel, one having pure inductance and resistance in series and the other pure capacitance. Develop an expression which is a close approximation for the impedance of the circuit at radio frequencies when the condition of resonance exists.**

**(ii) If L is 300 microhenries, C is 400 micro-microfarads and R is 12 ohms, compute the impedance of the circuit at resonance.**

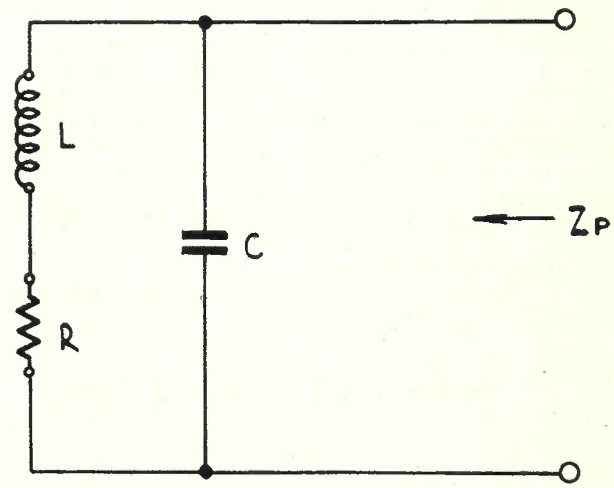


Fig. 1.

A.—The tuned circuit is shown in Fig. 1. If the capacitive branch of the circuit be called $Z_c$ and the inductive branch be likewise designated $Z_L$ then the parallel impedance, that measured across C, is as follows:—

$$Z_p = Z_c Z_L / Z_c + Z_L$$

at resonance the series resonant impedance of a combination of L, C and R, may be shown to equal R, therefore the denominator in the above expression may be replaced by R.

$$Z_p = Z_c Z_L / R$$
$$= \omega L / \omega CR$$
$$= L/CR$$

This latter expression is a close approximation to the parallel impedance of an RF tuned circuit where the value of $\omega L/R$ is high.

(ii) From the expression derived in (i)

$$Z = L/CR$$
$$= 300 \times 10^{-6} / (400 \times 10^{-12} \times 12) \text{ ohms}$$
$$= 62{,}500 \text{ ohms}$$

**Q. 7.—(i) In designing a resistance-coupled amplifier, state the precautions which must be taken in order to ensure that the amplification is uniform over the band 35 to 10,000 c.p.s. The effect of input and output transformer may be neglected.**

**(ii) A resistance-coupled amplifier, using the triode portions of 6B6-G type tubes, has the following constants per stage.**

$R_b = 250{,}000$ ohms, $R_c = 500{,}000$ ohms, $C = 0.01$ microfarads,
$\mu = 100$, $r_p = 100{,}000$ ohms, $C_g = 100$ mmf.

where $R_b$ = plate load resistance.
$R_c$ = grid terminating resistance.
C = coupling condenser.
$\mu$ = amplification factor of tube.
$r_p$ = plate impedance of tube.
$C_g$ = input capacitance of tube including stray capacitance of wiring.

**Compute the gain per stage in decibels at frequencies of 35, 1000 and 10,000 c.p.s.**

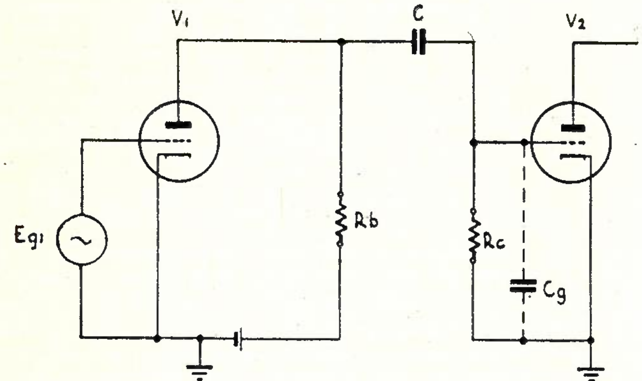
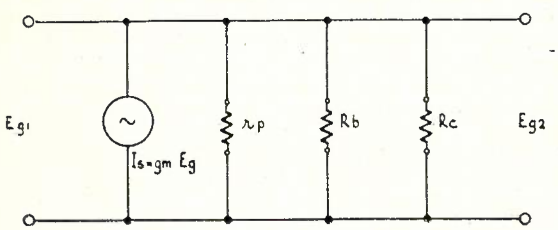
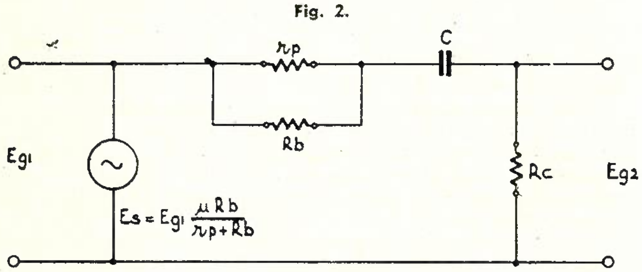


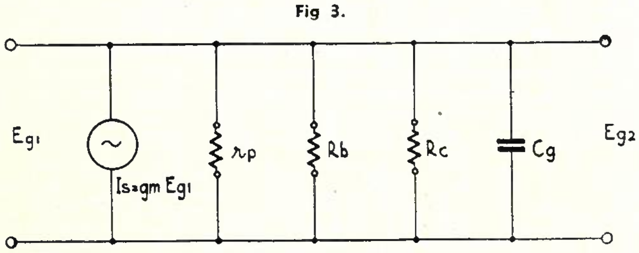

Fig. 1.




EQUIVALENT CIRCUIT AT MIDDLE FREQUENCIES,
VALVE AS CONSTANT CURRENT GENERATOR.
Fig. 2.




EQUIVALENT CIRCUIT AT LOW FREQUENCIES.
VALVE AS CONSTANT VOLTAGE GENERATOR.
Fig 3.




EQUIVALENT CIRCUIT AT HIGH FREQUENCIES.
VALVE AS CONSTANT CURRENT GENERATOR
Fig. 4.

**A.—(i)** The uniformity of amplification (frequency response) of a resistance capacity coupled amplifier is governed primarily by the ratio of the capacitances to the resistances used in the coupling circuits. Fig. 1 shows a resistance coupled triode amplifier, the components being designated in accordance with the symbols used in (ii).

Variations in amplification over the band 35 to 10,000 c.p.s. may be predicted by using the equivalent circuits of the amplifier at the centre and extremes of its operating band. Figs. 2, 3 and 4 show such circuits.

In Figs. 2 and 4, valve VI is replaced by a constant current generator of current $I_s = g_m E_{g1}$, while in Fig. 3 VI is replaced by a constant voltage generator of voltage $E_s = E_{g1}\mu R_b/(Rb+r_p)$.

In Figs. 2 and 4, at middle and high frequencies, it will be seen that the effect of the reactance of condenser C is so small that it may be neglected.

Summarising the precautions which must be taken to ensure uniform amplifications:—

(a) From Fig. 3 to ensure that the potential $E_{g2}$ is not reduced at low frequencies condenser C should have a reactance which is small compared with the parallel combination of $r_p$ and $R_b$ as well as with $R_c$.

(b) From Fig. 4 to prevent a reduction of voltage at the high frequencies the reactance of $C_g$ should be high compared with $R_c$.

In order that the amplification of such an amplifier may be predicted, the following expressions may be utilised:—

(i) (See Fig. 2) Amplification at middle range of frequencies—

$$= \frac{E_{g2}}{E_{g1}} = \mu \frac{R_L}{R_L + r_n} \quad (\text{where} R_L = \frac{R_b R_c}{R_b + R_c})$$

(ii) (See Fig. 3).

$$\frac{\text{Amplification at highest frequency}}{\text{Amplification at middle frequency}} = \frac{1}{\sqrt{1 + \left(\frac{R_q}{X_s}\right)^2}}$$

$$\text{where } X_s = \frac{1}{2\pi f C_g}$$

$$R_q = \frac{1}{\frac{1}{r_p} + \frac{1}{R_b} + \frac{1}{R_c}}$$

(iii) (See Fig. 4)

$$\frac{\text{Amplification at lowest frequency}}{\text{Amplification at middle frequency}} = \frac{1}{\sqrt{1 + \left(\frac{X_c}{R}\right)^2}}$$

$$\text{where } X_c = \frac{1}{2\pi f C}$$

$$R = R_c + \frac{R_b R_p}{R_b + R_p}$$

Substitution of the constants given in the above expressions give stage gains as follows:—
35 cycles = 48.6 = 33.8 db.
1,000 cycles = 62.5 = 35.9 db.
10,000 cycles = 58.4 = 35.3 db.

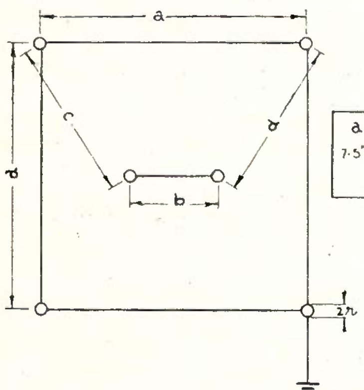
**Q. 8.—Consideration is being given to the type of transmission line to be provided for connecting to:—**

**(i) a medium frequency transmitting aerial comprising a vertical mast;**

**(ii) A high frequency receiving aerial of the rhombic type.**

**Describe the type of transmission line you would provide in each case, giving reasons for your preferance, and show the types of coupling units which would be required between the line and the radiating system.**

**A.**—(i) Recent practice has been to use a multi-wire, open wire, type of transmission line to connect a medium frequency transmitter to a vertical mast radiator. Such a line will usually be of the six wire type shown in Fig. 1 for powers up to 10 kilowatts, or may be made to have lower loss as well as less radiation from the line itself by using a wire construction with additional wires




| a | b | c | d | r |
|---|---|---|---|---|
| 7·5" | 1·75" | 4·725" | 5·9" | ·069" (300 lb. H.D.C.) |

Zo = 200Ω

Fig. 1.

in parallel as the inner conductor, as well as extra wires in the outer group. Such lines have higher characteristic impedance values than the previously used concentric line, have lower attenuation, lower installation and maintenance costs, and enable an efficient match between aerial and transmission line to be effected. Its only deficiency when compared with its predecessor, the buried coaxial cable, is its tendency to radiate more energy along its length. This unwanted radiation is still so small that it may be neglected for most applications. The coupling circuit required between line and radiator will vary in configuration with the electrical height of the vertical radiator. The circuit shown in Fig. 2 is that used when the radiator is operating in the $\lambda/2$ region.

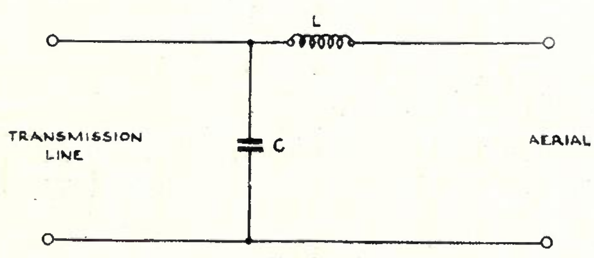



Fig. 2.

(ii) A high frequency rhombic aerial may be connected to its associated receiving equipment by either of two means:—

(a) Open wire line. Usually of the two wire type with a characteristic impedance of 600 ohms, which thus matches the input impedance of the rhombic aerial and quite frequently permits direct connection to the receiver input circuit without impedance transformation. This type of connection is thus simple and inexpensive. Its failings lie in its proneness to extraneous signal and noise pick-up.

(b) Buried coaxial cable. When the latter is used to feed the output of a rhombic aerial to its receiver an impedance matching transformer is required at the aerial terminals to match the balanced 600 ohms aerial to a 50 ohm-100 ohm unbalanced transmission line. When the distance from aerial to receiver is appreciable an amplifier is used at the aerial to provide the impedance matching, and, by amplifying the received signal at its received strength, the signal to noise ratio at the receiver input terminals will be maintained at its highest value.

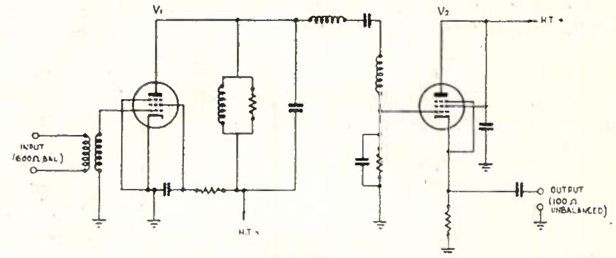



Fig 3.

Fig. 3 shows such a connection. The amplifier shown uses a cathode coupled stage to feed the received signal to the coaxial line.

**Q. 9.—(i) Discuss the factors which must be taken into consideration in determining the useful service area of a medium frequency broadcasting station.**

**(ii) Give a brief explanation of your views as to whether a given strength of signal would provide the same grade of service in any location within the Commonwealth.**

**A.**—(i) The useful service area of a medium frequency broadcasting station is usually considered to be that area, surrounding the station, in which reception is not impaired by the presence of electrical noise, or by fading of the signal due to the presence of both direct and reflected waves.

The factors which influence the extent of this service area are:—

(a) Transmitter power. Without changing the design of the aerial system, increases in transmitter power will increase the signal to noise ratio within the primary service area, but will not increase the extent of this area, i.e., transmitter power increase will give listeners a better signal but will not increase the number of listeners.

(b) Aerial design. For every broadcast station installation there is an optimum aerial design. The radiation pattern will be determined by the surrounding soil conductivity, the type of terrain, the frequency to be used, and by the disposition of listeners around the transmitting point.

(c) Frequency of operation. As ground wave attenuation increases with frequency, the service area of a lower frequency station will extend further than that of a higher frequency station, all other factors being equal.

(d) Soil conductivity. As in (c) an increase in the conductivity of soil surrounding the transmitter will reduce ground wave attenuation and extend the service area.

(e) Presence of electrical interference. Since the measure of useful service area is the ratio of signal to noise at the receiving point, the presence of high livels of electrical noise, either man-made or natural (static, tropical static, etc.), will reduce the service area to that in which the level of received signal far exceeds that of the interference.

(f) Fading. The useful service area of a medium wave broadcast station is bounded by an area of bad distortion of received signals. The distortion is caused by the simultaneous presence of ground wave energy and energy reflected from the ionosphere; due to their differing paths of travel the two waves will not possess the same phase characteristic and will alternately add and subtract in value, giving rise to severe fading and a badly distorted signal. The size of this fading area and its distance from the transmitter may be adjusted by aerial design, and there is a theoretical aerial directivity which will reduce the area to zero, the point at which reflected energy appears being made to coincide with that at which the ground wave has fallen to a low value.

(ii) As has been stated, the sole measure of grade of service is the ratio of signal to noise at the receiving point, and, as the prevailing electrical noise will vary with the locality, viz., city, metropolitan area, country town, country district, etc., it will be appreciated that a considerably larger value of signal will be required in busy areas than that required in quiet country localities. Typical approximate field strength values required to provide usable reception in the various localities are—City areas, 10-50 millivolts/metre; country towns, 0.5-2 millivolts/metre; country districts, 0.25-0.5 millivolts/metre.

**Q. 10.—(i) Explain the terms "constant velocity" and "constant amplitude" as applied to lateral recording on discs, and discuss the reasons for using a combination of both methods.**

**(ii) State the meaning of "pre-emphasis" in disc recording and give the advantages to be derived from this type of recording characteristic.**

**A.**—It is considered that a very complete answer to the above question is provided by Mr. F. O. Viol in his article "Sound Recording and Reproducing," Part 1, The Telecommunication Journal of Aust., Vol. 6, No. 5, p. 280-283. Part (i) of the question is dealt with in the section commencing at the top of column (ii), p. 280, and proceeding to the end of paragraph 2 of column (ii), p. 282. Figs. 1, 2, 3, 4 should be noted carefully.

Part (ii) of the question is covered by paragraph 3, column (ii), p. 283, and by Fig. 5. In his treatment the author does not use the term "pre-emphasis," the term which has more recently been adopted to describe the application of an "orthacoustic" or similar characteristic to a recorded disc in an attempt to improve the overall signal to noise ratio of recorded signal.

## EXAMINATION No. 2824—SENIOR TECHNICIAN—TELEPHONE

**J. Hardie**

### TELEPHONY 1

**Q. 3.—(a) Various circuits such as incoming trunks (09), etc., terminate on the test desk in an automatic exchange—**

**(i) List these circuits.**

**(ii) Indicate the tests which may be carried out on a subscriber's line by means of the testing circuit on the test desk.**

**A.**—(i) 1. Inspector trunks (09).
2. Trunks to test distributor.
3. Lines to U.G. side of M.D.F.
4. In and out test lines to switchboard side of M.D.F.
5. Circuits to give temporary service on faulty lines.
6. Complaint trunks (00 on some desks).
7. In and out lines.

(ii) The following tests may be carried out on a subscriber's line from a test desk:—
1. Condenser discharge.
2. Loop resistance.
3. Insulation resistance by means of 400V rectifier unit.
4. Earth on either side of line.
5. Foreign battery on either side of line.
6. Dial testing, speed, ratio and digit count.
7. Transmission efficiency 25 and 40 db network.
8. Test into exchange equipment for correct connection of battery and earth to L and K relays.
9. Test for dial tone and correct operation of L and K relays.
10. Facilities to enable subscriber to dial while Technician listens to progress of the call.

**Q. 3.—(b) In an automatic exchange subscribers' meters are tested at specified frequencies—**

**(i) What is the frequency of test?**

**(ii) What tests are applied?**

**(iii) When a meter is reported subnormal by the Telephone Branch, what additional tests are necessary on the meter and exchange equipment?**

**A.**—(i) Meters are tested half-yearly and a routine examination is carried out every two years.

(ii) The following tests are applied:—
(a) Crossed trunks.
(b) 9 operations of the meter with a pre-determined "operate" current.
(c) Saturate followed by a non-operate current value and, finally, an operate. Total 10 calls.

The bi-yearly examination is carried out in the same way, but the operation of the meter is observed with the cover off.

(iii) A test call is made over each outlet from the subscriber's line, the meter being observed for correct operation on each call.

**Q. 3.—(c) Automatic Routiners are provided in all new 2000 type exchanges. What are the main advantages of these routiners over manual or semi-automatic test sets?**

**A.**—With manual routiners, the whole of the testing officer's time is taken up. With automatic routiners, it is only necessary to operate a Start Key to commence testing and then record faults when the routiner stops.

About one-sixth of the total time spent by the maintenance staff in an automatic exchange is expended on routine testing.

The following considerations justify the provision of automatic routiners:—

(i) Modern switches and circuits are complex, and the many functions which require to be tested necessitate complex and bulky test sets, which are difficult to move about and cause obstruction in gangways, etc. If automatic routiners are installed, these difficulties are overcome and, in addition, relatively unskilled staff can perform the testing.

(ii) In large busy automatic exchanges where the number of switches is large, the testing must be performed during slack hours. If manual test sets are used this creates staff problems.

(iii) If automatic routiners are provided when exchanges are installed, the frequency of performance of routiners on busy and important switches can be increased at little or no extra cost.

**It is desirable that important major switches be routined once daily in busy exchanges.** This is impracticable without automatic routiners.

(Tele. Comm. Journal, Vol. 4, No. 2—Mr. T. T. Lowe)

**Q. 3 (d) Repeaters and junctions are tested by means of a standard test set or routiner:—**

**(i) What is the frequency of test?**

**(ii) What functions are tested?**

**A.**—(i) Frequency of test—daily.

(ii) The functions tested are:—
(a) Impulsing over long and short lines on Auto-Auto repeaters.
(b) Test that "P" wire is not earthed.
(c) Test that "P" wire is being guarded.
(d) Prove that junction is not reversed.
(e) Prove that reversal of battery from distant exchange occurs.
(f) Prove that registration is correct.
(g) Test that "private" wire does not go open circuit when reversal occurs.

In addition to these tests, auto. to manual repeaters must be tested for a momentary open on the release trunk when the loop is removed and the plug is still in the jack at the manual exchange.

**Q. 4.—(a) When calling a subscriber via a 2000-type 200 line final selector, it is necessary to discriminate between the odd or even hundred lines—**

**(i) Indicate the method of jumpering the trunks from the 4th selector levels to 200 line final selectors.**

**(ii) How is the switching accomplished in the 200 line final selector?**

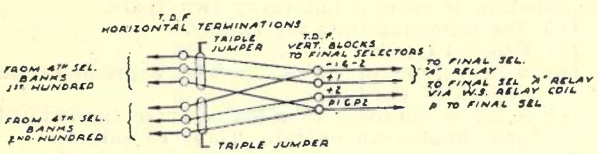



Fig. 1.

A.—(i) Fig. 1 indicates the method of jumpering trunks from 4th selectors to 200 outlet final selectors.

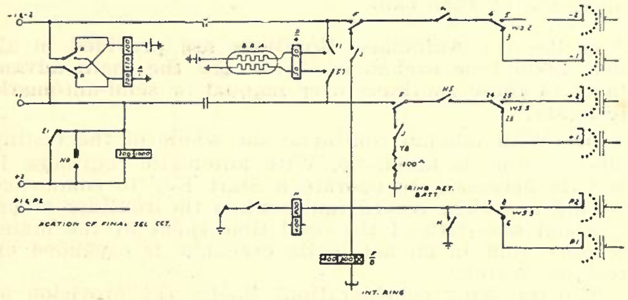


Fig. 2.

(ii) A call for a number in the 1st hundred operates "A" relay over the loop from the fourth selector via — 1 and + 1. W.S. does not operate and wanted subscriber is rung in the normal manner (see Fig. 2).

When a number in the 2nd hundred is called "A" relay again operates over the loop from the 4th selector, but in this case the + incoming trunk is jumpered to the final selector "A" relay via W.S.200 ohms coil; W.S. operates during the vertical train of impulses and locks on its 1000 ohms winding; thus the call is directed into the 2nd hundred banks via W.S. contacts operated.

**Q. 4.—(b) The standard lamp signalling P.B.X. provides for a trapping circuit for follow on calls, on incoming exchange lines:—**

**(i) Why is this provided?**

**(ii) Describe briefly the circuit conditions.**

A.—(i) A trapping circuit is provided on each exchange line to recall the telephonist and to prevent the ring going through to the extension if another exchange call is received prior to the clearing of a through connection.

(ii) The exchange line equipment is under the control of relay Z. (See Fig. 3.) When the call is completed and extension loop is removed, relays Z and ZZ restore. If another exchange call is received before the plug is withdrawn, relay L operates and locks. The line lamp circuit is completed to interrupted ground via K1 contacts. The flashing line lamp attracts the operator's attention, who then removes the calling plug from the extension jack and operates the speak key. If the answering plug is withdrawn before the call is answered, the flashing lamp is replaced by a steady glow.

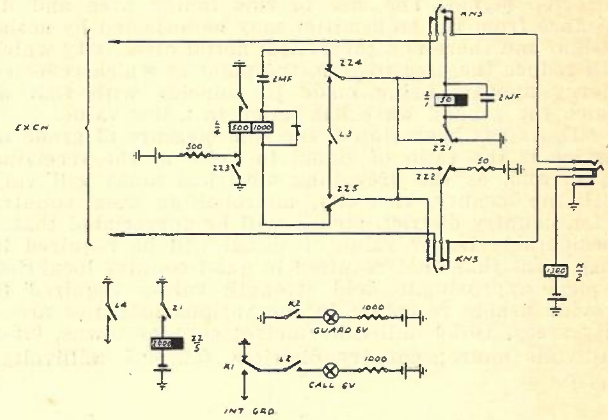


Fig. 3.—Exchange line circuit.

**Q. 4.—(c) Ballast resistors (Barretters) are fitted on certain switches in automatic exchanges:—**

**(i) On what switches are they fitted in—**

**(a) Main exchanges?**

**(b) Branch exchanges?**

**(ii) Why are they used?**

A.—(i) (a) In main exchanges Ballast Resistors are fitted to two main groups of switches—

1. Impulse repeaters in conjunction with 50/50 ohm "A" relays.
2. Final selectors, in the transmission bridge on the called subscriber side in series with 50/50 ohm "D" relays.

(b) In branch exchanges they are fitted to—

(i) Impulse repeaters.

(ii) Final Selectors.

(iii) Discriminating selector repeaters in conjunction with 50/50 ohm "A" relays.

In addition to the above, some incidental switches have ballast resistors incorporated in their circuits.

(ii) Ballast resistors have made possible the use of a lower resistance transmission relay using nickel iron sleeves, and by so doing gain a higher overall transmission efficiency on subscribers' lines.

The requirements of a transmission bridge in an automatic exchange are:—

(1) High A.C. impedance.

(2) Low D.C. resistance to ensure high sending efficiency of the subscriber's telephone.

(3) D.C. resistance sufficiently high to minimise fire risk under fault conditions.

(4) Reliable operation and suitability for impulsing.

When low resistance transmission relays are used, some method is necessary to—

(1) Regulate the transmitter current as between subscribers' lines of low and high resistance.

(2) Overcome heating difficulties and provide a suitable means of protection under fault conditions.

These difficulties are overcome by using a resistance in series with the low resistance bridge relay, providing the resistance has the characteristic of being low resistance when the current passing through it is low, and high when the current passing is high. Such resistances are known as "ballast resistors."

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