The
Telecommunication Journal of Australia

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THE POSTAL ELECTRICAL SOCIETY OF VICTORIA

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In advancing this object by the publication of this Journal the Board of Editors is not responsible for the statements made or the opinions expressed in any of the articles in this Journal, unless such statement is made specifically by the Board.

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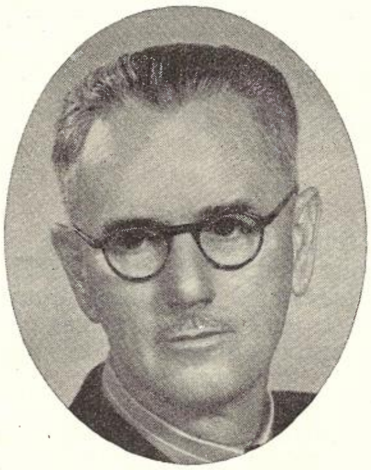
DIRECTOR-GENERAL - RESIGNATION - APPOINTMENT



MR. L. B. FANNING, I.S.O.

On March 16, 1949, Mr. Fanning resigned from the position of Director-General, and took over his new duties as Chairman of the Special Board which has been set up to control, develop and co-ordinate broadcasting services in Australia. It is with considerable regret that the Postal Electrical Society records the departure of Mr. Fanning after a long and meritorious service with the Department.

Entering the Post Office as a telephone attendant in Sydney in 1905, Mr. Fanning saw service in New South Wales and Queensland before coming to the Central Administration in 1918, where he was responsible for the formation of the Telephone Branch. He became the first Chief Inspector (Telephones), and in 1941 was appointed to the new office of Assistant Director-General, Posts and Telegraphs.

In succeeding Mr. McVey as Director-General in 1946, Mr. Fanning brought to the position a wealth of experience and administrative ability, characteristics which he ably demonstrated during the heavy burden of the war years when Mr. McVey was occupied on other essential national activities.

In completing 44 years of service in the Post Office, Mr. Fanning must feel great pride in the part he has played in the building up of the organisation to its present standards and the thanks of all members of the Post Office are due to him. Coupled with the regret of losing his services is the knowledge that, as Chairman of the Broadcasting Control Board, his organising ability and administrative experience will be of inestimable value in the great future developments which must take place in Australia in the fields of radio and television in the next few years. The Society wishes Mr. Fanning every success and happiness in his new sphere.

MR. G. T. CHIPPINDALL

The appointment of Mr. Chippindall to succeed Mr. Fanning as Director-General is a worthy tribute to an outstanding administrator, not only in the Post Office, but in the Public Service as a whole. Commencing in Victoria as a telegraph messenger in 1908, Mr. Chippindall graduated through the telegraphs, mail and postal activities of the Department to the Telephone Branch. After some years' experience as a Telephone Traffic Officer, Mr. Chippindall came to Central Office and was associated with Mr. Fanning in the establishment of the Telephone Branch. From the latter, Mr. Chippindall turned his abilities to Personnel Branch matters and was instrumental in the organisation of that Branch, of which he was first Chief Inspector.

In 1940 he left the Post Office and held in succession the positions of Deputy-Director, and Director-General of War Organisation of Industry, and Secretary of the Department of Supply and Shipping. These positions entailed heavy executive responsibilities which were increased by reason of his occupancy of the position of Chief Executive Officer of the Economic

Cabinet, and membership of the Prices Stabilization Committee and of the War Commitments Committee. Other appointments held by Mr. Chippindall included those of Chairman of the Australian Shipping Board and Chairman of the Disposals Commission. In 1946, on the appointment of Mr. Fanning as Director-General, Mr. Chippindall returned to the Department as Assistant Director-General, and subsequently became Deputy Director-General.

The wide experience gained by Mr. Chippindall in the Post Office and other branches of the Public Service has well fitted him to succeed Mr. Fanning, and we are confident that he will maintain the high standard set by his predecessors. His task is not an easy one as the post-war problems facing the Department today are of the first magnitude. Unprecedented subscribers and trunk line development is taking place at a time when heavy wartime arrears have, in a large measure, yet to be overtaken.

Mr. Chippindall can be assured of the loyalty and co-operation of all members of the Society in the tasks that lie ahead.

RE-ORGANISATION OF THE CONSULTATIVE COMMITTEES OF THE INTERNATIONAL TELECOMMUNICATIONS UNION

J. C. Harrison

The International Telecommunications Conference which met at Atlantic City in 1947, among other things, agreed to the re-constitution and re-organisation of the Consultative Committees associated with the International Telecommunications Union.

Three such Committees are in existence, namely—

(i) the International Telegraph Consultative Committee (C.C.I.T.);

(ii) the International Telephone Consultative Committee (C.C.I.F.);

(iii) the International Radio Consultative Committee (C.C.I.R.).

It might perhaps be interesting to outline the purpose and the development of each of these Committees before discussing the changes decided upon at Atlantic City.

The International Telegraph Consultative Committee (C.C.I.T.)

The C.C.I.T. was created as a result of a decision reached by the International Telegraph Conference which was held at Paris in 1925, and it was then charged with the task of studying technical questions and working arrangements concerning international telegraphy, particularly as regards long-distance telegraphy, and the necessary measures for obtaining the best output from the installations. The Committee was not authorised at this stage to undertake studies concerning tariffs, and the periodicity of the meetings was not specified.

The 1925 Paris Conference was a periodical Administrative Conference of the International Telegraph Union and was held in accordance with the provisions of the St. Petersburg Convention of 1875. The Paris Conference nominated the German Administration to organise the first meeting of the C.C.I.T.

The International Telegraph Conference and the International Radio Conference, which were simultaneously held at Madrid in 1932, agreed to the establishment of a common Convention for both telegraph and radio services. The International Telecommunication Convention, which was drawn up there, provides, in Article 16, for Consultative Committees to be set up to undertake the study of questions relating to telecommunication services, the number, composition, functions and working arrangements of the Committees being stated in the Regulations annexed to the Convention. The International Telegraph Regulations concerning the C.C.I.T., drawn up at Madrid, contained provisions similar to those adopted at the 1925 Conference, but introduced certain innovations, including the following—

(a) the Director of the Bureau of the Union and representatives of other Consultative Committees—C.C.I.F. and C.C.I.R.—were given the right to take part in the meetings of the Committee in a consultative capacity;

(b) the regulations specified that, in principle, the C.C.I.T. should meet every two years, with the qualification that a meeting might be put forward or postponed by the Administration which called it, on request of ten participating Administrations;

(c) the Rules of Procedure to be observed by the C.C.I.T. were set out in Annex No. 2 to the Regulations; and

(d) the Secretariat of each meeting is to be provided jointly by the Managing Administration in collaboration with the Bureau of the Union.

The International Telegraph Conference held at Cairo in 1938 extended the purpose of the C.C.I.T. to include the study of tariff questions which are submitted to it by a Plenipotentiary or Administrative Conference or by at least twelve participating Administrations. The Cairo Regulations (Article 103) amended the Regulations to provide that the meetings of the C.C.I.T. should take place every three years.

Since its establishment in 1925, the C.C.I.T. has undertaken some very valuable studies on important technical and other aspects of the international telegraph service. The conclusions reached by the Committee on the matters submitted to it for study are expressed in the form of "Opinions" as a general rule, the Bureau of the Union arranging for them to be printed and distributed to Administrations.

The Opinions of the Committee form the basis of amendments to the Regulations where the latter are involved. For example, the Telegraph Regulations adopted by the Madrid Conference in 1932 incorporated Article 64 which recognised the right of Administrations to organise an international phototelegram service, the charges and conditions being fixed by direct agreement between the Administrations concerned. Subsequently, after the C.C.I.T. had given consideration to the technical standards and rules, the Cairo Conference decided to include in the Regulations the detailed conditions applicable to the phototelegram service in the European system, 63 paragraphs being involved.

The C.C.I.T. has met on six occasions: at Berlin in 1926 and 1929, at Berne in 1931, at Prague in 1934, at Warsaw in 1936, and Brussels in 1948.

As an indication of the volume of the work undertaken by the C.C.I.T., it might perhaps be mentioned that the documents relating to the matters studied at the 1929 meeting comprised more than 400 pages of closely printed matter, and the 1936 documents contained over 800 pages.

An indication of the nature of the problems which have been studied by the C.C.I.T. in past years is given hereunder:—

Definitions relative to telegraphic transmission, including the adoption of the term BAUD as the unit of telegraphic speed;

Determination of service distortion;

Definition of the margin of telegraph instruments;

Standardisation of voice frequency telegraph carrier wave systems;

Determination of characteristics of electromagnetic relays for telegraph purposes;

Adjustments of telegraph relays;

Unification of tariffs for code, cipher and plain language telegrams;

Standardisation of start-stop instruments (teleprinters, teletypes);

Protection of telegraph circuits from electrical interference.

Although 12 years elapsed between the 1936 and 1948 meetings, the C.C.I.T. was not inactive throughout that period, nine Reporters' Commissions, or Study Groups, having been established to examine various questions referred to them by the Plenary Assembly, and the Final Reports submitted by the Reporters' Commissions constituted the basis on which the 1948 meeting of the C.C.I.T. formulated its recommendations.

The matters studied at this meeting included the following:—

Adoption of a uniform world-wide ceiling tariff for international telegrams;

Introduction of an international teleprinter exchange service;

Technical conditions regarding the transmission of phototelegraphy by radio and land-line combined;

Substitution of electro-mechanical relays by electrical devices;

Quality of telegraphic transmission;

Unification of telegraph tariffs in code, cipher and plain language;

Protection of telegraph circuits from interference;

Standardisation of telegraphic devices.

Australia was represented at the 1948 meeting of the C.C.I.T. and this was the first occasion on which a Commonwealth representative attended any meeting of a Consultative Committee of the I.T.U. The Commonwealth's representatives were Mr. F. R. Bradley and Major-General J. Stevens.

The International Telephone Consultative Committee (C.C.I.F.)

This Committee was first established in 1924, prior to its formal recognition by the International Telegraph Regulations in 1925. In 1922, international telephonic communication in Europe was somewhat restricted. An International Conference at Paris in 1923, at which a limited number of European nations was represented, drew up a list of questions relating to international long-distance telephony, the Conference expressing some provisional views as a basis for future study. This Conference was followed in 1924 by a meeting of nineteen European Telephone Administrations at Paris at which it was decided to form an International Committee. This meeting made some general recommendations for the establishment of an international telephone system and it agreed upon the creation of a provisional international Consultative Committee for Long-Distance Telephone Communication.

The International Telegraph Conference of Paris, 1925, decided to incorporate in the International Telegraph Regulations, in the section devoted to the International Telephone Service, provision for the establishment of an International Consultative Committee for Long-Distance Telephonic Communications. This Committee was given the task of studying questions relating to technical standards and operating questions relating to long-distance international telephony. The Paris Regulations provided for this Committee to choose its organisation and establish its own internal regulations and method of work. Those Administrations which desired to participate were required to address their declarations in this respect to the Administration of the country where the last International Telegraph Conference had been held.

The Madrid Conference of 1932 adopted a separate group of regulations relating to the international telephone service. These regulations are known as the International Telephone Regulations, but they are applicable only to the European system and not to the overseas radiotelephone services. Consequently, Australia, as well as many other countries outside Europe, has not adhered to these Regulations.

The Regulations of Madrid extended the scope of the matters to be studied by the C.C.I.F. to include tariff questions. They also stipulated that the Committee should meet every two years and that the Director of the Bureau of the Union or his deputy and the representatives of the other International Consultative Committees—C.C.I.T. and C.C.I.R.—have the right to take part in the meeetings of the C.C.I.F. in a consultative capacity.

The Rules of Procedure for this Committee, drawn up at the 1932 Conference, provide for the C.C.I.F. to comprise four organisations—

(a) the Plenary Assembly;
(b) the Committee of Reporters;
(c) the Laboratory of the European Fundamental System of Reference for Telephone Transmission; and
(d) a General Secretariat.

The C.C.I.F. in the past, therefore, has been somewhat differently constituted from the other Consultative Committees of the Union in that provision has been made for many years for a permanent staff to be associated with the Committee.

The conditions concerning the C.C.I.F. in the Cairo International Telephone Regulations are very similar to those of Madrid.

At the periodical Plenary Assembly meetings, the C.C.I.F. adopts recommendations or opinions on the matters submitted to it for study, and these are published in French. After its tenth meeting, the whole of the earlier recommendations were revised and issued in one work, the Livre Blanc, or White Book, of 5 volumes. Other publications include phrase books in a number of languages for the use of telephonists and maintenance personnel.

The Plenary Assembly sets up the necessary Committees of Reporters to deal with the questions which it has scheduled for study. A number of such Committees is established to deal with separate problems such as Protection, Corrosion, Transmission, Radiotelephony, Operational Procedures, Tariffs and Standard Symbols.

The task of the Committees of Reporters is to make a close study of new questions and to present to the next Plenary Assembly a detailed report on each problem, accompanied by a draft opinion. A Principal Reporter is appointed to direct the work of each Committee and he is given authority, subject to the approval of his Administration, to call together the members of his Committee when questions cannot be settled satisfactorily by correspondence.

The Laboratory of the C.C.I.F. is located in Paris and it incorporates the European Fundamental System of Reference for Telephone Transmission, abbreviated to SFERT from the French designation. SFERT serves as a centre for the measurement of transmission and co-ordination of transmission data relating to telephone systems used in European countries. It also calibrates telephone apparatus at the request and expense of Administrations or private enterprises. In addition, it conducts, at the request of the Plenary Assembly, or the Committee of Reporters, experiments and tests intended to facilitate the solution of new questions scheduled for examination.

The General Secretariat is managed by a Secretary-General who is responsible for the recruitment and control of the staff of the Secretariat and the Laboratory. The Secretary-General also takes part in the meetings of the Plenary Assembly and of the Committees of Reporters, in a consultative capacity. He arranges the agenda of the Plenary Assembly in accordance with submissions made by the Principal Reporters and furnishes to each Plenary Assembly an account of the activities of the C.C.I.F. since the previous meeting.

Although the activities of this Committee are concerned primarily with the European system, some of the Administrations outside Europe have in past years participated in the work of the Committee, e.g., Japan and Persia, while for many years the American Telephone and Telegraph Company has been represented at its meetings.

The C.C.I.F. co-operates closely with a number of other international organisations, including the C.C.I.T., C.C.I.R., the International Broadcasting Union and the International Railways Union.

The C.C.I.F. has held fifteen meetings since its establishment. From 1924-1932, Plenary Assemblies were held annually, the first three at Paris and then at Como, Paris, Berlin, Brussels, Paris and Madrid, successively. The Tenth Assembly was held at Budapest in 1934, while the eleventh meeting took place at Copenhagen in 1936. Another meeting of this Committee took place in London in December, 1938.

Immediately after the end of World War II, a meeting of the C.C.I.F. took place in London in October, 1945, to resume the work interrupted by the war.

This Committee held further meetings at Montreaux in 1946 and at Stockholm in June, 1948. Another meeting is scheduled to be held at The Hague in April, 1949.

The matters which have been studied by the C.C.I.F. include the following items:—

Protection of telephone channels from interference due to power systems;

Protection of Cable Sheaths from Corrosion;
Transmission Problems;
Co-ordination of telephony and telegraphy circuits;
Broadcast transmissions over telephone circuits;
Television transmission;
Carrier circuits on loaded cables;
Measurement of harmonic distortion in negative feed-back repeaters;
Development of new European switching plan utilising either co-axial cable or 12-channel systems;
Questions of charges;
Maintenance procedures on international carrier wave circuits.

Bearing in mind that, in accordance with a decision reached by the Atlantic City Conference, the International Telephone Conference which is to be held at Paris in 1949 will undertake the revision of the Telephone Regulations so as to make them applicable to overseas radiotelephone circuits connecting different countries, as well as to the European land-line system, the work of the C.C.I.F. will be extended over a wider sphere in the future.

So far, Australia has not been represented at any meeting of the C.C.I.F., but, with the extension of the International Telephone Regulations to the overseas radiotelephone links and the growing importance of the work of this Committee, it appears likely that the Commonwealth will be represented at future meetings.

The International Consultative Committee for Radiocommunication (C.C.I.R.)

The C.C.I.R. was set up in accordance with article 33 of the International Radiotelegraph Regulations annexed to the International Radiotelegraph Convention of Washington, 1927, this Committee being allotted the task of studying technical and related questions which concern international radio communication and which are submitted to it by the participating Administrations or private enterprises. Its function was limited to giving opinions on the questions which it had studied. It was required to transmit these opinions to the International Bureau with a view to their communication to the Administrations and private enterprises. The Netherlands Administration was charged with the task of organising the first meeting of the C.C.I.R. and the Administrations which were represented at a meeting of the Committee were to decide which of the Administrations should call the succeeding meeting. The Regulations stipulated that, in principle, the meetings of this Committee should take place every two years.

The International Radio Regulations drawn up at Madrid in 1932 entrusted the Committee with the task of studying technical radio-electric questions and other questions of which the solution depends principally on considerations of a technical nature and which are submitted by the Administrations and by the companies operating radio-electric installations. These Regulations provided that, in principle, the C.C.I.R. should meet every five years, the Director of the Bureau and representatives of other Consultative Committees of the Union being given the right to participate in a consultative capacity in the meetings of the Committee. The Cairo International Radio Conference of 1938 further amended the Radio Regulations so as to stipulate that the Committee is charged with the study of technical radio-electric questions and operating questions which depend for their settlement principally on consideration of questions of a technical nature. The Cairo Regulations also provide that the Committee should meet every three years.

The C.C.I.R. has met on five occasions, including meetings at The Hague in 1929, Copenhagen in 1931, Lisbon in 1934, Bucharest in 1937 and Stockholm in 1948.

Among the matters studied by this Committee at its 1948 meeting were a number of important questions referred to it by the Atlantic City Radio Conference, including the following:—

International co-ordination of studies of radio propagation;
Standard Frequency Broadcasts and Time Signals;
Co-ordination of International monitoring;
Review of Appendices 3, 4 and 5 of the International Radio Regulations relating to Table of Frequency Tolerances, Table of Tolerances for the Intensity of Harmonics and Parasitic Emissions, and Band of Frequency required for certain types of radio communications;
Study of the efficacy of the Radio-telephone Distress Calls;
Use of automatic devices for ensuring a continuous watch on the frequency 2182 kc/s;
Standardisation of performance requirements for photo-telegram equipment;
Ratio of desired to undesired signals.

The Australian Administration was represented at the 1948 meeting of the C.C.I.R. by Mr. D. McDonald, of the Post Office, Dr. Woolley, Commonwealth Astronomer, and Dr. Pawsey, of the Council for Scientific and Industrial Research, this being the first meeting of the Committee at which Commonwealth representatives were in attendance. Mr. McDonald was appointed Vice-Chairman of the Broadcasting Committee.

At the 1948 meeting, a total of 34 Administrations were represented either directly or by proxy. The 28 countries which were represented directly included the following Administrations outside the European zone, namely: Australia, Canada, China, French Overseas Territories, Egypt, U.S.A., New Zealand and South Africa.

This meeting commenced on 12th July and was concluded on 31st July.

In order to expedite the treatment of the work, eight Committees were created, namely:—

1. Frequency Separation;
2. Propagation;
3. Standard Frequencies and Time Signals;
4. Monitoring;
5. General Technical;
6. Broadcasting;
7. Organisation;
8. Drafting.

The meeting adopted a number of recommendations relating to important technical matters and laid the foundation for the successful work of the C.C.I.R. in the future.

Over 300 documents were presented for consideration at this meeting and copies of these are being distributed to all the Administrations of the International Telecommunications Union.

In order to carry on the work of this Committee between plenary assemblies, a total of 13 study groups was appointed to undertake the examination of problems associated with the following items:—

1. Transmitters.
2. Receivers.
3. Complete systems.
4. Surface Radio Propagation.
5. Tropospheric Radio Propagation.
6. Ionospheric Radio Propagation.
7. Standard Frequencies and Time Signals.
8. Monitoring.
9. General Technical.
10. Broadcasting.
11. Television.
12. Operation.
13. Tropical Broadcasting.

The sixth meeting of this Committee is scheduled to be held in Prague in 1951 and it is anticipated that this session will have many important issues to decide, particularly as that will be the last meeting of the C.C.I.R. prior to the International Radio Conference which is to be held in Argentina in 1952.

Reconstitution of the International Consultative Committees by the Atlantic City Conference

The Plenipotentiary Conference which met at Atlantic City to revise the provisions of the International Telecommunications Convention decided to reconstitute the three International Consultative Committees on Telegraph, Telephone and Radiocommunication, respectively, with a permanent Director in charge of each body, assisted by a small Secretariat.

This decision meant, in effect, that the C.C.I.T. and the C.C.I.R. should be remodelled so as to resemble somewhat the organisation already established for the C.C.I.F., a permanent Secretariat having been associated with the latter for many years past.

The annual salary allotted to each Director represents 51,000 Swiss francs, approximately £A3100. The appointment of each Director is made by a Plenary Assembly of the respective Committee and is for an indefinite period subject to reciprocal right of terminating the appointment.

A strong move was made at Atlantic City for the establishment of a Consultative Committee on Broadcasting, but eventually the Plenipotentiary Conference decided that the C.C.I.R. could deal adequately with the radio problems associated with broadcasting. Recognising the need for some special action to be taken in order to ensure that the technical problems peculiar to broadcasting would be appropriately cared for, however, the Conference agreed that, in addition to the Director, the C.C.I.R. should also have a Vice-Director who should be specially qualified to deal with broadcasting matters.

The C.C.I.R. at its 1948 meeting elected Dr. Balth Van der Pol, Professor of Electronics, Delft Technical University, Netherlands, as its Director, and Mr. L. W. Hayes, O.B.E., of the British Broadcasting Corporation, as the Vice-Director, and these gentlemen will take up their new duties at Geneva as from 1st January, 1949. The budget of this Committee for 1949 contemplates that the Secretariat will comprise a permanent staff of:—

- 1 Secretary-Administrator,
- 2 Engineers,
- 3 Technical Editors,
- 4 Clerks,
- 1 Technical Employee,
- 7 Typists.

Article 8 of the Atlantic City Convention stipulates that the duties of the three Consultative Committees shall be to study and make recommendations on the following problems:—

C.C.I.T.—Technical, operating and tariff questions relating to telegraphy and facsimile.

C.C.I.F.—Technical, operating and tariff questions relating to telephony.

C.C.I.R.—Technical radio questions and operating questions the solution of which depends principally on considerations of a technical radio character.

This Article also provides that the questions to be studied by each C.C.I. are those submitted to it by a Plenipotentiary Conference or by an Administrative Conference, by the Administrative Council, by another C.C.I., or by the International Frequency Registration Board, or by at least 12 Administrations, each Committee comprising members of the Union and recognised private operating agencies.

In the past the various Regulations have prescribed, in effect, that each Committee is composed of experts from the contracting Administrations or from private enterprises recognised by the respective Governments which notify their desire to take part in the work.

Article 8 also stipulates that each Consultative Committee shall work through the medium of—

(a) the Plenary Assembly meeting normally every 2 years;

(b) Study Groups set up by the Plenary Assembly to deal with questions to be studied;
(c) a Director to be appointed by the Plenary Assembly for an indefinite period, the Director of the C.C.I.R. being assisted by a Vice-Director specialising in broadcasting;
(d) a specialised Secretariat to assist the Director; and
(e) Laboratories or technical installations set up by the Union.

The Rules of Procedure to be observed by each C.C.I. are incorporated in the General Regulations annexed to the Convention and these set out:—

Conditions of participation;
Duties of the Plenary Assembly;
Convocation of meetings of the Plenary Assembly;
Languages and the method of voting;
Duties of the Director and the Secretariat.

The General Regulations provide that the salaries of the Directors of the Consultative Committees shall be included in the general expenses of the Union and that, as previously, the expenses of the meetings of the Plenary Assemblies and Study Groups of these Committees shall be borne by the Administrations, private operating agencies and scientific, as well as manufacturing, organisations which participate in such meetings.

The International Radio Regulations adopted by the Radio Conference at Atlantic City also contain provisions peculiar to the C.C.I.R. When the International Telegraph and Telephone Conferences meet in Paris during 1949, consideration will be given to the provisions of the Telegraph and Telephone Regulations concerning the C.C.I.T. and the C.C.I.F. to bring them into harmony with the Atlantic City Convention.

SOUND RECORDING AND REPRODUCING — PART 3

F. O. Viol

WIRE AND TAPE SYSTEMS—MAGNETIC AND MECHANICAL

The greatest advances made in sound recording during the last few years have been in connection with magnetic wire and magnetic tape systems, and, of the two, the former has already found an important place in the broadcast field, particularly in circumstances where portability is an important factor. The magnetic tape system, using magnetic oxides, is new, so far as Australia is concerned, but it is felt that it will play an equally important part in this country as a recording medium, for the reasons that the performance of this type of equipment is excellent and the tapes can be used repeatedly, with a consequent reduction in operating costs.

History

The process of magnetic recording was introduced by Poulsen in 1900 under the name of the Telegraphone, and was used in conjunction with his arc system of radio telegraphy. Signals were transmitted at high hand-speed and were recorded at the receiving station on a steel wire driven at a higher speed than was used for replay. The receiving operator then transcribed the signals at a convenient speed. Although Poulsen had shown that sound could be recorded on wire, little advance was made with this system until the introduction of the electron tube.

About 1924 a German engineer, Dr. Stille, commenced his research on the subject. His work was entirely devoted to the problems associated with sound recording and was responsible for the introduction of steel tape instead of wire, an innovation which overcame certain magnetic and mechanical difficulties. In addition, he developed an electromagnetic system which resulted in a reduction in waveform distortion.

The British Broadcasting Corporation commenced research on the steel tape system in 1930 and had equipment in use by the end of 1932 for the Empire transmissions. The development continued until 1936, when disc recording gradually superseded it.

In Germany, research was continuous, and in 1930 work commenced on a tape consisting of paper coated with iron powder. The paper was found unsatisfactory and other materials were tried until a cellulose acetate base coated with iron oxide particles in cellulose nitrate was finally developed about 1938. This was an important step, as it resulted in an improvement to the technical standard while, at the same time, reduced the weight and bulk of the tape.

The next important step was the use of high frequencies during erasing and recording, whereas all earlier systems had used D.C. for these purposes. By 1945 the magnetic tape system was in general use throughout the German broadcasting network.

Developments of this type were not peculiar to Germany, for a magnetic wire system which also used high frequencies for erasing and biassing had been developed in U.S.A. By 1945 equipment was being produced commercially by a number of companies and quantities were in use for various war purposes.

General Description

There are four essentials for a magnetic tape recording and reproducing system:—

(a) A length of magnetic tape driven at constant velocity.
(b) A wiping (erasing) head.
(c) A recording head.
(d) A replay head.

In addition, oscillators and amplifiers are required, and the basic system is shown in Fig. 1 in a block diagram.

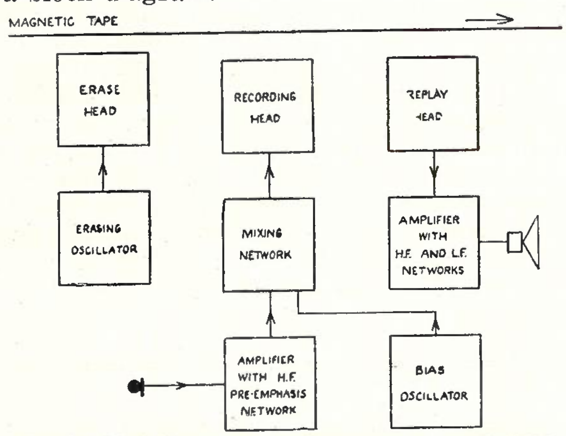


Fig. 1.—Block diagram of basic magnetic tape recorder.

The tape is first fed past the wiping head which removes any previous recording and prepares the particles for the recording by first magnetically saturating them and then completely demagnetizing them.

A high frequency current, sometimes as high as 100 kc/s, is supplied to the recording head. The audio-frequency currents are superimposed upon and do not modulate the high frequency current which is used to improve the linearity of the magnetic characteristics of the tape and improve the signal/noise ratio. The audio-frequency signals are fed to the recording head from a pentode or similar tube to obtain, ignoring compensating networks, constant current through the head which is inductive.

The tape then passes the replay head and audio-frequency signals are obtained. The high frequency bias has no part in the reproducing process and is not heard because the frequency is too high. During the recording and replay process the lower and higher frequencies are attenuated and correcting networks are necessary to compensate for the losses experienced.

Fundamental Processes

Before these processes are considered, it is necessary to discuss briefly the more important points relating to the magnetic theory so that the explanations which follow may be more clearly understood.

The important features of a magnetic material are the relations between the strength of the magnetic field applied to it, called the magnetizing force H, and usually measured in oersteds or in ampere turns/inch, and the induction or flux density B, in gauss or in lines/square inch, which is produced in the material. The relations for a freshly demagnetized sample of a typical high permeability metal are shown in the dotted curve of Fig. 2.

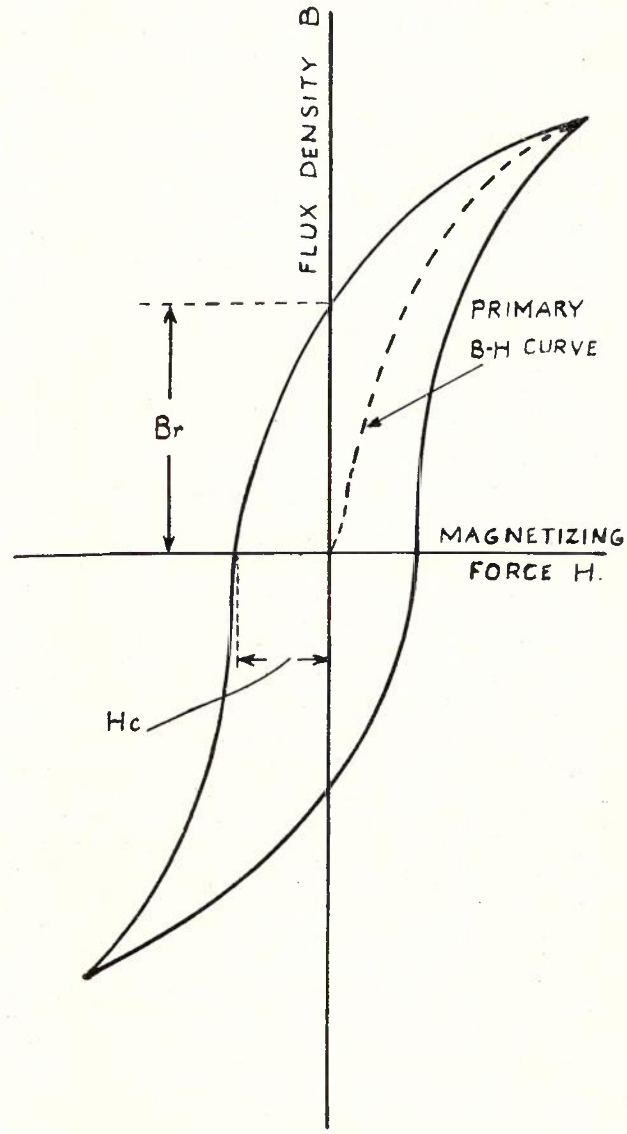


Fig. 2.—B-H curves for initially unmagnetized sample.

If the magnetizing force is varied cyclically between large equal positive and negative values, its relation to the resulting induction is shown by the closed curve of Fig. 2, called a hysteresis loop. At least on the steep portions of these curves, changes of induction take place in very rapid, random, discrete jumps, and this phenomenon, called Barkhausen Effect, can produce noise in audio systems under certain conditions. The induction remaining in a material after the removal of a field producing saturation is called retentivity, and the coercive force requried to reduce the flux density in the material to zero from a condition corresponding to saturation flux density or saturation induction, is the coercivity.

When a magnetic material is being symmetrically cyclically magnetized, the value of the flux density for the condition of zero magnetizing force is the residual flux density or residual induction Br. The magnitude of the magnetizing force at which the flux density is zero when the material is being symmetrically cyclically magnetized is the coercive force Hc.

The present-day theory of magnetism indicates that a ferromagnetic substance can be considered to have a crystalline structure with the atoms of the lattice arranged in a definite orderly manner, and the orientation of the atoms within the crystal lattice determines the magnetic property of the material. When, for example, an iron crystal is completely unmagnetized, tiny regions, called domains, are completely magnetized. The individual regions, however, have their magnetic moments in different directions, and these moments add to zero over the whole crystal. The application of an external field is believed to result in an enlarging of the domains with magnetic moments in the general direction of the applied field at the expense of the domains with moments less favourably situated. As the applied field is increased, the position of the domain moments is in line with the direction of the flux. This is the condition of saturation.

Erasing or Wiping Process: For convenience of discussion the three processes, wiping, recording and reproduction, will be considered independently as used for a high quality magnetic tape system in which each process is performed by an independent head. The description which follows applies to a particular system.

The wiping head is annular in shape, made of laminated permeable metal. Each ring comprises two symmetrical parts, each part carrying half the turns of the coil. The head has a gap of about 0.5 mm, with a copper spacer. The current in the head is about 150 ma at 35 to 40 kc/s. The tape speed, which is a standard, is 77 cm/sec.

The wiping is required to erase signals which may be on the tape and then leave the magnetic particles of the tape in a completely demagnetized, i.e., non-magnetized condition. Consider now a particle of the tape as it passes the wiping head. A magnetic field exists across the gap with a maximum in the middle of the gap and falling away rapidly on both sides. A magnetic particle passing across will undergo, owing to the alternating nature of the field, a continually reversing magnetization, first in a steady increasing field to saturation and, after the middle of the gap, in a steadily decreasing one, as shown in Fig. 3. The flux density and the magnetizing force experienced by the particle are also shown.

Recording process: The recording head of the same general shape and structure has a gap of 0.045 mm and, without a copper spacer, a rear gap of 0.3 mm, to reduce residual magnetism caused by strong surges. The bias current is 10 ma at a frequency of 80-100 kc/s, and superimposed is the audio frequency signals with a peak current of 5 ma at 1 kc/s.

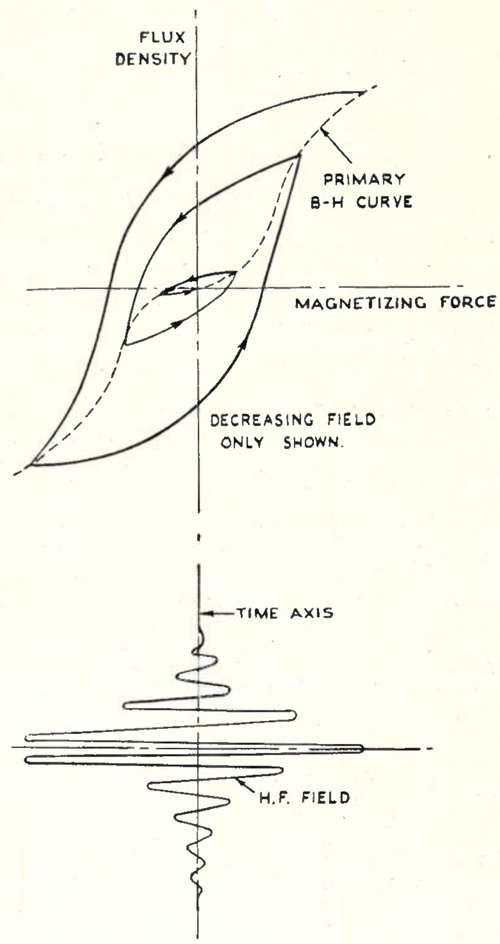


Fig. 3.—Particle magnetization during erasing process showing bias frequency in gap and assumed changes in field intensity acting on a particle of the recording medium.

Assume a particle approaches the recording head. With no audio frequency currents flowing in the head, as is experienced in practice at short and frequent intervals, for example, pauses in speech, the biassing current will have the same action on a particle as did the wiping current, and it will leave the recording head in a demagnetized condition. This is an important point, for a non-magnetic particle will not induce background noise in the reproducing head. It will be appreciated that low level noise on a programme will only be heard during pauses and not while the actual sound is being transmitted.

If, now, there is superimposed on the biassing current a sinusoidal audio frequency current, the field experienced by particles of the magnetic material would be as shown in Fig. 4, in which it is assumed that the gap length of the head is such that 1.5 cycles of biassing current will have been completed during the passage of the particle through the gap, i.e., time T. This means that, as each particle passes through the gap, it will be subjected at least once to a field corresponding to the instantaneous audio signal plus the peak value of bias field in the same direction. The resultant maximum instantaneous field is the one which, in large measure, determines the value of the remanent flux density.

The magnetization experienced by three particles will be examined for the positive half cycle of the audio frequency current. Assume a particle enters the gap in a demagnetized condition at time t_1, at which time the resulting field is zero. As the field rises to its first positive maximum value P, the flux density in the particle follows the initial magnetization curve to point P_1. Succeeding variations PQRS in the resultant field cause the flux density to follow the path P_1 Q_1 R_1 to S_1. At this instant the particle is assumed to start its passage past the second pole piece of the head and is shielded from the influence of the recording field. Thus the resultant field acting, at this instant, on the particle remanent flux density corresponds to the signal recorded on the particle. The action on the particles for time t_2 and t_3 is also shown and a similar treatment can be given for particles influenced by the negative half cycle of the audio frequency current. In all, a linear system can only exist if the values of remanent flux density are in direct proportion to the corresponding instantaneous values of audio frequency current.

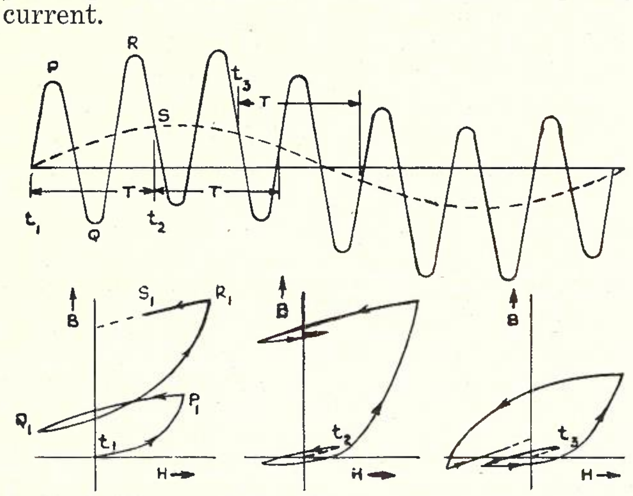


Fig. 4.—Particle magnetization during recording process—
(a) Audio frequency and bias frequency in recording gaps.
(b) Curves showing assumed changes in gap field intensity acting on particles of recording medium.

While the above explanation is satisfactory for individual particles it is necessary to consider the averaging effect for a complete audio frequency cycle to determine the method by which the biassing current causes greater linearity in the transfer characteristic of the magnetic system.

If, now, the bias current with a sinusoidal audio frequency current be considered in relation to the residual flux density curve of the magnetic material, it is possible to construct the flux signal recorded on the tape, as shown in Fig. 5. It will be seen that the bias current causes operation at the lower knee of the residual flux density curve. With no audio frequency signal present the resulting magnetization will be low, due to the high frequency used, with consequent self-demagnetization, and also the lower knee is situated on the curve at a point of relatively low residual flux density. With audio frequency currents present there will be small variations in the combined signals recorded on the tape corresponding to the bias frequency, but it will have short time average values which are nearly proportional to the instantaneous magnitudes of the audio frequency signals. The small variations are eliminated because the reproducer will not respond to the bias frequency.

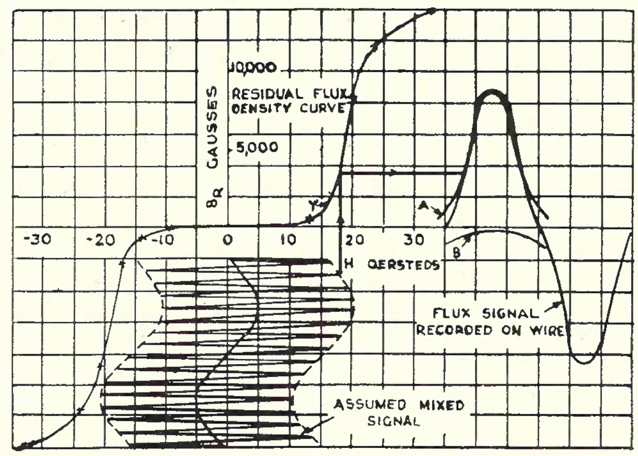


Fig. 5.—Graphical analysis showing combined action of audio frequency and bias frequency in the recording head gap. Construction shows how recorded flux is obtained from combined magnetizing field and magnetization curve.

The construction of the transfer curve is then possible. The positive peak values of resultant field are projected up to the residual flux density curve and plotted on the time axis curve at the right, giving curve A. The negative values are found in a similar manner, and are plotted as curve B. The sum of curves A and B represents the residual flux density. By repeating this construction for the lower half of the residual flux density curve the flux signal on the tape can be determined, neglecting the effects of self-demagnetization.

The above analysis is somewhat similar to the explanation of the operation of a pair of triodes as a class AB pushpull amplifier and high level audio frequency currents will cause distortion in a somewhat similar manner by working in the upper knee of the residual flux density curve. It will be apparent that the aim is to have the linear portion of the overall transfer characteristic long in order to record as large an audio frequency signal as practicable and so obtain a satisfactory signal/noise ratio. Thus it will be seen that the purpose of the bias current is to improve the linearity of the transfer characteristic of the magnetic system and leave the magnetic particles in a demagnetized condition when no signal is present, thus further reducing the signal/noise ratio. It has also been shown (1) that the correct value of bias current to be used must be considered in relation to the high frequency response of the system.

Reproducing Process: If no audio frequency signal is present in the recording head, the tape will, as stated above, be completely demagnetized, and thus will induce no e.m.f's in the reproducing head coil. Any recorded audio frequencies will, however, produce corresponding e.m.f's in the coils. The magnetic fields in the tape and head are shown in Fig. 6.

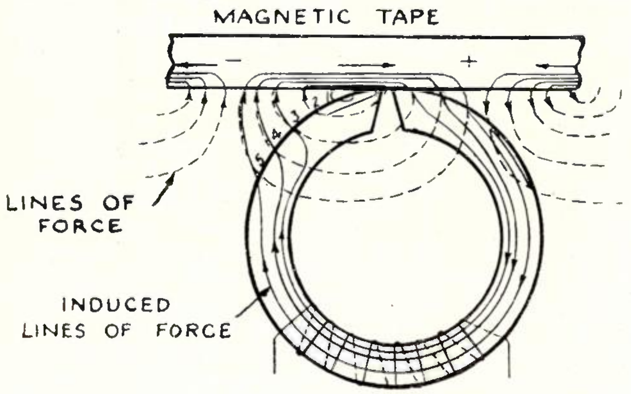


Fig. 6.—Reproducing head showing tape magnetization, flux leakage and flux induced in head at a given position of the head with respect to a recorded half wave.

Frequency Response: The overall frequency response of the system is limited by the recording process, the replay process, the magnetic properties of the tape and its linear velocity. Each will need to be examined in turn before the overall response can be considered.

During the recording process, as explained earlier, it was assumed that the audio frequency field was constant while the particle passed the gap in the recording head. This is not necessarily so at the higher frequencies in the region of 10,000 c/s. At such frequencies, due to the finite width of the gap, the wave-length of the audio frequency current may permit a noticeable change in phase and, therefore, in the resulting amplitude during the time the particle is passing through the field. This results in a reduction of the magnitude of the residual flux density. To compensate for this it is usual to insert a pre-emphasis network in the recording amplifier.

The time rate of change of the lines of force leaving the surface of tape at one pole and returning through the magnetic circuit of the reproducing head to the other pole determines the value of the e.m.f's induced in the windings of the head. The maximum rate of change for a constant total number of lines of force is thus directly proportional to the frequency. This should produce a constant rise in output voltage with frequency at the rate of 6 db/octave. This, however, is only true at the lower frequencies. As the frequency is increased, the width of the gap, the tape speed and magnetic characteristics of the magnet material of the tape all influence the output voltage obtained in accordance with the following equation:—

$$E = KB_m S_t (\pi W_g/\lambda)$$

When E = the r.m.s. voltage at the terminals of the reproducing head.

B_m = the maximum value of the remanence corresponding to the maximum instantaneous audio frequency signal.

S_t = the tape speed.

λ = the wavelength corresponding to the audio frequency signal recorded on the tape.

W_g = the width of the air gap in the reproducer head.

K = a constant depending on the coupling between the tape and the magnetic circuit, the size and configuration of the magnetic circuit, the properties of the reproducer head, etc.

Magnetic Properties of Medium: It has been shown (2) that the higher the permeability of the magnetic material of the tape the greater the relative attenuation at the higher frequencies. A better transmission of the higher frequencies is obtained if the medium has a relatively flat hysteresis loop and high coercive force. Fig. 7 shows the magnetization loops for a number of recording media, while Fig. 8 shows the reduction in output voltage E experienced at the higher frequencies with various tapes. While a high retentivity will give a high output voltage at the lower frequencies, a high coercive force is required to prevent demagnetization at the higher frequencies. It is recognised that the materials which have a high coercive force will also have low retentivity. Thus output voltage must be sacrificed if a satisfactory frequency response is to be obtained.

Gap Width: At low frequencies $\sin \pi W_g/\lambda$ is approximately proportional to the frequency and the output voltage should rise at the rate of nearly 6 db/octave. At higher frequencies $\sin \pi W_g/\lambda$ is

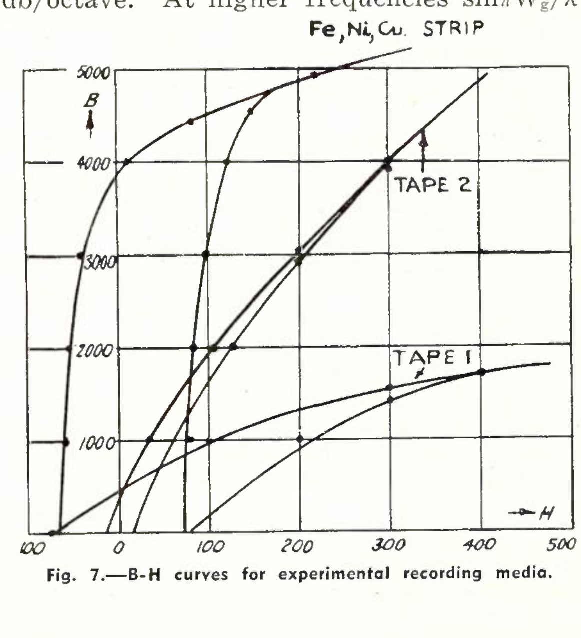


Fig. 7.—B-H curves for experimental recording media.

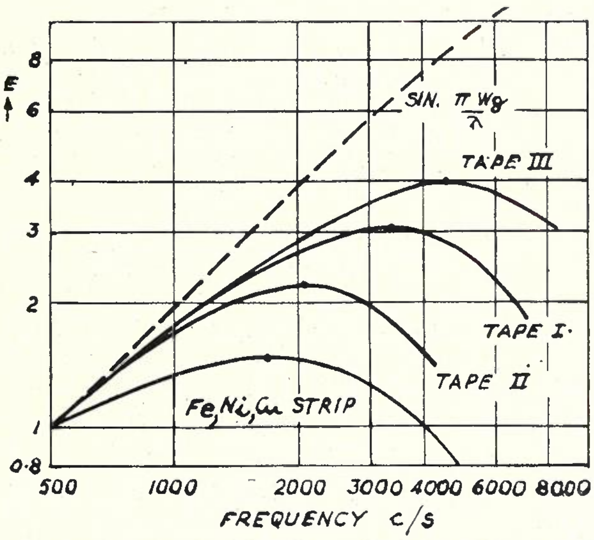


Fig. 8.—Output voltage of reproducing head for various recording media when W_g = 0.745 mm, V = 95 cm/sec. and recording head current constant.

not always proportional to the frequency. It will be seen that, at a frequency such that $W_g = \lambda/2$, the output voltage E reaches a maximum, and then falls to a minimum when $W_g = \lambda$. The voltage again increases to a maximum at a frequency such that $W_g = 3\lambda/2$, falls to a minimum at $W_g = 2\lambda$, and so on. Such a curve is shown in Fig. 9 for constant current to the recording head, a gap width of 0.745 mm and a tape speed of 95 cms/sec. In practice, a gap width of 0.22 mm is used which fulfills the requirement that W_g can be equal but should not be greater than $\lambda/4$ of the shortest wavelength to be replayed, i.e., 0.08 mm. At the lower frequencies the output voltage is almost independent of the gap width of the reproducing head.

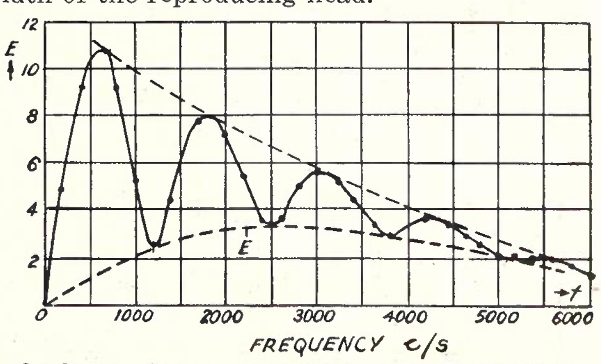


Fig. 9.—Output voltage of reproducing head when W_g = 0.745 mm, V = 95 cm/sec. and recording head current constant.

Tape Speed: The speed at which the tape is driven has a pronounced effect on the high frequency response of the magnetic recording system, but at the lower frequencies the speed has only a slight effect. The output voltage of a tape driven at various speeds is shown in Fig. 10, to illustrate this point. It will be seen that for each speed the output voltage E rises to a maximum until $W_g = \lambda/4$ of the recorded sound and then falls away. As $f = V/\lambda$, the greater the tape speed V, the higher the frequency which can be reproduced. At low frequencies self-demagnetization is negligible, so that the remanent flux density is independent of wavelength and hence of the speed which, at any given frequency, determines wavelength. At the higher frequency provided the gap width W_g is small enough, the output voltage is dependent solely on the wavelength of the recorded sound and on the demagnetization of the medium, which is inversely proportional to wavelength.

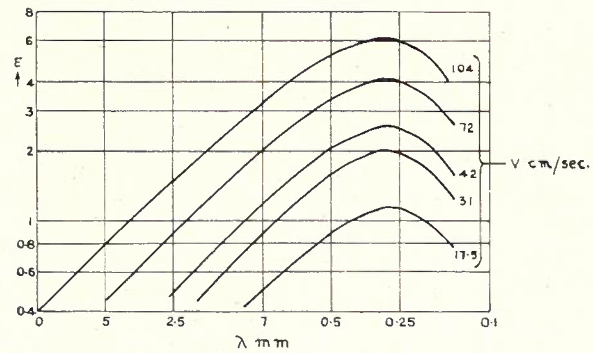


Fig. 10.—Output voltage of reproducing head for various recording medium velocities. Recording head current and recording speed constant.

Sources of Noise: In any magnetic recording system there are two major sources of noise which will determine the overall signal/noise ratio of the system. Firstly, there is the noise due to the magnetic medium, tape or wire, and, secondly, the noise due to all other causes of mechanical and electrical origin.

The magnetic noise in a tape can be due to the Barkhausen effect, as mentioned earlier, and is probably the limiting factor in the ideal system, but, in the practical case, noise from other sources limits the signal/noise ratio obtained. The Barkhausen effect should not be evident on a tape which is not carrying an audio frequency signal, for the reason that the magnetic particles should be in a completely demagnetized condition after passing the recording head. But, with the application of a signal, noise will be evident and will increase as the amplitude of the signal is increased. More important, however, is the manner in which the recording medium is manufactured. In the case of tape, one of the main causes of noise lies in the inhomogeneity of the magnetic layer. This can be due to non-uniformity in the thickness of the magnetic layer on the base, or a clustering of the magnetic particles. Ideally, each particle should be uniformly small, insulated from all others, and evenly distributed throughout the layer; conditions difficult to obtain in practice.

In the case of magnetic wire the noise can be due to the composition of the wire, heat treatment, cold working, etc., but it is the lack of uniformity throughout the wire that will produce uneven magnetization. In addition, it is necessary that the wire be of uniform diameter, without surface irregularities, otherwise noise will be experienced.

There is yet another factor that can be regarded as influencing the signal/noise ratio, i.e., crosstalk. This is the effect of adjacent turns or layers of the recording medium on each other when wound on a spool for storage. It is possible for one turn of strongly magnetized recording medium to magnetize an adjacent turn. This re-recorded signal may be heard as an objectionable noise, particularly during quiet passages of a selection where it would not be masked by the desired signal. Crosstalk can be reduced to a negligible amount by choosing a recording medium having low retentivity and high coercive force. It will be apparent that crosstalk may be a more serious factor with wire than with tape. With tape, the magnetic layers are separated by the base material, but the turns of wire lie closely together.

Noise caused by mechanical imperfections can be of a relatively high level in portable equipment, particularly of the wire type. Either transverse or longitudinal vibrations of the medium as it is drawn past the recording and reproducing heads result in corresponding pulsations of flux linkages, and a noise voltage, in addition to the signal voltages, appears at the output of the system.

The sources of noise due to electrical causes are many, and, again, are more serious in portable equipment. Electrostatic and electromagnetic coupling between power transformers, chokes, motors and the reproducing head can induce noise and, in practice, may determine the signal/noise ratio of the system. The output of the reproducing head is only in the order of a few millivolts, hence the replay amplifier must be carefully designed to maintain the noise at low limits.

Compensating Networks: It is necessary to compensate for the overall audio frequency losses due, firstly, for the characteristic of the replay head which attenuates the lower frequencies at the rate of 6 db/octave and, secondly, for the magnetic characteristics of the medium, tape speed and width of gap in the reproducing head, which all cause losses at the higher frequencies. Additional compensation may be used to pre-emphasize the higher frequencies to improve the signal/noise ratio, as is done in disc recording. The tape speed of 77 cm/sec has been chosen to cause the tape noise to be in that range of frequencies where pre-emphasis is most effective.

The pre-emphasis network is in the recording amplifier, and a variable high frequency network may be fitted to compensate for the losses experienced as the reproducing pole tips wear. In the replay amplifier there are two networks, one to compensate for the low frequency losses and another which is designed to offset the pre-emphasis introduced earlier and at the same time compensate for the overall high frequency losses.

In certain instances, the low frequency compensation may be divided over the two amplifiers. If all of the compensation were applied in the replay amplifier, it would be necessary to have an exceedingly high signal/noise ratio at these frequencies, due to the accentuation they receive. In portable equipment, where residual hum may be difficult to eliminate, the low frequency compensation may be divided over the two amplifiers, but the limiting factor is the incremental peak power in speech and music. If the equipment is designed for speech only, then an appreciable portion of the compensation can be applied to the recording amplifier. The limiting factor, so far as the application of pre-emphasis for either purpose is concerned, is the overload characteristics of the recording unit as a whole, but, in particular, is generally limited by the overload characteristics of the recording medium.

Engraved Film (Philips-Miller) System

The film used in this system consists of three layers, firstly, a carrier of cellulose acetate C, secondly, a specially prepared transparent layer of gelatine G and, thirdly, a thin black layer of colloidal mercury-sulphide D. A sapphire stylus, in the form of an obtuse wedge attached to a moving iron recording head, removes a shaving from the gelatine layer of the tape which passes at constant velocity beneath the stylus. A section

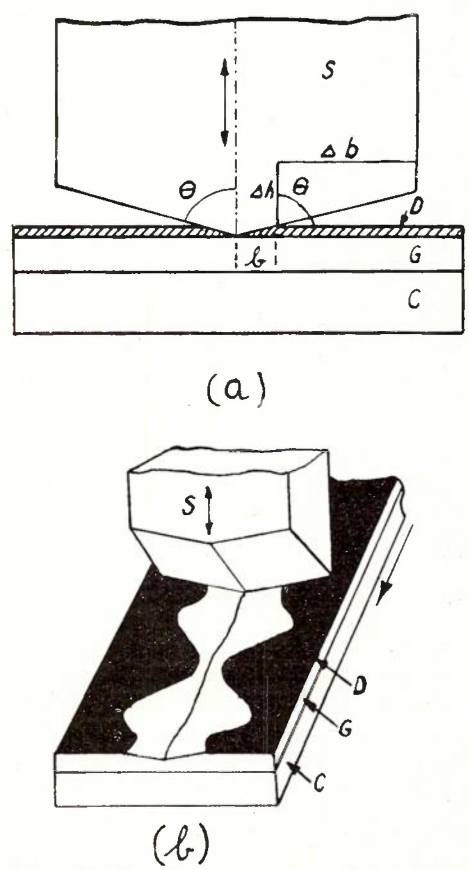


Fig. 11.—(a) Section through wedge-shaped cutter and recording tape. (b) The track recorded by the cutter is also shown. (d) Black layer of colloidal mercury-sulphide. (g) Transparent layer of gelatine. (c) Carrier of cellulose acetate.

through the stylus and tape is shown in Fig. 11a, while Fig. 11b illustrates the type of track cut in the tape when sound is applied to the head.

An examination of Fig. 11a will show that, when the stylus is stationary, a groove of uniform width, 2 b, is cut in the film below it. Along this groove the thin top coating and a part of the gelatine layer are removed, so that a transparent trace is obtained on an opaque background. If the stylus is now brought deeper into the film by a distance Δh, the groove cut will become wider by a small amount $2\Delta b$, and if θ is half the included angle of the wedge the relationship $2\Delta b = \Delta h \times 2 \tan \theta$ will apply. When $\theta = 90°$ $\tan \theta$ will be infinity, and it will be seen that if θ is nearly 90°, a slight displacement Δh of the cutter will produce a marked alteration $2\Delta b$ in the width of the recorded track. With 87°, the angle of the wedge used in practice, the "amplification" obtained will be $2\Delta b/\Delta h = 2 \tan 87°$, i.e., about 40.

As the stylus moves up and down in synchronism with the signals applied to the cutting head, a transparent track on an opaque background, with a width varying in synchronism with the applied signal, will be produced on the moving tape. To obtain a maximum width of track of $2b = 2$ mm, as commonly used in sound-on-film practice, the displacement of the cutter need only have an amplitude Δh of $2000/40 = 0.05$ mm. The principal characteristic of the whole method is the small amplitude necessary to produce the required track width.

The recorded sound is reproduced by the usual method used in motion picture work. The tape carrying the sound track is passed at constant velocity between a photo-electric cell and a small, brightly-lit illuminated slit positioned transversal to the motion of the tape. The intensity of the light falling on the photo-electric cell thus varies with the variable width of the sound track, and the resulting current fluctuations in the photo-electric cell are amplified and transmitted to line.

In the recording machine a replay unit is fitted within a few inches of the recording stylus to permit complete monitoring during recording, and a switch enables an immediate comparison to be made between the incoming programme and the programme recorded on the tape. A similar feature is to be found on magnetic tape machines, provided that the recording head is not used as the replay head, as is done in some cases.

The tape is supplied in lengths of 1000 metres and, at a velocity of 77 cm/sec, provides a recording time of 20 minutes. Copies could be made photographically, but this is not very practical, and it is usual to re-record (dub) when copies are required. Although the overall electrical performance is satisfactory for broadcasting purposes, there are two important reasons why this type of equipment is not in general use:—

(a) The tape can only be used once. This is not important if the recorded programme is to be held for a long period for several replays, but, as the majority of programmes are only required to be played back once or twice, the cost of the tape then becomes excessive when compared with disc or magnetic systems. Although discs can only be recorded on once, they are cheap, and the aluminium base can be re-coated, which further reduces the cost. In the case of the magnetic systems, it is possible to use the medium many times to the point where the tape or wire cost per programme becomes negligible.

(b) It is not possible to obtain copies readily. This applies to magnetic tape and wire equally as well. In the case of discs, two methods are used to obtain copies, namely, dubbing (re-recording) and processing (pressed copies from a metal master obtained by electro-plating). It is this latter method which enables copies to be obtained in quantity and at small cost.

One important feature of the engraved tape in comparison to the recorded disc system is the ease with which the tape can be edited and any part cut out. This is an advantage for the building-up of programmes or the replacement of a section which may carry a defect in programme production. As the track is visible it is practicable to remove a single word, a feature not possible with other systems.

Conclusion

Two systems of sound recording have been discussed, namely, mechanically engraved tape and magnetic wire or tape. Of these, the use of the former system will probably be limited, due to excessive cost. The latter system, however, is already playing an important part in broadcasting in Australia. Portable wire recorders are in general use for the recording of speech, and have been of value in areas where disc equipment would not have been as reliable; for instance, in the Antarctic and in the tropics. Again, the portability of this type of equipment is of advantage where transport is not readily available; for instance, in Arnhem Land.

Portable magnetic tape recorders are available overseas, and will be used in Australia in the near future. They have the advantage, when compared with wire recorders, that they are simpler in mechanical design and should be even more reliable. In addition, the tape can be readily cut and joined for editing purposes.

Stationary tape recorders are being made available and will be of use for programmes which are only required to be replayed once or twice, permitting the same tape to be used frequently. The overall quality is of a high standard, with a frequency response extending from 30 to 10,000 c/s, a signal/noise ratio in the order of 50 db and harmonic distortion not in excess of 5% at full modulation, but with a figure of 2% as the design objective. This type of equipment should be of value for the recording of long programmes, copies of which are not required and which need only to be played once. For instance, where time differences exist within a broadcast network, such as Perth in relation to the Eastern States, it will be possible to record long programmes in Perth for replay at a time more convenient for the listening public in that State.

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SOUND RECORDING AND REPRODUCING—PART 1—ADDENDUM

Disc Recording

(Except where otherwise indicated, figure references are to the original paper—Part 1, Vol. 6, No. 5.)

Since Part 1, dealing with disc recording, published in the October, 1947, issue of the Journal, was prepared, information has been received which has an important bearing on disc recording standards for broadcasting purposes, and it is now proposed to examine certain conclusions reached therein.

Recording Characteristics: Although the reproduction of discs falls into two classes, namely, commercial and cellulose nitrate, it would be desirable to have, in any broadcast network, equipment which would, as far as practicable, play both types equally as well. In the National Broadcasting Network this has been possible, as one common replay characteristic has been used throughout. Elsewhere, the position is not so satisfactory, as the characteristic for the two types is different. For nitrate discs the standard of the National Association of Broadcasters of America (N.A.B.) (Fig. 5) is being used by commercial stations generally, while the B.B.C. has adopted a characteristic (Ref. 6) which enables the discs to be replayed equally as well with equipment suitable for the N.A.B. characteristic and that of the commercial discs (Fig. 4).

Other characteristics are also used, even for commercial discs, which makes standardisation difficult, but, in England, Electrical and Musical Industries Ltd. (Columbia, H.M.V.) have proposed a standard recording characteristic (Fig. 2) for commercial discs which is of such value that its use for nitrate discs is being recommended. The recording characteristic is shown in Fig. 1 addendum, and is virtually the practical curve of a similar curve discussed earlier (Fig. 4). It will be seen that the only difference is at the cross-over frequency at 250 c/s, where the requirements have now been clearly defined.

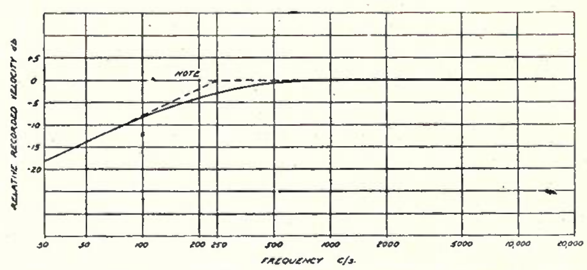

Fig. 1 (Addendum).—Recommended Recording Characteristic.
NOTE.—The cross-over frequency is defined as the point of intersection of the asymptotes to the constant-amplitude and constant-velocity portions of the response curve and the response at the cross-over frequency of 250 c/s is not more than 3 db below the level of this point of intersection.

It is claimed that a reproducer suitable for playing commercial discs to the recommended characteristic will play, satisfactorily, recordings made generally in accordance with Fig. 1, addendum (although with a lower top cut-off), over a period of forty years, and that it will also play such records made in a number of different countries. This characteristic has the advantage that, when compared with the N.A.B. characteristic, it does not introduce distortion at the higher frequencies, nor does it accentuate, to the same extent, machine rumble at the lower frequencies. The use of better record materials without abrasives to improve the signal/noise ratio is contemplated.

If the recommended characteristic were adopted generally for both classes of recordings then only one replay characteristic would be required. This would be of advantage, particularly for process discs (pressing obtained from cellulose nitrate master), for they could be played on any machine suitable for the playing of commercial records. The position is not quite the same with the nitrate type, as, in this case, the gramophone pick-ups are of special types. Even so, the adoption of one characteristic would go far to clarify the confusing situation existing at present.

In Australia, the position is satisfactory in the National Broadcasting Service for, as stated earlier, the recommended characteristic has been in use for many years. Elsewhere, the N.A.B. characteristic is used, but the recommended characteristic could be adopted with minor equipment changes and at small cost.

Direction of Cut: At present, 33⅓ r.p.m. discs are recorded from inside to outside, which means that the low groove velocity part of the disc is always used, while for programmes less than 15 minutes' duration, the outer part of the disc, which provides the best quality, is wasted. It would be better to record outside to inside, so that short programmes would have a uniformly high technical standard. Air suction plant would be needed to remove the swarf, but this would also enable pick-ups to be used for monitoring while the recording is being made.

Automatic Equalisers: The use of automatic equalisers cannot be avoided but, by using pick-ups having a low vertical force and a satisfactory armature compliance, the overall loss would not be as great as shown in Fig 7, the curves of which were obtained with a crystal pick-up. Provided the recommended characteristic is used with satisfactory replay equipment, the harmonic distortion introduced by automatic equalisers need not be excessive.

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P.A.B.X. CALL-BACK FACILITIES

E. G. Wormald.

"Call-back" facilities are provided in P.A.B.X.'s so that, after receiving an incoming call, an extension may hold that call and originate an outgoing call for the purpose of obtaining information. The outgoing call cannot be overheard by the waiting caller and, when finished, the original "in" call may be continued.

Type "C" and "CA" P.A.B.X.'s: In unit-type P.A.B.X.'s, the call-back is effected by momentary operation of a non-locking push-button to earth one side of the extension line. Generally, the push-button is fitted on the telephone instrument and the earth connection obtained via the extension line cable sheath. In the event of rubber-insulated wiring being used for an extension requiring a call-back, an extra conductor (or, generally, a pair) is necessary to provide the earth connection for the push-button.

The facility is effective only on calls incoming to the extension from an exchange line, as the operation of the special call-back relay set is controlled by a differentially-balanced 15 + 15 ohm relay "D" in the exchange line relay set, which operates when the line is unbalanced by use of the push-button, resulting in a sequence of operations which disconnect and hold the exchange line and connect the extension to a special spare extension line circuit. This is then located by a free link finder in the usual manner, so that the extension may set up the "out" call by dialling. The original "in" connection is regained by re-operation of the push-button on completion of the "out" call. Further details, including explanations of the circuit operation and the method of using the push-button for automatic transfer of an incoming exchange line call to the called extension, are given in an article by A. R. Gourley, in Vol 2, No. 1, June, 1938.

Use of Call-Back Relay Sets in Larger P.A.B.X's: In P.A.B.X's, other than unit types, "C" and "CA," it has been the practice to provide call-back facilities by circuit arrangements generally similar to those shown in Fig. 1, the final selector bank and extension jack multiples being dissociated from the extension line (calling) equipment to form separate "in" and "out" lines, which are connected by separate line pairs to a call-back box No. 1, consisting of a standard 2-position lever key mounted in a small wooden box. This is installed with an associated magneto bell and 1 μF condenser at a convenient point in proximity to the extension telephone—often in the knee-space of an office table. The key allows the extension telephone to be switched between the two lines, and the magneto bell and series condenser are connected across the "in" line when the telephone is switched to the "out" line. Call-back relay sets mounting four call-back circuits on pre-2000 type relay set bases are installed in the P.A.B.X. The operation of the circuit is as follows.

If the extension telephone is disengaged, the corresponding extension multiple jack sleeves and final selector private bank contacts (henceforth referred to as "sleeve" or "private") are connected to negative battery through the 1300 ohm resistor YA, indicating the extension as disengaged to the cord circuit "click" test, and providing a circuit for preliminary operation of the switching relay H or full operation of the sleeve relay SB on calls incoming to the extension from a final selector or cord circuit respectively. The

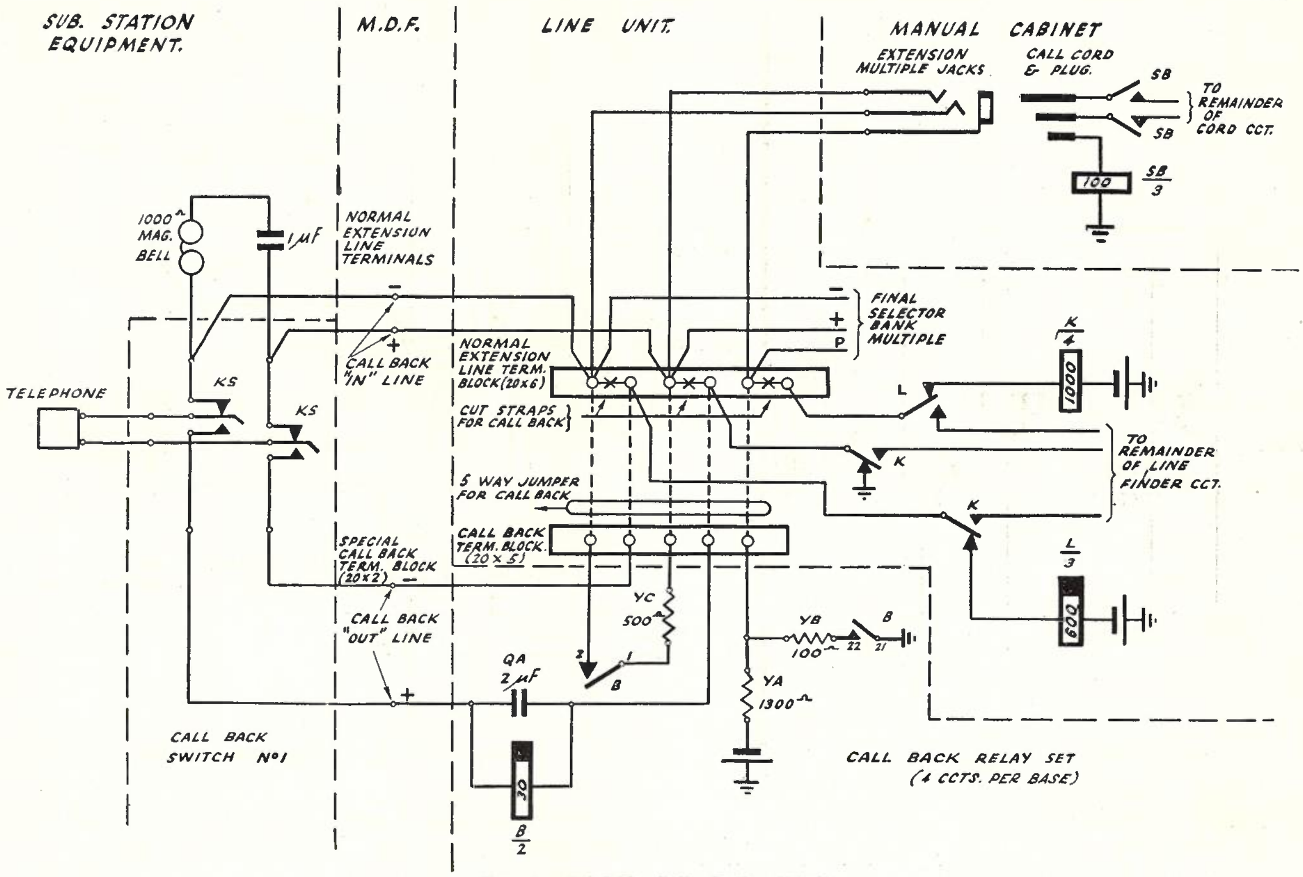

Fig. 1.—P.A.B.X. Call Back Circuit.

potential of the sleeve and private is changed to that of earth or approximately 3.5 volts, respectively, as a result of full operation of relay H or connection of the sleeve to earth through the 100 ohm relay SB, causing the extension to test "busy" to further intending "in" calls. The operation of relay H or SB completes the ringing circuit and interrupted ring is transmitted to the extension via the "in" line. The call is answered with the key in the normal position.

If it is desired to call back, the key is operated, switching the telephone from the "in" to the "out" line. The line relay operates over the telephone loop and the call is completed in the usual manner. The series relay B operates on the line current, connecting the 500 ohm resistor YC across the "in" line at B.1-2 to prevent a clearing signal being given to the manual switchboard telephonist and to provide a voice-frequency termination for trunk connections. Relay B is fitted with a ½" slug on the heel end of the coil to prevent chattering during dialling, and is shunted by a 2 μF condenser QA to minimise the transmission loss and impulse distortion resultant on the insertion of the relay in the line. Contacts B.21-22 fulfil no useful function at this stage, connecting the 100 ohm resistor YB across relay SB, whose adjustment should be such that it does not release. On completion of the "out" call the key is restored to normal, opening the "out" line to clear the switch train and releasing relay B to restore normal conditions on the "in" line so that the original "in" call may be resumed. On completion, this call is cleared in the normal fashion.

If the extension desires to originate a call, the key is operated and the telephone used in the usual manner, the line loop operating relay B. Contacts B.21-22 connect the 100 ohm resistor YB from the private to earth, changing the potential of the private and sleeve from battery to approximately 3.5 volts and causing the extension to test "busy" to intending "in" calls.

A call-back box No. 2, consisting of a box similar to a wooden-cased bellset, fitted with changeover and hold keys as well as with magneto bell and condenser (see Fig. 2), is used in many installations instead of the separate key, magneto bell and condenser described above. This has the advantage of a neater and more compact installation for approximately the same cost, and gives rise to a minor difference in circuit operation, in that an incoming call can only ring one bell, i.e., in the call-back box or the telephone, depending on the position in which the key is left after the previous call. The "hold" key cannot fulfil any useful function in this type of installation.

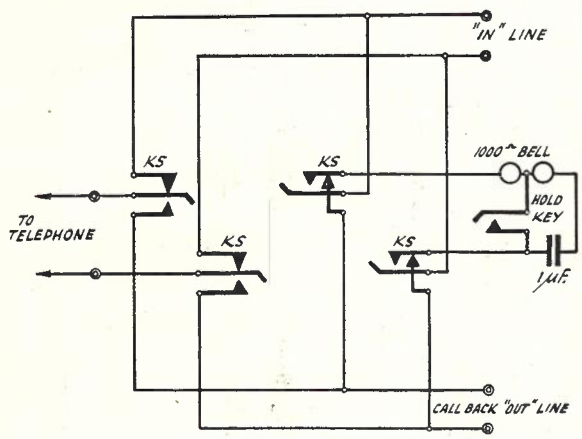

Fig. 2.—Call Back Switch No. 2.

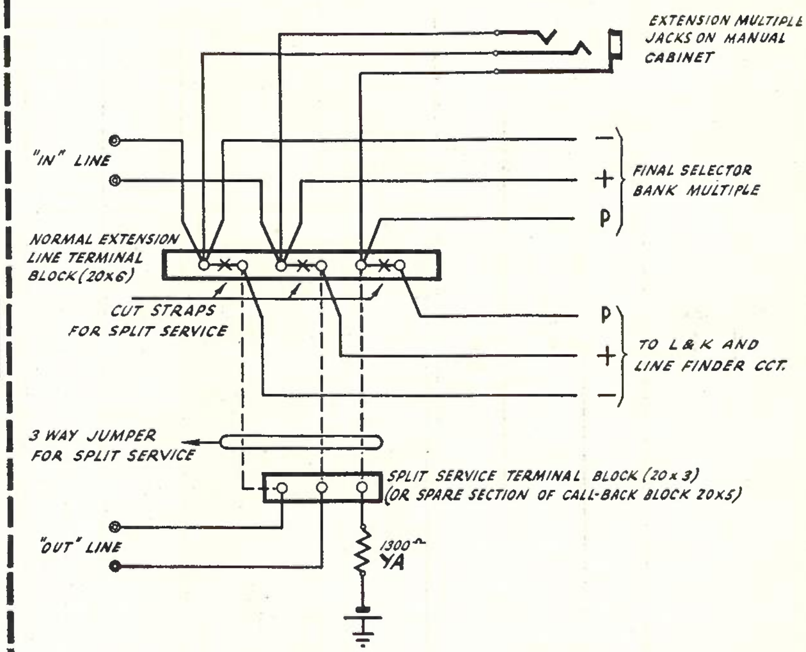

Fig. 3.—P.A.B.X. "Split" Extension Circuit.

"Split" Services: Some subscribers, particularly those with large "enquiry" groups of extensions, consider that an extension with call-back facilities should not be placed out of reach to incoming calls each time an "out" call is made. This requirement is met by the provision of a "split service," with circuit arrangements similar to that shown in Fig. 3. The operation of this circuit is generally similar to that of Fig. 1, except that it is necessary to operate the "hold" key on calls back, to avoid giving a clearing signal on the cord circuit supervisory lamp.

The provision of call-back or "split service" facilities to Fig. 1 or Fig. 3 involves the installation of additional terminal blocks on the M.D.F. and line unit, of call-back relay sets (which may be mounted on either the line unit or trunk board) of resistance spools (almost invariably mounted on the line unit), and of the necessary cabling between these items. Call-back circuits are associated with individual extensions by jumpering from the terminal blocks on the line unit and M.D.F., as required, the exact details varying in the different installations with the type of line unit and other factors.

Call-Back Facility Incorporated in Cord Circuit: A recent development in the provision of P.A.B.X. call-back facilities has taken the form of a modification of the standard P.A.B.X. cord circuit by the addition of two relays to the cord circuit relay set, with discrimination effected by means of a non-locking push-button arrangement similar to that used on the type "C" P.A.B.X. This results in the call-back facility being restricted to manually-handled calls incoming to suitably-equipped extensions. Equipment of this type is installed in a number of P.A.B.X's in Sydney, with circuit arrangements as shown in Fig. 4, the added relays being S and T, with additional wiring and resistors YC and YD, as shown. The operation of the circuit is as follows.

When the "answer" plug is inserted in the jack of a calling exchange line, relay SA operates to connect the tip and ring of the plug through to the transmission bridge at SA.1-2 and SA.3-4. The "answer" supervisory lamp circuit is closed momentarily by SA.21-22, but is disconnected at LA.1-2, when relay LA operates to the exchange line battery. LA.21-22 prepare the warning tone circuit. When the "call" plug is inserted in the multiple jack of the required extension after the engaged test has been applied, relay SB in the cord circuit and relay K in the extension line circuit operate simultaneously in series, relay K disconnecting the extension line from the L relay and earth, in the usual manner. SB.4-5 connect the tip of the plug to battery through the 200 ohm resistor YB as ring return, SB.21-22 momentarily close the "call" supervisory lamp circuit and SB.1-2 operate relay RS. Ring voltage is connected to the extension line at RS.21-22 through the 300 ohm winding F.d-e to the ring of the plug, and the "call" supervisory lamp flashes at ring pulse frequency by connection to interrupted earth at RS.4-5.

Ring tone is transmitted to the calling subscriber through condenser QC and contacts RS.1-2. When the extension answers, relay F

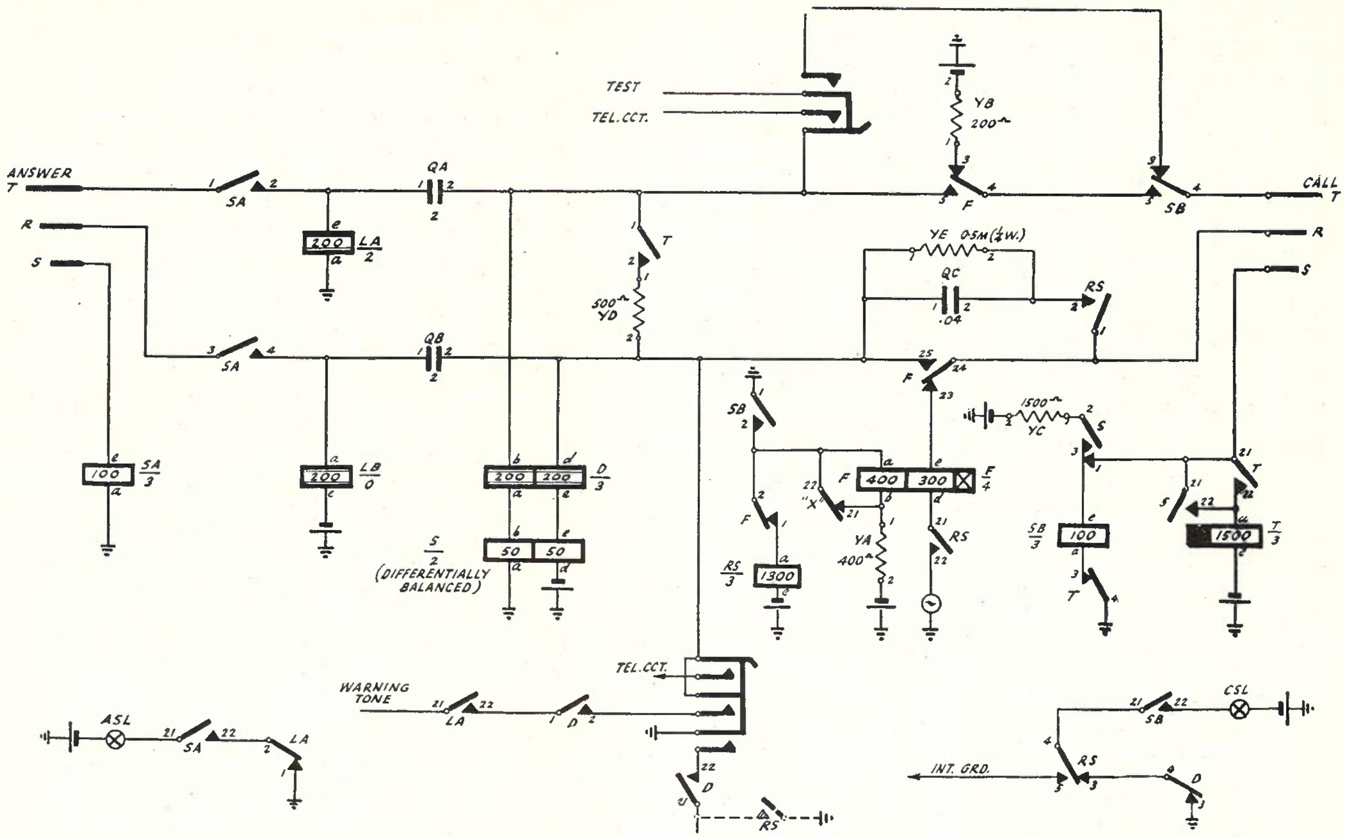

Fig. 4.—Cord Circuit Modified for Call Back Facility.

operates in series with the line loop, opening "x" contacts F.21-22 and ensuring the full operation of relay F on winding a-b. F.3-4-5 and F.23-24-25 disconnect the ring supply circuit and connect the called extension to the transmission bridge, when relay D operates in series with relay S and the extension line loop. Relay S does not operate, having equiturn (sandwich) windings connected in opposition. Meanwhile, relay RS releases after disconnection at F.1-2, and the "call" supervisory lamp is extinguished by the operation of D.3-4. D.1-2 extend the warning tone (where provided) to the "speak" key for injection to the line if the key is opened once the connection has matured.

When the extension line clears, relay D releases to energise the "call" supervisory lamp at D.3-4, or, if the switch-hook is operated intermittently, the supervisory lamp is "flashed" by those contacts to attract the attention of the operator for re-direction of the exchange line. The action so far described is practically the same, whether the cord circuit has been modified for the call-back facility or not.

If a suitably-equipped extension which has been connected to an incoming exchange line by a modified cord circuit in the above manner, should then desire to contact another party for the purpose of obtaining information during that conversation, the call-back push-button is momentarily operated to earth one side of the extension line. This shunts the winding a-b of relays D and S, allowing relay D to hold and relay S to operate, each on its d-e winding. The sleeve relay SB is held in series with the 1500 ohm resistor YC by S.2-3, but is disconnected from the sleeve circuit at S.1, allowing relay K in the line circuit to release and reconnect line relay L.

Relay L operates to earth at the push-button in series with half the resistance of the extension line, usually after a slight delay occasioned by its armature-end slug, although this is not fitted on all types of primary line equipment. The operation of relay L earths the extension private and sleeve for guarding purposes, operating relay T via S.21-22. T.1-2 connect the 500 ohm resistor YD across the line to provide a voice-frequency termination, and T.3-4 disconnect relay SB. SB.1-2 disconnect relays F and RS, and the "call" supervisory lamp is disconnected at SB.21-22, while the tip and ring conductors of the "call" plug are opened at SB.4-5 and RS.1-2, respectively, to entirely disconnect the cord circuit equipment from the extension line. Relay S now releases as the unbalanced line circuit is disconnected, and relay T holds via T.21-22.

Meanwhile, the extension line has been connected to a selector repeater or other major switch through the primary equipment, and dial tone returned to the extension. The person using the extension telephone should then release the call-back button, and the outward call may proceed in the usual manner by dialling the required number. At this stage, no indication is given to the manual operator that a call-back has been made.

On completion of the outward call, the extension line is cleared by replacing the telephone receiver, releasing the switch-train by removal of the holding earth from the private at the selector repeater. This releases relay T after a period of approximately 150 milliseconds, due to its heel-end slug, and T.3-4 reconnect the sleeve relay SB. The conditions are now exactly as if the operator had just inserted the call plug in the extension line jack (including the flashing supervisory lamp), and the original "in" call is resumed by lifting the receiver to trip the ring.

Design Considerations: Some points in the design of the circuit, which are not immediately apparent, may be of interest:—

(a) Ring-tone condenser QC is shunted by a ½-megohm resistor YD to prevent "dry-contact" faults at RS.1-2.

(b) When the extension clears the outgoing call preparatory to the reconnection of the original "in" call, the private is unguarded for the release period of relay T, during which any other party calling that extension will obtain connection instead of the original "in" call held by the cord circuit. However, the probability of a call intruding in this manner is quite small, and the intrusion merely results in an additional delay in regaining the original call without introducing any circuit complications. It is not desirable to reduce this unguarded period by a re-design of relay T which is slugged to ensure that the line equipment has fully released before the sleeve relay SB is re-applied to the private, otherwise a triple connection of incoming call, extension line and selector will occur, forming a "lock-up" condition which will not allow the supervisory lamp to be displayed, and yet which cannot be released except by removing the "call" plug from the extension jack. This is particularly likely in P.A.B.X's employing plunger type line equipment, which is usually subject to a noticeable release delay, due to the inertia of the plunger, and retarding forces of friction and residual magnetism.

(c) The provision of the 1500 ohm resistor YC and contacts S.1-2-3 (to hold relay SB for the interval of time between the operation of relays S and T) would not be required if the release of relay F (consequent on its dis-connection at SB.1-2) were delayed by its slug for a period sufficient to ensure that in all cases the extension line circuit had operated to earth the private wire and that relay T had operated. This would, however, involve critical timing relationships, which are undesirable, especially in view of the wide variety of line equipments in use in P.A.B.X's. In addition, if a fault in the line circuit or the intermediate wiring should prevent relay T from operating, the extension and caller would be subjected to a series of loud clicks as long as the call-back button is operated, owing to the repetition of a cycle involving relays S, SB, RS, F and D.

(d) The insertion of the 50 + 50 ohm relay S in series with the 200 + 200 ohm relay D, as shown in Fig. 4, has the effect in some cases of reducing the permissible length of extension lines, beyond which the use of intermediate repeaters is required. However, this battery feed resistance of 250 + 250 ohms is generally regarded as an acceptable value, being used, for example, in the link circuit of the type "C" P.A.B.X. Alternatively, it may be desirable to re-arrange the resistances of relays D and S to retain the standard battery feed of 200 + 200 ohms.

Comparison of Types: An analysis of the relative merits of the standard types of call-back equipment as compared with the cord circuit type under trial reveals the following points:—

(a) If the number of extensions requiring call-back facilities is small, the use of separate call-back relay sets results in a cheaper installation. However, the costs develop in an almost linear manner with the number of call-back extensions required, while the cost of the modified cord circuit equipment is invariable for a given P.A.B.X. It can be shown that with the costs of material now obtaining, the use of the modified cord circuits should result in a less costly installation in any new P.A.B.X. where the number of extensions requiring call-back facilities is numerically greater than the number of cord circuits minus three.

(b) The rack accommodation, cabling, terminal blocks and jumper-wiring required in the P.A.B.X. for the standard call-back equipment are not required when the cord circuits are modified.

(c) Only one extension line pair is required for any extension fitted with the cord circuit type of call-back facility. This will obviate any congestion in riser cabling which may occur because of unforeseen call-back requirements in a P.A.B.X. equipped with separate call-back relay sets.

(d) The use of the circuit under trial requires no change of instruments and operating procedure when a type "C" or "CA" is replaced by a larger P.A.B.X.

(e) The non-locking pushbutton is neater in appearance, does not present the mounting difficulties of the call-back key and should result in cheaper installations.

(f) Care must be taken to provide a continuous cable-sheath to the extension telephone when the circuit to Fig. 4 is installed. This will usually entail some work in bonding cables when a new P.A.B.X. installation takes advantage of an existing cabling scheme, and call-back circuits may be put out of action by jointing operations at any later date unless the simple but necessary precaution of sheath-bonding is taken before opening any sleeve. This should, however, be carried out as a matter of routine as the cable sheath is also used as the return conductor for power leads to P.B.X's and non-switching units.

(g) With the older type of circuit the call-back key is a source of much lost motion due to the necessity for operation to the position appropriate to the type of call, i.e., whether "in" or "out," and the fact that it is not immediately associated with the telephone. For the newer type of circuit the pushbutton is used only on calls back, giving a much smoother operating procedure.

(h) The use of modified cord circuits restricts the call-back facility to calls routed through a cord circuit to an extension, i.e., from an exchange or tie line, thus reducing the unnecessary holding of switches, which has been observed in some P.A.B.X's, due to calls-back while holding calls from other extensions.

(i) The existing circuits in general use require special arrangements for the call-back "out" lines to be accessible to the manual operator for trunk offering, and for testing with the standard cord type extension testing circuit. The circuit under trial, which has no separate "out" lines, caters for these facilities.

THE APPLICATION OF PULSE TECHNIQUE TO THE LOCATION OF FAULTS ON TELEPHONE CIRCUITS

P. M. Hosken, B.Sc., A.M.I.E.(Aust.)

Introduction: The general principles of the location of obstacles by means of Radar, which played such an important role in both sea and air warfare throughout the recent World War, are now common knowledge. These same principles have been applied to locate faults on open-wire lines and cables. An experimental model of a fault-locator of this type was designed and assembled in the Research Laboratories, Chief Engineer's Branch, towards the end of 1947, and forwarded to Queensland for field trials. This article deals with the results obtained with the instrument and also touches on certain desirable modifications to make it of more general application.

General Considerations

In radar, the distance of an object from any particular point is measured by directing a short train of waves at the object and measuring the time which elapses before an echo is received. The general condition for reflection at the object is that its presence should cause an appreciable discontinuity in the medium propagating the waves. This technique can be applied to telephone circuits by virtue of the fact that a fault condition at any point on the line constitutes an impedance irregularity and causes a proportion of the incident wave to be reflected. The time taken for a pulse of electro-magnetic waves to travel to the fault and for the reflected pulse to return is known as the "Echo Time," and can be accurately determined. However, the distance to the fault can only be determined if the velocity of propagation of the waves along the wires is known. This quantity can be calculated with considerable accuracy if the constants of the line are known or, alternatively, an artificial irregularity may be placed at a known distance along the line, the echo time noted and the velocity determined experimentally. As the velocity of electromagnetic waves along practical telephone lines varies from about 20,000 to 180,000 miles per second, the echo times are normally measured in terms of microseconds. The normal test room practice of recording the loop resistance in ohms to various points along the line may be converted to pulse technique by recording the echo time in microseconds to these points. In radar the pulse consists of a short train of waves of some high frequency in the range 50-10,000 megacycles per second, but for the purpose under discussion a D.C. pulse is used. As against the pulse modulated carrier method the D.C. pulse has the dual advantage of reducing the maximum frequency involved in the pulse spectrum by more than 50% and allowing a direct indication of the nature of the fault (i.e., whether series or shunt).

The essential equipment must, therefore, consist of a D.C. pulse generator, a unit to display the received echoes and a means of measuring the time interval between the sending of a pulse and the receipt of its echo. Factors involved in the choice of the various parameters are set out in the following:—

Pulse Length: This should conform to the following conditions:—

(a) The outgoing pulse must be complete before an echo is received from the nearest irregularity.

(b) The pulse must be sufficiently short to allow for discrimination between echoes from two irregularities reasonably close together on the line.

These conditions would indicate that the shortest possible pulse would be best suited for the purpose, but the propagation characteristics of the line must be taken into account. To enable this to be done it is convenient to ascribe an equivalent frequency to each pulse length so that its attenuation may be calculated. An approximation to the equivalent frequency of the pulse may be obtained by considering it as a half cycle of a continuous wave, thus a one microsecond pulse could be said to have an equivalent frequency of 0.5 megacycles per second. However, as an approximately rectangular pulse is used in the instrument under discussion, it is desirable that at least the third harmonic should be allowed for and the equivalent frequency of a one microsecond pulse would be of the order of 1.5 megacycles per second. It must be understood that the transmitted pulse contains a range of frequencies depending on the shape and duration of the pulse. The increase of line attenuation with frequency causes the reflected pulse to suffer considerable distortion. Assuming a velocity of propagation of 180,000 miles per second, which corresponds to an echo time of

$2 \times 10^6/180{,}000 = 11.1$ microseconds per mile,

a four microsecond pulse would occupy an equivalent distance of

$4/11.1 = 0.36$ miles.

It would be expected then that with this pulse length a fault could be located at a minimum distance of from 0.5 to 0.75 miles, and that contiguous irregularities spaced about this distance apart could be resolved. The actual results achieved are shown later. As the length of line is increased it is necessary to reduce the attenuation by lowering the effective frequency of the pulse, that is, by increasing the pulse length. This reduces the discrimination, but the percentage accuracy in location remains approximately the same.

Pulse Repetition Frequency: A second pulse must not be transmitted before an echo is received from the most distant irregularity. For 150 miles of open-wire line the echo time would be approximately $2 \times 150 \times 10^6/180{,}000 = 1670$ microseconds, so that to satisfactorily operate over this distance it would be necessary to use a repetition frequency below $10^6/1670 = 600$ pulses per second. Provided the above condition is satisfied, the choice of pulse repetition frequency is not critical, an increase or decrease in this frequency merely having the effect of increasing or decreasing the intensity of the display on the cathode ray tube.

Measurement of Echo Time: An attractive method of measuring echo time is the use of a series of timing pips which normally appear at regular intervals along the trace. In another method a marker pulse which can be moved along the trace under the control of a calibrated potentiometer has advantages. There are, of course, various other methods. In the trial equipment both the foregoing methods were provided for comparison purposes.

Sensitivity of the Method: It is of interest at this stage to consider what happens to the pulse as it progresses from the transmitter to the fault and back to the receiver. The transmitted pulse will be attenuated as it travels along the line, and when it reaches the irregularity a percentage of the pulse energy is reflected back towards the receiver. The amount reflected can be accurately defined in terms of return loss by expressing the ratio between the incident and reflected pulses in db. The return loss is equal to $20 \log_{10} (Z_0 + Z)/(Z_0 - Z)$, where Z_0 is the characteristic impedance of the line and Z is the impedance at the fault, that is, line and fault combined. The reflected pulse then suffers further attenuation on its journey back to the receiver. The total attenuation suffered by the pulse is therefore twice the attenuation of the line (at the equivalent frequency of the pulse) plus the return loss at the irregularity. In the experimental unit described, the sending level of the pulse is approximately 10 volts and the receiving level is limited by line noise and crosstalk to about 1 millivolt. The total possible attenuation over which this equipment will work is, therefore, 80 db, and the equation becomes: 80 db $= 2 \times$ line attenuation $+$ return loss.

Advantages of the Method: The outstanding advantage of the pulse testing method is that it gives an instantaneous picture of all impedance irregularities along the line. It must be understood, of course, that it is not possible to see beyond a major irregularity such as a short or open circuit where complete reflection takes place. The method is particularly suitable for the observation of transitory phenomena such as intermittent faults and switching conditions. Some classes of fault which are extremely difficult to locate by D.C. methods, such as one leg open and grounded, can be accurately located by the pulse method. This method has also obvious advantages over the normal A.C. method of taking an impedance versus frequency run on the line and determining the distance to the fault from the frequency difference between successive peaks. It must be remembered, however, that the pulse method indicates the reflections and attenuations at all points along the line only at the predominating frequencies in the pulse spectrum, whereas a return loss versus frequency measurement indicates the combined effect at the measuring point of all the line irregularities over the range of frequencies used.

Description of Equipment

General: The basic set-up of the experimental equipment is given in Fig. 1. A standard oscilloscope with a 5" screen is employed to display the trace. The remainder of the equipment, with the exception of the hybrid coil, is mounted in a case of similar size to that of the oscilloscope, with terminals conveniently mounted to facilitate connections between the two cases. One output from the master multi-vibrator is used to synchronise the operation of the Pulse, Timing Pip and Time Base generators and to control the pulse repetition frequency. Another output from the multivibrator, 180 degrees out of phase, is fed via the Black-Out terminal to a special "Test Signal" terminal on the oscilloscope, whence it is injected into the circuit via an 0.1 μf condenser in such a way as to clarify and intensify the trace.

The output of the Time Base generator is fed to the "X" plates of the oscilloscope where it is used in place of the Time Base incorporated in the oscilloscope. It is also fed to the Marker generator, where it functions as described later.

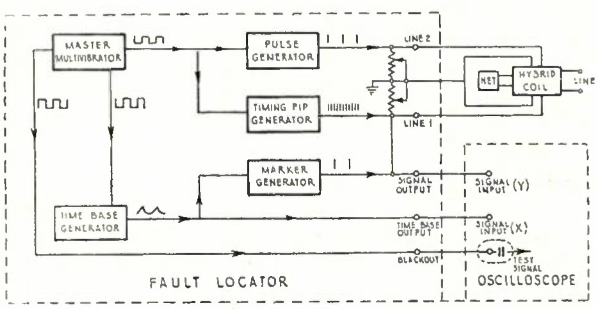

Fig. 1.—Block schematic of fault locating equipment.

The Pulse generator is fed to the "Line 2" terminal, and the outputs of the Timing Pip and Marker generators are fed in common with the "Line 1" terminal to the "Y" plates of the oscilloscope, thus the Echo Pulse, Timing Pips and Marker Pips all appear as vertical deflections of the horizontal trace. Irregularities in the line under test are therefore indicated by vertical deflections along the trace (either upward or downward, according to the nature of the fault) at positions depending on their distances from the testing equipment.

The two ganged variable resistors across the output were included to maintain the balance of the line to ground and to enable the impedance of the equipment to be adjusted to give minimum reflection of a returning Echo Pulse. In practice, it was found that this output arrangement in itself was unsatisfactory, and, to obtain effective results, either a transformer inserted between the line terminals and the line or a hybrid coil connected as shown in Fig. 1 was used. Both were capable of passing fairly high frequencies and the results obtained with each were approximately the same. The hybrid arrangement was found the more satisfactory as it provided a simple means of balancing out the initial pulse.

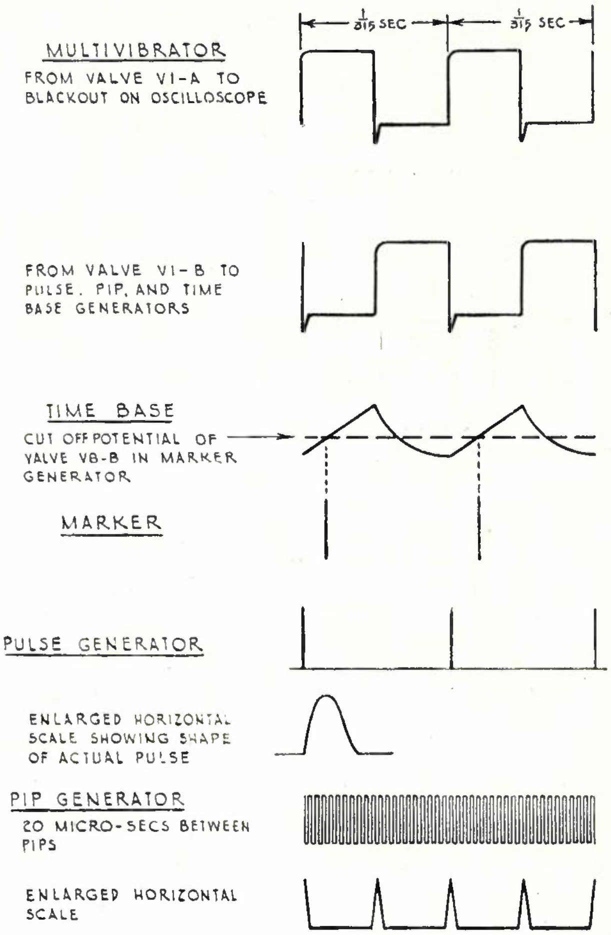

Fig. 2.—Wave-form timing chart.

An indication of the type of signal at various stages of the circuit is shown in Fig. 1, and a chart showing the relative time relationships of these signals is given in Fig. 2. A detailed schematic of the locator equipment is shown in Fig. 3.

Master Multivibrator: This has an output waveform approximately square and has a natural frequency of about 315 c/s.

Pulse Generator: The output from the multivibrator is fed through a buffer stage, amplified, phase-inverted and passed through a differentiating circuit before being fed to the output cathode follower which is biassed to pass the positive pulses only. The value of the capacity in the resistance-capacity network employed for differentiation can be varied by a panel control to enable pulse widths of approximately 4, 9, 18, 70 and 230 microseconds to be selected. A cathode follower output stage is used to cater for the varying range of line impedances. The pulse is fed to the "Line 2" terminal.

pair of tubes arranged as a "one shot" or "flip flop" multivibrator. By varying the common cathode resistor we can vary the point on the input saw-tooth wave (from the Time Base generator) where the "flip" occurs and thus move

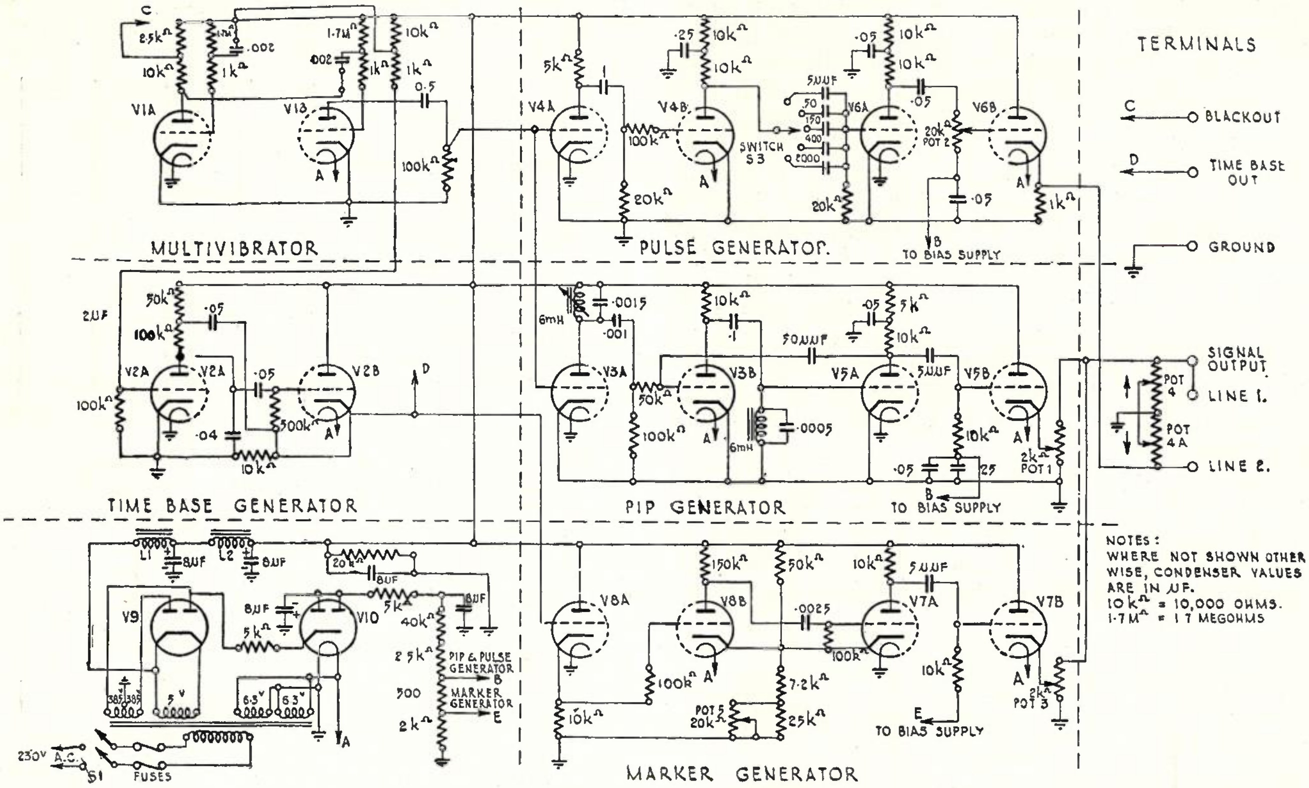

Fig. 3.—Schematic circuit of fault locator.

Time Base Generator: The negative pulse from the multivibrator controls the charge and discharge of a condenser and the approximately linear early portion of the curve is used to provide the time base saw-toothed wave. The multivibrator control ensures that the pulse is fed to line at approximately the same instant that the time base deflection voltage commences to rise.

Timing Pip Generator: This is also controlled by the multivibrator. A "ringing" circuit with a natural frequency of 50 kc/s is shocked into oscillation by the sudden drop in anode current caused by the application of the negative going edge of the multivibrator square wave to the grid of the first valve. The circuit is so arranged that the 50 kc/s oscillations are maintained for the duration of the time base trace. The oscillations, after amplification, are fed into a biassed differentiating circuit and then through the output cathode follower stage to the "Y" plates of the oscilloscope. An output potentiometer is included to control the amplitude of the pips. A chain of timing pips, spaced approximately 20 microseconds apart, can thus be introduced along the oscilloscope trace.

Marker Generator: This circuit incorporates a the marker pulse to any desired point on the oscilloscope trace. After differentiation the "flip" yields a short positive pulse and the "flop" a negative pulse which latter is suppressed. The marker pulse is fed through an output potentiometer to the "Y" plates of the oscilloscope. The dial fitted to the variable cathode resistor is calibrated in microseconds delay between the leading edge of the pulse transmitted to line and the leading edge of the marker. In practice it was found that greater accuracy was obtained by counting the timing pips than by reading the microseconds from the calibrated dial.

Field Test Results

In general, the equipment gives a field performance reasonably close to that expected by the designer. In the tests which follow, unless otherwise specified, a 4 microsecond pulse is used and the fault locator is connected to the open wire line via spaced leads which introduce negligible time delay. Fig. 4 illustrates the use of the instrument to locate a fault. Fig. 4(a) shows, at point "A," a short circuit at 21.0 miles on a voice frequency transposed pair. The upward pip at "B" shows the effect of a changeover from 14-inch spaced copper wire to 28-inch spaced steel wire to span a river at 3.8 miles. The pulse amplitude and the "X" and "Y" gains are adjusted so that a reasonable indication of the fault is obtained and maximum use is made of the extent of the trace. Fig. 4(b) shows the effect after the timing pips are added and the marker pip introduced and run along the trace until it is coincident with the leading edge of the "A" fault pulse. The line can be disconnected without disturbing the number of timing pips along the trace or the position of the marker, as shown in Fig. 4(c). This makes it easier to count the pips, which is done by running the marker from right to left along the trace. The distance to the fault is then calculated from the known length of line represented by the distance between pips.

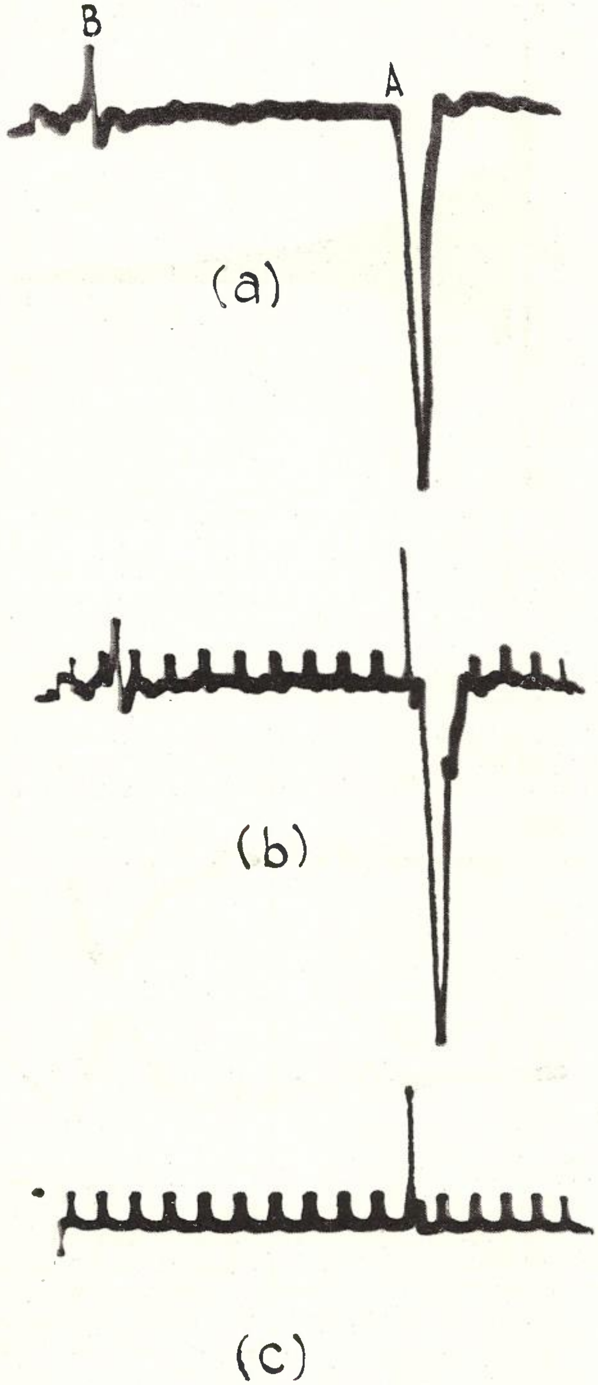

Fig. 4.—(a) Open wire line—Short circuit "A" at 21 miles and wire irregularity "B" at 3.8 miles.
(b) Timing and marker pips added to trace (a).
(c) Timing and marker pips only.

To illustrate the sensitivity of the equipment shunt and series resistors of such values as to cause a specified percentage reflection were connected across or in series with the line over a range of distances from the sending equipment. Fig. 5 shows, at point "A," the effect of a 2% series fault at 9 miles on a carrier transposed pair. This illustration was obtained by using the time base of the oscilloscope instead of that of the locator equipment and adjusting the frequency to obtain a multiple trace. This was done to expand the trace horizontally near the origin, owing to the limitation of the horizontal shift of the oscilloscope. It is of interest to note that practically all the irregularities indicated along this trace are caused by angles in the trunk route. Further tests indicated that a 2% fault was discernible on the trace at a distance of 62 miles.

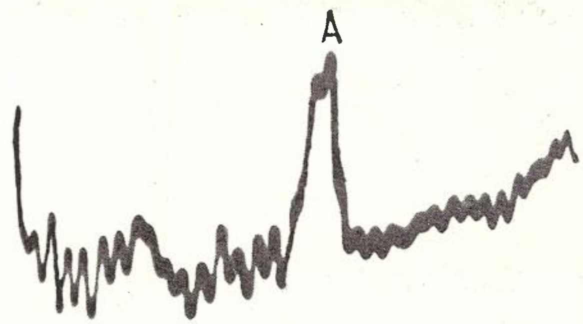

Fig. 5.—Open wire line—Series fault.

Fig. 6 shows, at "A" and "B," the effect of two 5% shunt faults at 21 miles $1\frac{1}{2}$ miles apart. It will be seen that contiguous faults considerably closer together than $1\frac{1}{2}$ miles would be resolvable at this distance from the testing point. Owing to the increase in pulse distortion as the length of circuit increases, there is a slight falling off in resolving power as the distance from the testing point increases.

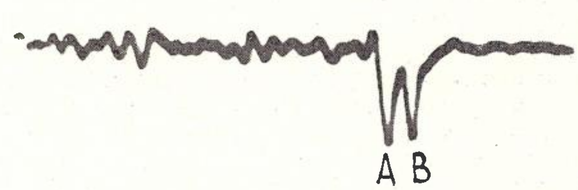

Fig. 6.—Two shunt faults 1.5 miles apart, 21 miles distant.

Fig. 7 shows, at point "A," a short circuit at 109 miles, using a 9 microsecond pulse and only a very low "Y" gain. It is evident that this is well within the range of the instrument and there is no need to increase the pulse length to detect an appreciable irregularity at this distance. A pulse length of 18 microseconds gives an echo pip about 4 or 5 times as high as that given by a 4 microsecond pulse.

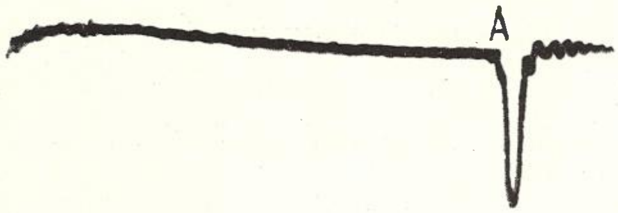

Fig. 7.—Short circuit in open wire line at 109 miles.

In Fig. 8, the fault locator is connected to the same line as in Fig. 4, the points marked "A" and "B" being as for Fig. 4(a), and "C" being a 5% shunt fault at 15.5 miles. Only a low "Y" gain was used to obtain this trace.

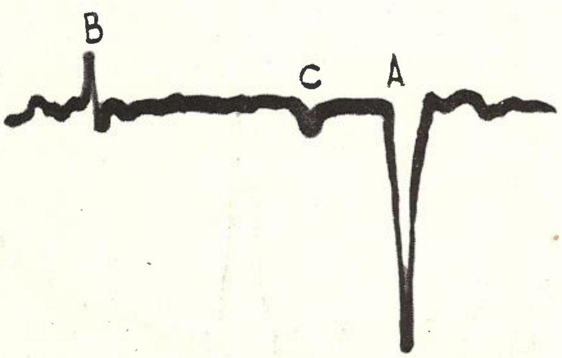

Fig. 8.—Open wire line showing a river crossing at 3.8 miles, shunt fault at 15.5 miles and a short circuit at 21 miles.

Difficulty was experienced when using the fault locating equipment at the trunk test room, owing to the effect of filters and loaded cables on the trace. Even when using the widest pulse width available on the instrument, a damped oscillatory effect was obtained which effectively marred a large proportion of the trace. An example of this is shown in Fig. 9, which shows the trace obtained at a type J 12-channel carrier system filter hut when sending the 4 microsecond pulse to line through a 35 kc/s high pass type J filter, the low pass filter being terminated in 600 ohms. In this case the oscillation covers 109 miles of line. The vertical pip at "A" is the marker. This difficulty has been largely overcome by reducing the pulse to approximately sine wave form. Thus, by using a pulse length of this form, giving a fundamental frequency below the cut-off frequency of the entrance cable, filters, etc., through which it is required to feed the pulse, a clear indication of the line irregularities can be obtained on the trace. The fault pip is, of course, much broader, owing to its much greater length and sine wave shape. Fig. 10 shows two traces obtained using a 100 microsecond sine wave pulse looking through a 5.6 kc/s low pass filter and one mile of carrier loaded cable to an open wire line with a fault at 21 miles. The fault "A" on the upper trace was a short circuit and the fault "B" on the lower trace was an open circuit. Some success in overcoming the foregoing oscillatory effect has also been achieved by using an identical loaded pair or filter in the hybrid balanced circuit.

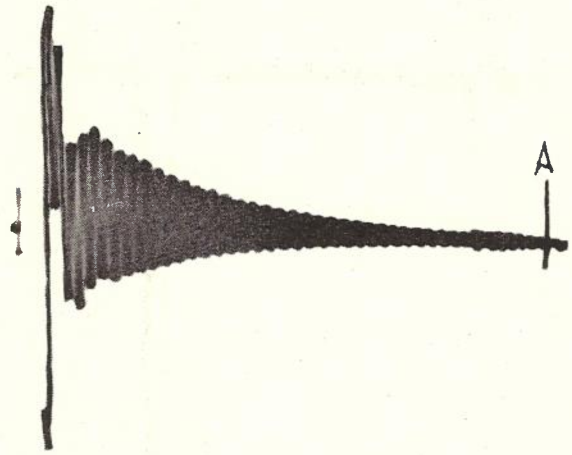

Fig. 9.—Short pulse through a 35 kc/s high pass filter.

It is necessary in testing from the trunk test room to ascertain the echo time of any apparatus or entrance cable in the circuit concerned, and this can be recorded in terms of microseconds or timing pip intervals from the origin to the various points along the circuit. The accuracy of location largely depends on how accurately the point can be fixed where the leading edge of the pulse begins on the trace. Present indications are that, with an experienced operator, the locations on lines not involving filters or V.F. loaded cables should be at least as accurate as those obtained with the normal D.C. testing methods, with the decided advantage of speed and the facility to locate accurately some types of fault which are almost impossible to fix by D.C. methods.

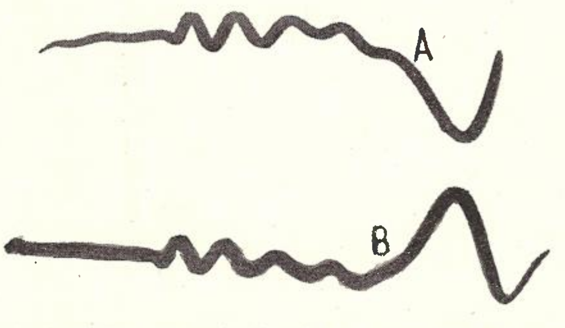

Fig. 10.—Long Sine wave pulse through a low pass filter and a carrier loaded entrance cable to faults at 21 miles in an open wire line.

The experience gained in the field trials has been incorporated in an improved model which is being developed by the Research Laboratories at the present time and no doubt will be described in a subsequent issue.

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PERFORMANCE TESTS ON RADIO RECEIVERS

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In order to assess the merits of various designs and types of radio receivers, and for acceptance tests of purchased equipment, it is necessary to subject them to a series of standard tests designed to show in what manner they perform the various functions expected of a receiver.

The more important functions of a radio receiver may be considered as being:—

(a) To select a desired signal from the heterogeneous signals intercepted by the aerial, and satisfactorily reject all others.

(b) To amplify the radio signal so selected.

(c) To demodulate or detect the signal to obtain the modulation frequency currents.

(d) To amplify these currents for reproduction by a loudspeaker, or for other use, without noticeable distortion.

(e) To carry out the above functions without requiring a large signal input to the receiver.

In addition, modern radio receivers possess other features such as tone controls, selectivity controls, automatic gain control, etc., and, if of the communication type, may have an oscillator for reception of C.W. telegraphy. An important requirement, particularly for an all-wave receiver, is accurate calibration of the tuning dial or dials.

A consideration of the above functions leads to the conclusion that tests should be chosen to determine the following characteristics:—

Sensitivity.
Selectivity.
Interference.
Fidelity.
Harmonic distortion.
Maximum undistorted output.
Automatic gain control.
Calibration.
Frequency drift.
Cross-modulation.

There are other tests, of course, but the above will enable the performance of the receiver to be ascertained. The terms will be briefly defined first and then the tests discussed.

Definitions

Sensitivity is the ability of a radio receiver to furnish an intelligent audio signal with a specified signal-noise ratio, from a low value input signal. It is usually expressed in microvolts of input signal e.m.f. fed through a specified impedance to give a standard output. The impedance referred to is specified to be approximately that of the type of aerial with which the receiver will be used and is termed a dummy aerial.

Selectivity is that characteristic of a receiver which determines the extent to which it discriminates between radio signals of different carrier frequencies.

Interference is the extent to which the receiver output is marred by signals on other frequencies, such as image frequency, cross-talk, inter-modulation or cross-modulation, etc.

Fidelity is the faithfulness (or linearity) with which a receiver reproduces at its output the modulation frequencies present in the R.F. input signal.

Harmonic Distortion is the magnitude of the spurious audio-frequency harmonics introduced in the electric output of the receiver during normal operation. It is usually expressed as a percentage of the fundamental frequency.

Maximum Undistorted Output: This has been arbitrarily expressed as that audio output for which the total harmonic distortion is not greater than 10%.

Automatic Gain Control: Automatic gain control is a circuit arrangement which automatically reduces the total amplification of the signal in a radio-receiver with increasing strength of the received signal carrier wave, thus tending to keep the output constant over a range of input levels.

Tuning Dial Calibration: Accuracy of calibration is the degree of precision with which the frequency or wave-length dial-markings are engraved, as compared to a precision frequency standard.

Frequency Drift: Frequency drift is a measure of the oscillator frequency stability with time and particularly after first switching on the receiver.

Testing Instruments

Before treating these tests in greater detail it will be of interest to discuss the instruments required for performing them, since some of these instruments may not be familiar to those not engaged in the science of radio communication and engineering. The essential instruments are:—

- Standard signal-generator (radio frequency oscillator).
- Dummy aerial for use with signal generator.
- Audio-frequency oscillator, 30-16000 c/s.
- Output power meter, or meter for measuring the audio output from the receiver.
- Noise measuring set) Often a combined
- Distortion measuring set) unit.
- Wave analyser.

The wave analyser is essential only when it is desired to know the relationship of individual harmonics to the fundamental. For most purposes the noise and distortion set is sufficiently accurate and has the advantage of simplicity, resulting in shorter testing time.

Signal Generator: This is the principal measuring instrument and consists of a radio-frequency oscillator of the vacuum tube type, which is adjustable over the entire carrier frequency range in which the receivers under test are expected to operate. This oscillator is provided with means of modulating it to any desired degree with audio-frequencies. It usually contains an internal modulation source of 400 c/s with provision for coupling an external source covering a range of about 30 to 20,000 c/s.

Within the signal generator the output of the modulated radio-frequency oscillator is attenuated by an adjustable and calibrated electrical network designed to vary the output voltage level over a wide range.

The desirable qualities of a signal generator are:—

(i) Frequency range: About 300 kc/s to 30 mc/s, for normal broadcast medium and high frequency coverage.

(ii) Accuracy of calibration of (i): At least 1%, but for selectivity tests should be 0.1% or better.

(iii) Scale: Open scale engraved directly in kc/s or mc/s, depending on the particular portion of the spectrum in use.

(iv) Voltage output: Continuously adjustable from 1 μV to 1 volt or more.

(v) Accuracy of voltage indication: Broadcast band within 10%. Higher frequency bands 20%.

(vi) Leakage: Sufficiently low so as not to affect measurements made at the lower output levels of the order of 1 μV.

(vii) Modulation Oscillator: Frequency accuracy 2%. Harmonic content less than 2%.

(viii) Modulation Level: A suitable indicator should be furnished to enable the depth of modulation to be read directly. The modulation level range should be calibrated from 10% to 100%.

(ix) External Modulation: Provision for externally modulating the carrier wave of the signal generator should be made and enable a substantially flat response from 30 to 20,000 c/s to be obtained.

The attenuator should be continuously variable over its entire range. Its impedance as viewed from the output terminals should be known and must be included in that of the dummy aerial. It should be calibrated in microvolts or in decibels below 1 volt. The frequency range (i) will, of course, be as required in the particular case.

Fig. 1a is a block diagram of a signal generator suitable for carrier frequencies up to about 60 mc/s, and Fig. 1b shows the outline circuit of such a unit.

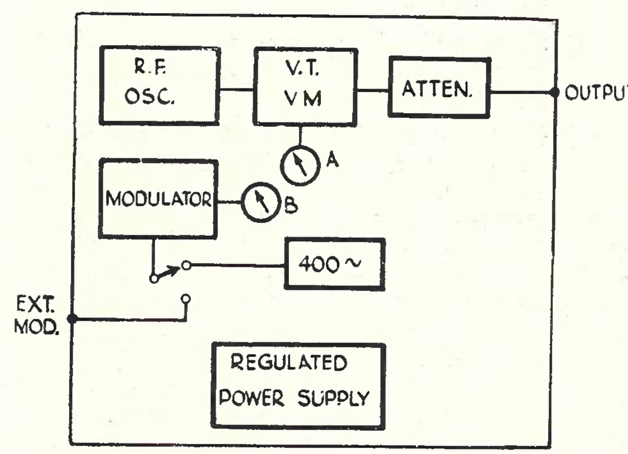

Fig. 1a.—Block diagram of signal generator.
Meter "A"—Output voltage.
Meter "B"—Modulation percentage.

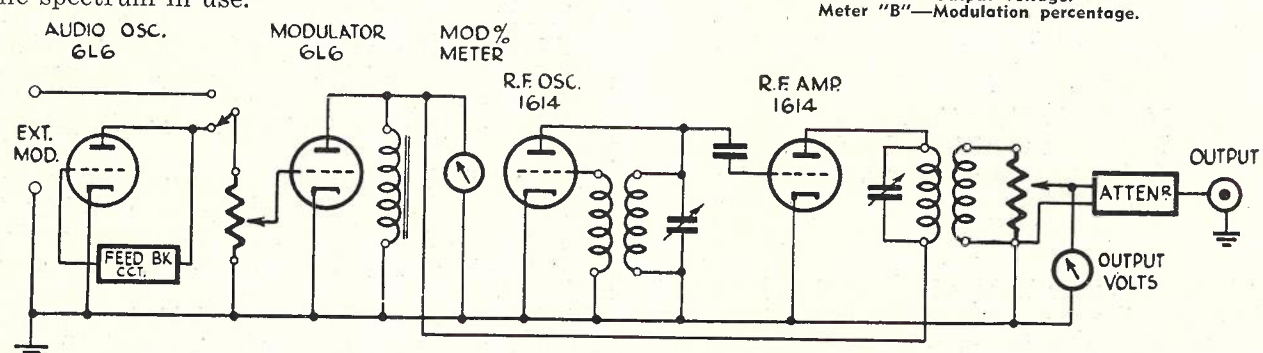

Fig. 1b.—Outline circuit of a typical signal generator.

Also included but not shown are:—
(a) Voltage regulated power supply.
(b) Vacuum-tube voltmeter circuit for output meter.
(c) Decoupling and bypassing circuits.

Anode modulation is employed, thus ensuring high quality modulation. Many precautions are taken to obtain a high degree of accuracy of frequency calibration and output voltage values, and to minimise leakage and frequency drift.

Dummy Aerial: The dummy aerial has the impedance characteristics of an average receiving aerial for the carrier frequency range. Fig. 2a shows a standard dummy aerial, and Fig. 2b its characteristics.

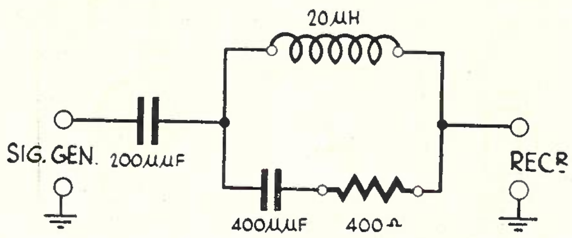

Fig. 2a.—Dummy aerial.

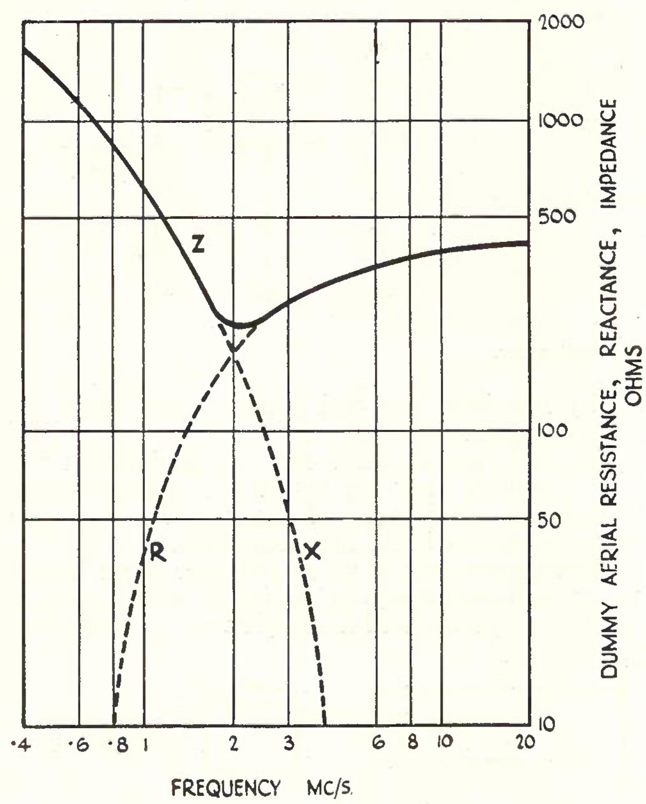

Fig. 2b.—Characteristics of dummy aerial.

Audio Oscillator: A standard oscillator covering the range 30 to 20,000 c/s is required, and is usually of the beat frequency type. It should possess the following characteristics:—
(i) Calibration Accuracy: ± 3 c/s below 80 c/s ± 2% above 80 c/s.
(ii) Output Power: At least 6 mW in 600 ohms.
(iii) Distortion: Less than 1% from 70 to 20,000 c/s.
(iv) Output Voltage Variation: Not more than ± 1 db. over the full range.

A beat frequency oscillator consists of a fixed oscillator and a variable oscillator operating at high frequencies. These oscillators feed a detector from the output circuit of which the difference frequency is selected. The detector is followed by a low pass filter and a two-stage wide band amplifier. The two oscillator outputs are isolated by a buffer amplifier, and an automatic volume control circuit maintains the output voltage constant with frequency. A vacuum tube voltmeter is used to measure the output voltage. A typical beat frequency oscillator circuit is illustrated in Fig. 3.

Output Power Meter: An output power meter with an adjustable input impedance is desirable and this should have the following characteristics:
(i) Range: 0.1 mW to 10 watts or greater.
(ii) Load: Purely resistive.
(iii) Calibration: In milliwatts (or watts, depending on the scale) and decibels relative to 6 mW in 600 ohms zero level.

In a typical instrument, power outputs up to 100 watts may be measured, and an auxiliary decibel scale is provided on the meter to facilitate comparison measurements, such as frequency response. The impedance range may be from 2.5 to 20,000 ohms, reasonably accurate to about 12 kc/s. Decibel ranges average from about –10 to +40 db, referred to 1 mW.

The schematic circuit of such an instrument suitable for measurements of power output and internal impedance of radio receivers, amplifiers, oscillators, etc., is shown in Fig. 4.

It will be seen from the diagram that the instrument is equivalent to an adjustable load impedance, across which is connected a voltmeter calibrated directly in watts dissipated in the load.

Copper-oxide rectifier type voltmeters, vacuum-tube voltmeters or thermo-couple type ammeters may be used as suitable substitutes for measuring power output in conjunction with a parallel load resistance.

Noise and Distortion Measuring Set: The instrument used to measure the total audio-frequency distortion generated in a receiver should be capable of indicating the distortion with an accuracy of 5% between 0.5 and 30 per cent. of the fundamental. It must not draw sufficient power from the dummy load to modify the magnitude of the distortion being measured.

For making harmonic analyses by the measurement of each harmonic separately, it is desirable to have an instrument with a frequency range of at least 30 to 16,000 c/s. Typical of the instruments available for these measurements is that shown in Fig. 5. This meter is intended for use in radio broadcasting stations, receiving stations and laboratories where it is desired to measure audio-frequency distortion, noise and hum level, automatic gain control characteristics, etc.

It consists of a linear rectifier, a filter, an amplifier and a vacuum tube voltmeter. The meter reads distortion directly in per cent. of fundamental voltage, and carrier noise level or hum level directly in decibels with respect to normal transmitter input or receiver output. In use the signal, say, receiver output, is fed into the audio input terminals to a shielded balanced transformer, the secondary of which is connected directly to a noise level "multiplier bank," and through a 400 c/s high-pass filter to the distortion measuring network.

The receiver modulation must be 400 c/s ±20 c/s for distortion measurements, but noise may be measured from 30 to 20,000 c/s.

This instrument has several disadvantages:—

(a) Total harmonic distortion is given, not individual harmonic values.

(b) Receiver hiss and power supply noise are measured together.

(c) It is suitable for 400 c/s modulation frequency only on distortion measurements.

But the advantages of speed and convenience often outweigh these disadvantages.

Wave Analyser: A wave analyser is an instrument for measuring the amplitude and frequency of the components of a complex wave form, such

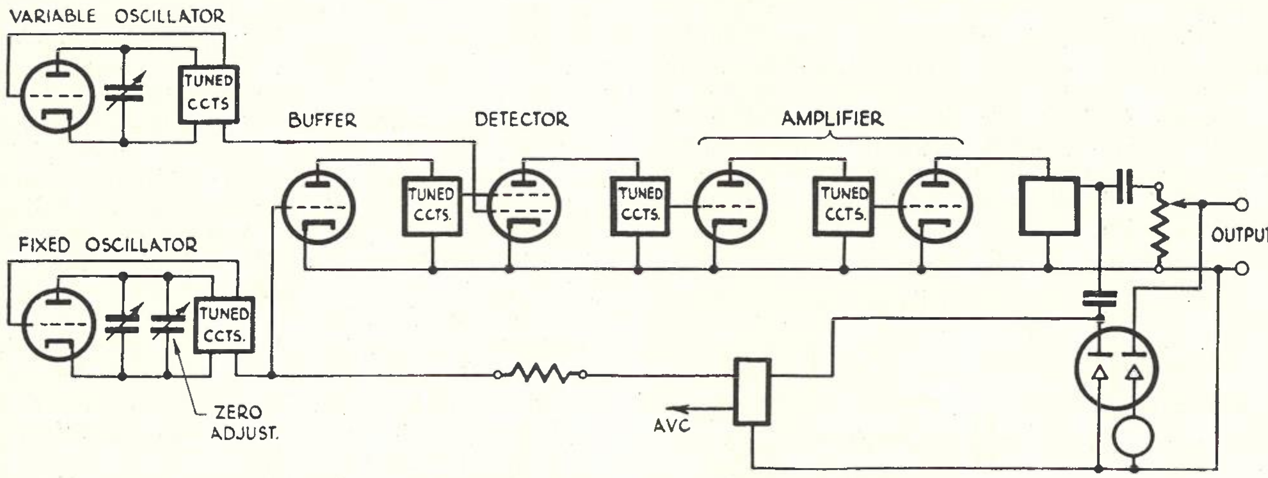

Fig. 3.—Simplified circuit of beat frequency oscillator.

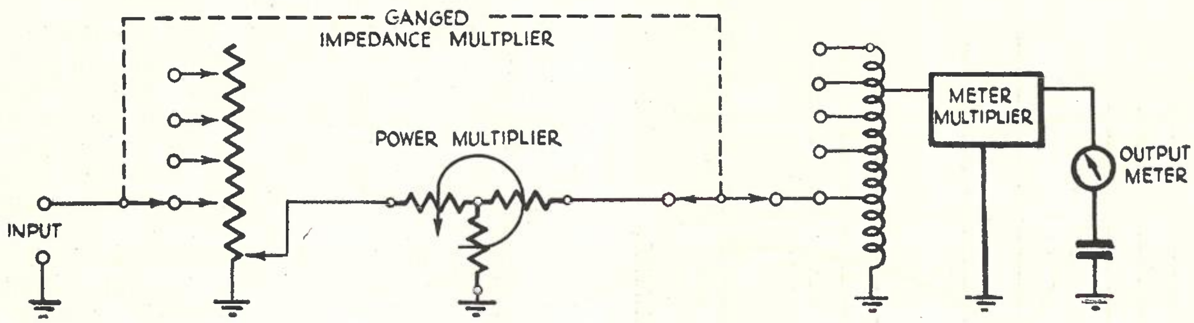

Fig. 4.—Typical power output meter.

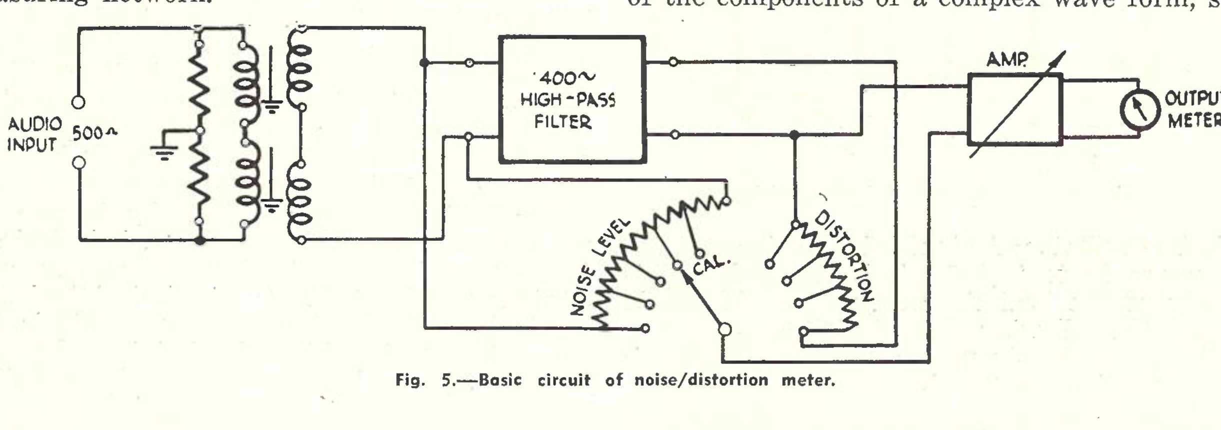

Fig. 5.—Basic circuit of noise/distortion meter.

as might be encountered in audio-frequency equipment, radio transmitters and receivers, public address systems and broadcast programme equipment. This instrument usually consists of a heterodyne type of vacuum tube voltmeter. The signal to be measured is amplified and then applied to a balanced modulator together with the output of a linear oscillator. Following this is a "flat top" crystal filter, an amplifier and output meter.

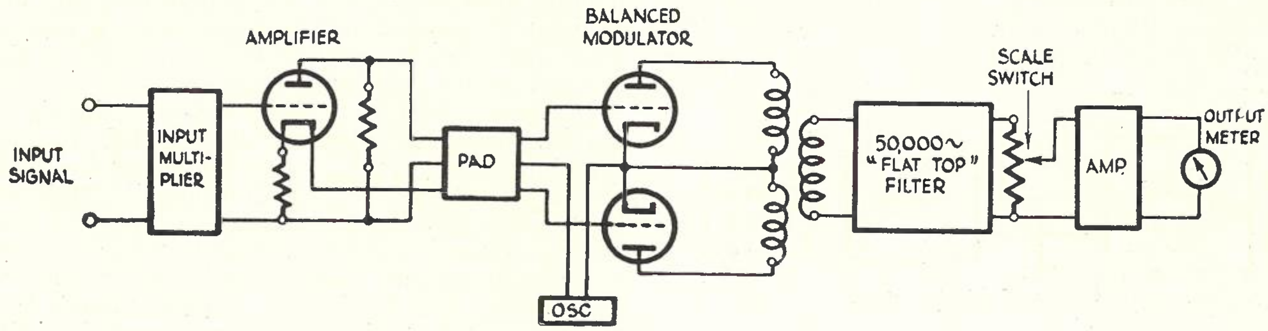

Fig. 6.—Elementary wave analyser circuit.
The calibrated oscillator supplies carrier at a frequency such that A + C = 50 kc/s.
Where A = Signal component frequency (fundamental or harmonic)
C = Carrier frequency.

The filter is designed for 50 kc/s pass frequency of about 4 c/s bandwidth, and this signal is obtained from the modulator output by suitable tuned circuits. The local oscillator is so designed that the sum of the local oscillator and the signal or component of signal being measured is always 50 kc/s.

In use the signal to be measured is fed to the input circuit and the analyser tuned to the fundamental signal frequency, say, 1000 c/s. The output control is adjusted for a convenient reading on output meter, say, 100 units. The analyser is then tuned successively to 2000 c/s (2nd harmonic), 3000 c/s (3rd harmonic), 4000 c/s, and so on, to the highest harmonic it is desired to measure. The output is noted for each frequency and, if the fundamental reading was 100, the successive readings will indicate the percentage of the particular harmonic that is contained in the coupled wave. For example, if fundamental was 1000 c/s and gave a reading of 100, then a value of 33 for 2000 c/s would indicate 33% second harmonic, and so on. Fig. 6 shows in elementary form the main circuits of a typical wave analyser, the input being suitable for a complex wave having components between 0 and 16,000 c/s.

Performance Tests

A description of the performance tests will now be given. Fig. 7 is a block schematic of a typical set-up for testing receivers. The signal generator is the principal item of equipment, the output measuring devices varying according to availability.

Sensitivity and Signal-to-Noise Ratio: These two features should be considered together, since in a receiver of high gain the lower limit of signal input is fixed, not by the inadequacy of the audio output, but by the necessity for a signal/noise ratio of 15 to 20 db for intelligent speech, where the average modulation depth is 30%.

In a well-designed receiver the main source of noise will be the thermal agitation of the electrons in the first tuned circuit. (As a point of interest, the power developed in this circuit is 1.64×10^{-20} watts per cycle bandwidth at 300° absolute temperature.) The noise output of the receiver depends on the amplification and on the overall bandwidth. As noise voltages on either side of

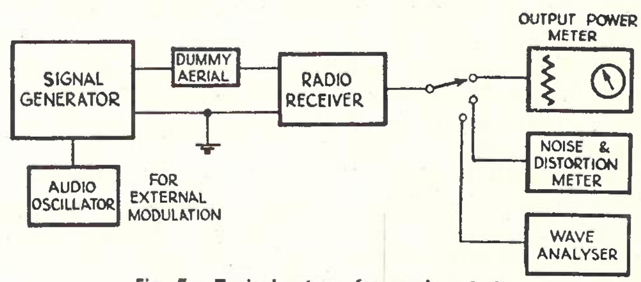

Fig. 7.—Typical set-up for receiver tests.

the carrier contribute equally to the noise output, the bandwidth to be considered is twice the normal audio bandwidth of the receiver.

Fig. 8a. shows the set-up for this test, which is as follows: Originally the sensitivity test was applied to determine the least input signal which would give a standard output (50 mW for low power receivers; 500 mW for others) with controls at maximum gain. It is the practice now to determine the least input which will produce a given signal-to-noise ratio in the receiver output with all controls set for maximum gain. A figure of 15 db has been adopted by the British Post Office as the minimum signal-to-noise ratio for radio-communication, and this seems to represent average conditions, although a higher ratio is desirable for broadcasting services (20 db).

With the automatic gain control of the receiver switched off, or otherwise rendered inoperative, the signal generator is connected to the receiver through the dummy aerial and set to the desired frequency. (In multi-range receivers, tests are usually made at three frequencies in each band.) The signal generator is modulated 30% at 400 c/s.

The receiver is tuned to the test frequency and the audio-frequency gain control and signal generator attenuator adjusted until the standard output (0.5W with most modern receivers) is obtained with the desired signal/noise ratio. This is observed by noting the output readings with the modulation on and the modulation off. The results should be recorded and graphed as in Fig. 8b.

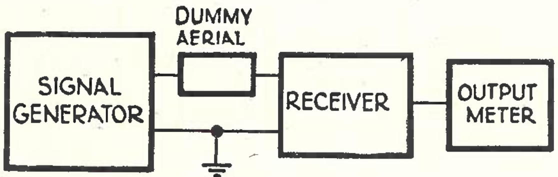

Fig. 8a.—Sensitivity set-up.

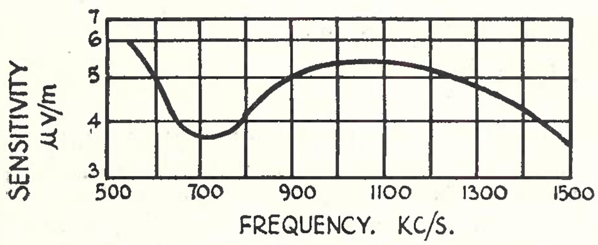

Fig. 8b.—Typical graph for sensitivity measurements.

In the case of a multiband receiver, the results may be plotted on logarithmic paper, which allows the whole coverage of the receiver to be shown on one graph.

Selectivity: Selectivity is expressed in the form of a curve that gives the signal strength required to produce a given receiver output at the resonant frequency and at frequencies above and below resonance, usually in 10 kc/s steps. The same set-up is used as in the sensitivity test.

Method: With the automatic gain control switched off, the signal generator is set to the desired frequency. It is necessary to tune the receiver to the signal generator and adjust it to a convenient output with the generator modulated 30% at 400 c/s. The signal generator is then varied by progressively increasing amounts from the frequency to which the receiver is tuned, and the signal-generator voltage increased as necessary to maintain constant receiver output. Selectivity curves should be carried out to 100 kc/s off resonance or to 80 db above response at resonance, whichever is encountered first. In a superheterodyne receiver, the selectivity is mostly achieved in the I.F. amplifier. Thus a curve showing the response of the I.F. amplifier over a range of frequencies on both sides of the midband frequency represents the selectivity of the receiver, except at the lower signal frequencies, where the R.F. tuned circuits give some additional attenuation. In the case of a tuned R.F. (straight) receiver the selectivity may vary considerably with signal frequency, so that a number of response curves should be measured at suitable frequencies. By using a modulated signal generator to provide the test signal, the measurement will give the average response at the two sideband frequencies, but the method is sufficiently accurate for most receivers, excepting those having high selectivity, in which case an unmodulated signal should be used, using a carrier level meter as the indicator, or by noting the current in the diode load resistor.

In the case of I.F. amplifier response the signal at intermediate frequency is applied to the frequency-changer grid after rendering the local oscillator inoperative. Modulation is 30%, as before, and the input required to give any convenient output is then measured at various frequencies above and below the midband frequency. See Fig. 9a. At the higher frequency bands this is the only reliable method of measuring the selectivity, since the adjustment of the signal generator in incremental steps of 10 kc/s, say, at 28 mc/s, would be somewhat difficult in most cases. Where the I.F. stages incorporate variable selectivity it is preferable to make this test at the I.F., and also in the case of an all-wave receiver where there may be difficulty in adjusting the signal-generator in the small incremental steps at the higher frequencies.

The results should be recorded and graphed, as shown in Fig. 9b.

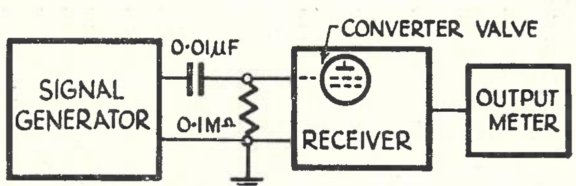

Fig. 9a.—Selectivity at I.F. freq.

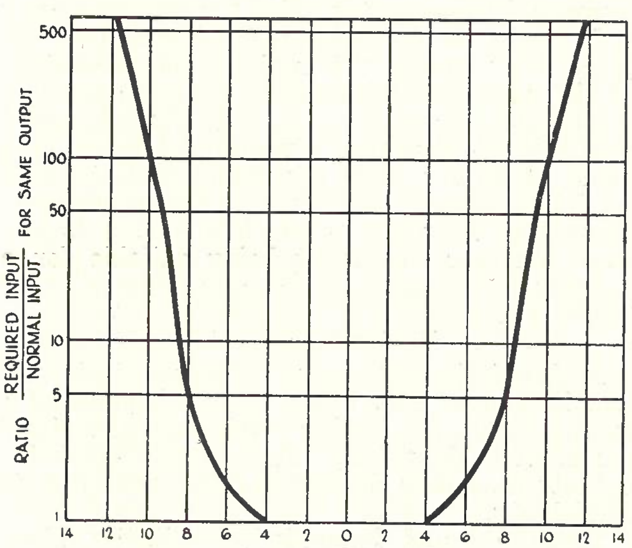

Fig. 9b.—Hi-Fidelity position.

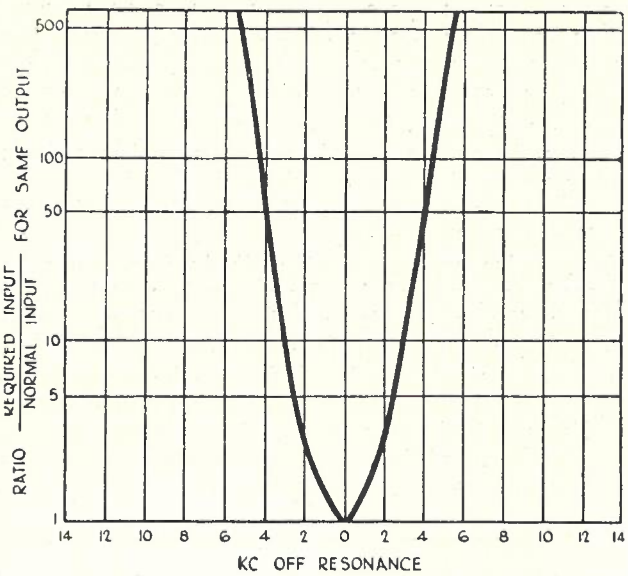

Fig. 9c.—Moderately sharp cut-off.

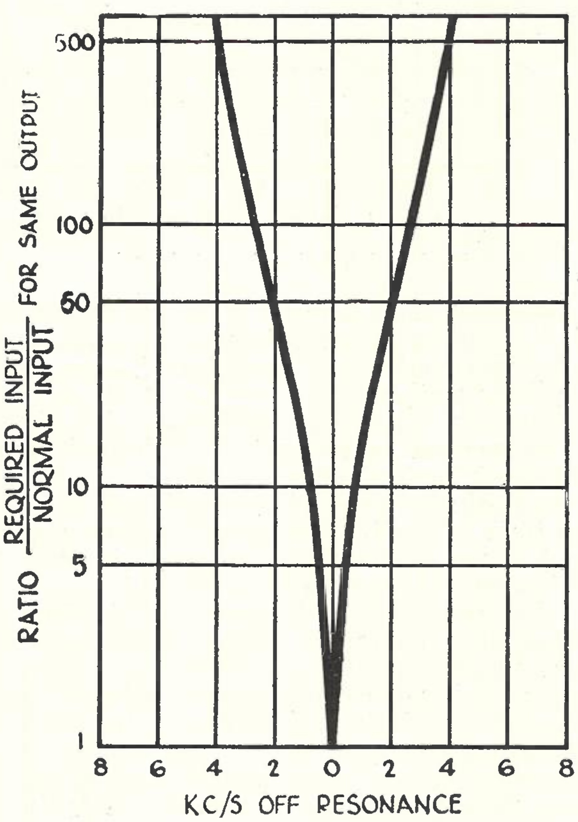

Fig. 9d.—Crystal filter "in."

Image Ratio: To determine the image ratio the receiver is tuned to the signal generator at the desired signal and adjusted for convenient output, the set-up being as in the former tests. The signal generator is then set to the desired signal frequency, plus twice the I.F., and adjusted for same audio output as before. The image ratio is then the ratio of the signal generator output at image frequency to the signal generator output at the desired frequency. This is more often expressed as a ratio rather than in graphical form.

Fidelity: The fidelity or audio response is measured by modulating the signal generator 30% from an external source and noting the audio frequency output over the modulation frequency range from 30 to 10,000 c/s. The output is usually measured across a resistive load, and thus the tests do not represent the performance with a loudspeaker load, but are indicative of general performance. Fig. 10a shows the set-up. This test should be applied at various selectivity positions and tone control positions, if tone controls are fitted. The results are usually plotted on logarithmic paper, and the output at 1000 c/s is usually taken as reference level. An example is given in Fig. 10b.

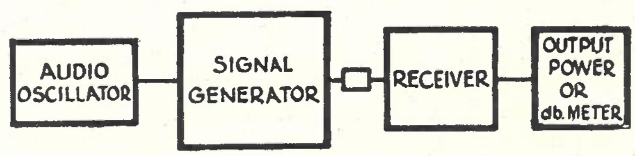

Fig. 10a.—Electrical fidelity test.

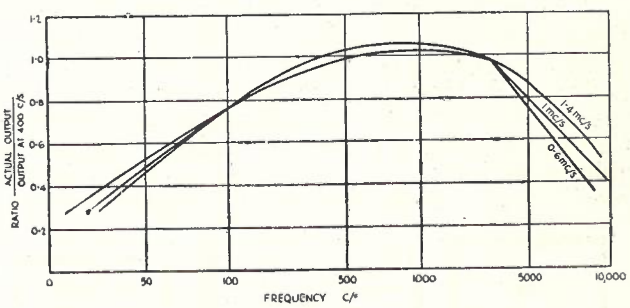

Fig. 10b.—Typical fidelity graph.

Linearity and Distortion: Distortion of the audio waveform results from three major causes:

(a) Overloading of radio-frequency amplifier.
(b) Failure of the detector to reproduce accurately the envelope of the modulated carrier when the percentage modulation is high.
(c) Overloading of the audio-amplifier or output-stage.

In the absence of these conditions, the output voltage will be proportional to the modulation percentage, except in a receiver in which the automatic gain control bias is affected appreciably by the depth of modulation. No one complete set of conditions can be prescribed for this test, because harmonic distortion depends on so many details of design and operating conditions.

Some idea of the distortion introduced during normal operation may be obtained by considering the receiver functionally. Thus it may be divided into:

(1) Radio frequency amplifier,

(2) Detector or demodulator,
(3) Audio frequency amplifier,
and tests are arranged to cover these sections individually. Before these tests are performed, it is convenient first to ascertain the maximum undistorted output.

Maximum Undistorted Output: The signal generator output is adjusted to a figure which could be expected not to overload the R.F. stages, say, 1 millivolt, the modulation depth being 30%. Then the A.F. output should be increased until the total distortion indicated is 10%. This output value is noted and on succeeding tests should not be exceeded. This test could be considered as a test of performance of the A.F. section of receiver.

For the R.F. test the output is chosen as in the previous paragraph; the R.F. input to the receiver is varied from about 10 microvolts to 1 volt in 10 db steps, the audio output being adjusted to the same value each time and the distortion noted. Any increase in distortion over the 10% obtained previously is probably due to overloading in R.F. or I.F. circuits.

To determine the detector linearity. The R.F. input signal and audio output are set at values which previous tests have indicated will not overload these stages, and the modulation depth of signal generator is varied from 10% to 100% in in 10% steps. The audio output should be adjusted each time to give the same output, and the distortion noted for each percentage modulation value. These three tests will give a reasonably good indication of the performance of the receiver, as far as overloading is concerned.

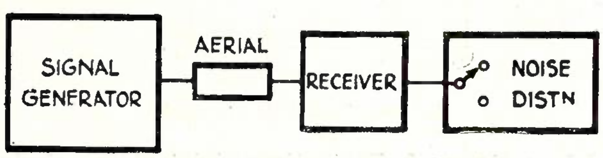

Fig. 11a.—Noise and distortion set.

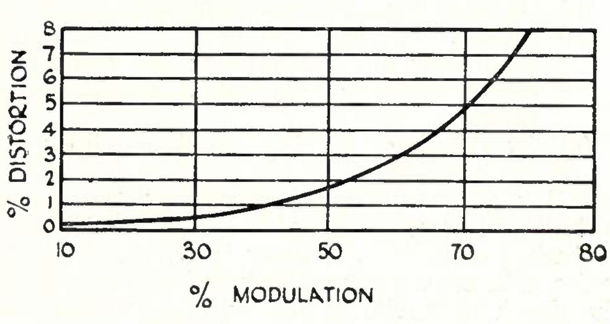

Fig. 11b.—Typical distortion graph.

As a matter of interest, signal-to-noise ratios are often noted at a number of the above readings, at low and high level R.F. and A.F. signal values. This is readily accomplished when using a combined noise and distortion measuring set. Referring to Fig. 5, in conjunction with Fig. 11, the 400 c/s audio signal from receiver is fed into A.F. terminals and the high-pass filter blocks the 400 c/s fundamental, but the harmonic frequencies pass on to the amplifier and output meter. The amplifier is adjusted, with switch in "CAL" position, to give a certain reading on the output meter, the switch is then moved to the "distortion measuring" position and distortion read directly on the distortion scale.

For noise measurements, it is necessary to proceed as outlined in the foregoing, but, **after** setting the scale to a given reading, signal generator modulation is switched off, and the noise and distortion set switched to "noise measuring" position, where the noise in db below signal level is read directly in db. This is the signal-to-noise ratio of the receiver at the carrier frequency and carrier level concerned.

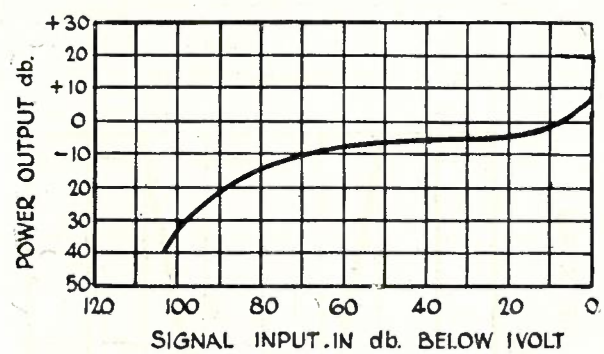

Fig. 12.—Automatic gain control graph.

Automatic Gain Control: This test is to ascertain the operation of automatic volume control under non-overloading conditions in the audio-frequency section. The test is usually made at the middle frequency of each band. See Fig. 8a.

The receiver is tuned to the desired signal, modulated 30% at 400 c/s, with the A.F. gain control adjusted to avoid overloading at any input less than one volt. The output is then read, as input is varied from one microvolt to one volt. The results are plotted as in Fig. 12.

Calibration: This test consists of checking the tuning dial calibration against a standard frequency source of high accuracy. A crystal calibrator, giving harmonic outputs related to 100 kc/s and 1 mc/s, is very useful for this test, the results being more accurate if the calibrator has been checked previously against a standard frequency source, and the test results corrected, if necessary.

Frequency Drift: This measurement should be made towards the high frequency end of the tuning band, since the drift will be most serious there. A source of frequency of high known accuracy is required.

Method: The receiver is allowed to warm up for 5 minutes initially, and the tuning control then set at a high frequency, say, 28 mc/s. A signal is injected at the intermediate frequency into the I.F. circuit, and the resultant beat note measured on a stable A.F. oscillator. At the end of an hour this beat frequency is again measured, care being taken to ensure that the audio oscillator is correctly calibrated again.

The difference in the beat note values will indicate the oscillator drift. It may be advisable to measure the drift at intervals of 10 or 15 minutes to obtain a better record. Fig. 13 shows typical results.

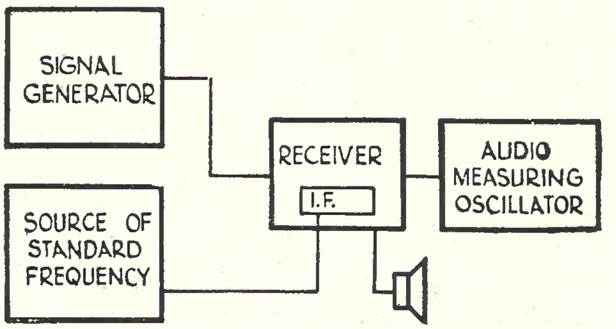

Fig. 13.—Frequency drift.

Two-Signal Tests (Cross-Modulation)

(a) **Cross-Modulation Interference Test:** It is not always possible to make this test, since two signal generators are required. Its purpose is to ascertain the interference due to "cross-modulation," referred to earlier in the paper.

The two signal generators are connected to receiver, as in Fig. 14a or 14b. The radio receiver is tuned to the desired signal set at one of standard input voltages (see Table 1). The receiver volume control is set to give normal test output when the signal is modulated 30% at 400 c/s, after which the modulation is switched off.

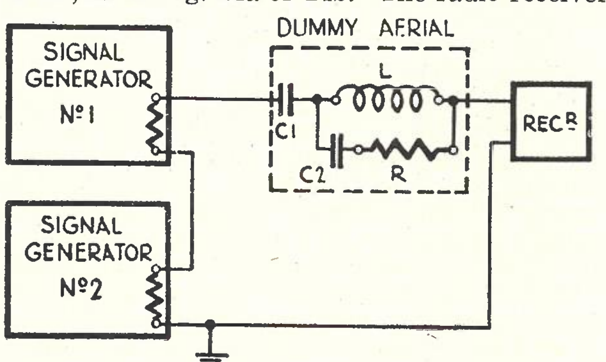

Fig. 14a.—Series connection.

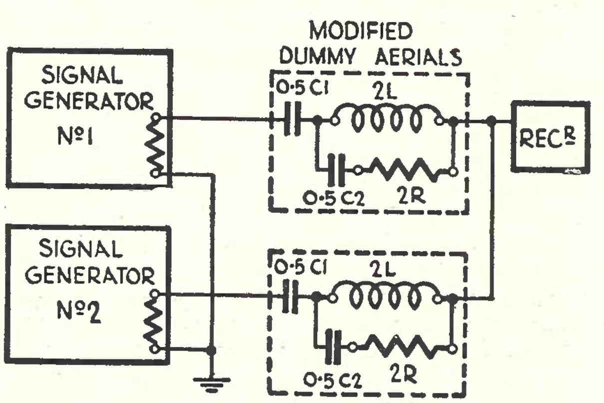

Fig. 14b.—Parallel connection.

An interfering test voltage is then applied to the receiver, in addition to the desired signal carrier, which remains unchanged. The interfering signal is modulated 30% at 400 c/s. The interfering test signal is then varied above and below the frequency of the desired signal, and the signal generator adjusted to give the normal test output. In most cases ± 10 kc/s steps will be sufficient, since broadcast station separation is normally 10 kc/s.

Fig. 14c shows the manner of plotting these results. This test is also applied to receivers having automatic gain control which cannot be rendered inoperative.

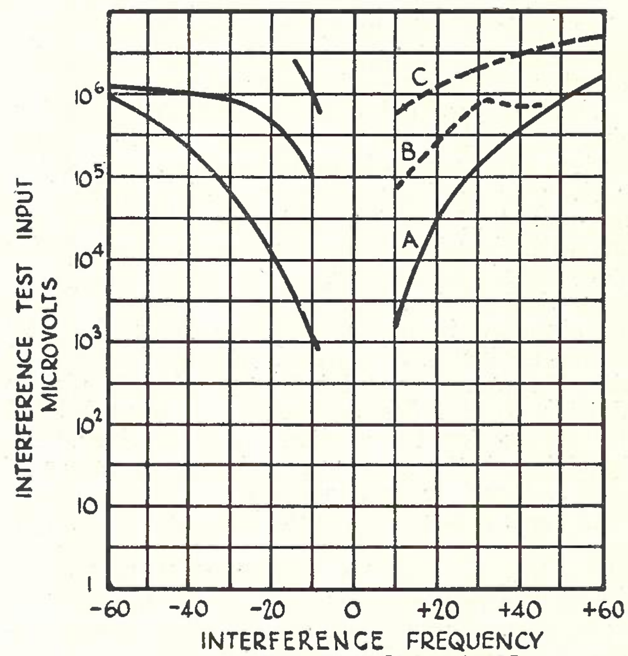

Fig. 14c.—A = desired signal 50 μV.
B = desired signal 5 μV.
C = desired signal 100 μV.

(b) **Whistle Interference:** This test is designed to ascertain the extent of interference due to beat note whistles when two carriers are present. The circuit arrangement is similar to that for the cross-modulation test. First, the desired carrier is switched on and modulated 30% at 400 c/s. The output is adjusted to the normal test output value and then the modulation is switched off. At 30% modulation the permitted interference output power is 0.001 of (or 30 db below) the desired modulation output power. This latter value should be noted or otherwise remembered, and is termed "B" below.

The interfering signal generator is now tuned (modulated 30%) through a wide frequency range, and the interference test input voltage, which gives output "B" or greater, is observed wherever its value is less than one volt.

Both the interference frequency and its value in microvolts are recorded and plotted, Fig. 14d

(c) Local-signal voltage 100,000 μV (20 db below 1 volt).

(d) Strong-signal voltage 2 volts (6 db above 1 volt).

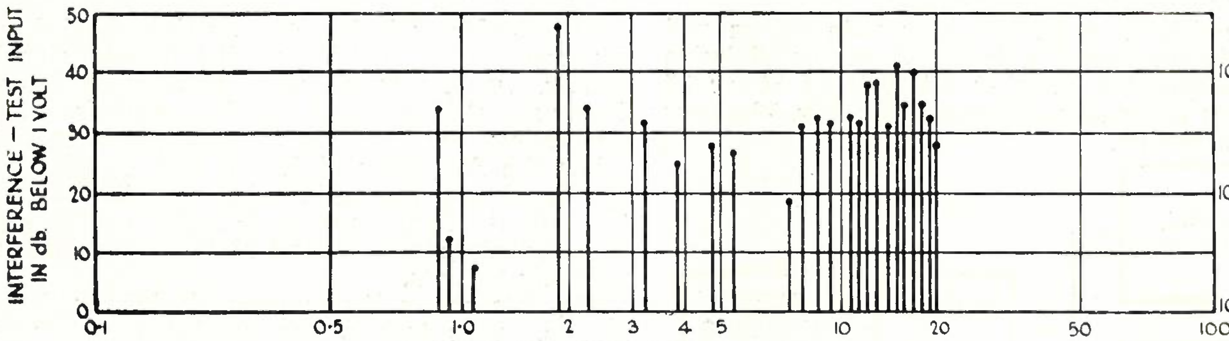

Fig. 14d.—Whistle—Interference spectrum desired signal 5μV at 1000 kc/s.

being typical. Frequencies other than 400 c/s may be used for determining the interference-test output, with the same procedure.

(c) **Blocking Test:** This is designed to determine the extent to which an undesired-signal carrier affects the desired-signal output of the receiver, or, in other words, it is intended to show the amount of variation of the desired-signal output with input voltage and frequency of the undesired-signal carrier. The receiver is tuned to the desired signal at a standard test frequency and standard input voltage (see Table 1). The volume control is adjusted to normal test output with the signal modulated 30% at 400 c/s. In addition to the desired signal, an unmodulated interfering signal is applied to the receiver. This signal is set at various pre-determined values of input voltage or frequency, while the other of these quantities is subjected to continuous variation.

The interference frequency and its value are recorded whenever the output of the receiver drops, together with the degree of volume reduction of the receiver output. These may be plotted in the form most convenient for the required tests.

TABLE 1

Test frequencies and test voltages suggested by I.R.E. Standards Committee (U.S.A.)

A. Test frequencies in broadcast band

kc/s		kc/s
540	alternatively	600
600		1000
800		1400
1000		
1200		
1600		

B. Test input voltages

(a) Distant-signal voltage 50 μV (86 db below 1 volt).

(b) Mean-signal voltage 5,000 μV (46 db below 1 volt).

Miscellaneous Tests

There are many other tests which can be applied to a radio-receiver to determine miscellaneous characteristics such as the performance of tone controls, muting, C.W. oscillators, automatic frequency control, etc. A selection of these will be given in order to indicate some of the characteristics which have to be considered in receiver design.

I.F. rejection.
Spurious responses.
Antenna input impedance.
Cross-signal distortion products.
Effect of power line voltage on frequency.
Antenna input unbalance.
C.W. oscillator.

I.F. Rejection: The equipment is set up as in the sensitivity test and adjusted to produce standard output at 30% modulation at three frequencies in each receiver tuning range. After tuning the receiver to a test frequency and adjusting for standard output, the signal generator is tuned to the intermediate frequency and the signal increased until the receiver output is restored to its value at resonance. The ratio of this input to the input at the receiver's resonant frequency is the I.F. rejection ratio.

Spurious responses: Spurious responses are measured by the same method as the I.F. and image rejection ratios, except that the signal generator frequency is varied throughout the frequency range of the receiver, and any responses at frequencies other than the desired or image frequencies are noted and the rejection ratio measured as for the I.F. Rejection case. Tests for spurious responses are usually made at two frequencies in each receiver tuning range.

Antenna Input Impedance: This measurement, if required, is made with a radio frequency bridge, generally with one side of the antenna input circuit grounded. The receiver tuning is adjusted for zero or minimum input reactance, which coincides with or closely approximates resonance of the receiver with the applied signal.

Cross-Signal Distortion Products: This test is made by applying two strong signals, having widely different frequencies, to the input of the receiver. Any distortion in the R.F. stages will produce beat frequencies equal to the sum and difference of the impressed signal frequencies, as well as other combinations. Two unmodulated signal generators are used, tuned to different frequencies, and each having an output of one volt. The receiver is tuned to a frequency equal to the sum of the test frequencies, adjusted for CW reception, and the 1000 c/s AC output is noted. Then one signal generator is turned off and the other tuned to this sum frequency. Its output is then reduced until the receiver output is equal to that produced by the combination of the two interfering signals. The ratio of this signal to the interfering signals is used as a measure of the discrimination against this type of interference. The same procedure is used to measure the difference frequency signal. This test is applied, using at least five pairs of frequencies for each receiver. The frequencies are selected to cover the entire tuning range as far as practicable. On receivers provided with selectivity controls, the I.F. bandwidth is adjusted as nearly as possible to 2 kc/s.

Effect of Power Line Voltage on Frequency: Several procedures for measuring the frequency shift, due to line voltage changes, have been investigated, and the following was found to be most satisfactory.

The receiver is tuned to resonance with a frequency meter and the beat frequency oscillator adjusted to give a convenient audio frequency beat note. An audio frequency meter is used for visual measurement of the audio beat frequency. The primary power supply voltage is adjusted to exactly 230 volts, by means of a variable auto-transformer, and this value is maintained until the receiver becomes stable, as indicated by the audio frequency meter. When a stable condition is reached, the line voltage is increased abruptly by 10 volts, and the change in beat frequency is recorded after 15 seconds, 30 seconds, one minute, and each minute thereafter for thirty minutes.

Antenna Input Balance: This measurement is made by first connecting the receiver to the signal generator and output meter, in the same manner as for sensitivity measurements, except that, in place of the 100-ohm resistance between the high potential terminal of the signal generator and the corresponding terminal at the receiver, a 50-ohm resistor is connected between these points, and another 50-ohm resistor is connected between the low potential terminals of the signal generator output and receiver input. The signal level is adjusted to produce an output of 10 milliwatts from the receiver. Then the connection between the 50-ohm resistor and the low potential terminal of the signal generator is removed, and this resistor is connected to the high potential terminal of the signal generator, leaving the other end of the resistor connected to the low potential terminal of the receiver. The result of this change is to connect both receiver input terminals to the high potential terminal on the signal generator. The low potential terminal of the signal generator is then connected to the ground terminal of the receiver, and the signal level is increased until the receiver output is again 10 milliwatts. The ratio of this input to the input required with the original connection is used as the balance ratio. It is a measure of the stray signal fed into the receiver by the combined effect of capacity coupling and unbalanced magnetic coupling when the receiver is operated from a balanced transmission line. This measurement is made obviously only on receivers provided with a balanced input circuit. If the artificial aerial has a value other than the 100-ohm resistance, the value is halved in a similar manner.

C.W. Reception: When using the beat frequency oscillator for the reception of C.W. signals, the extent to which the output level of the beat note varies with the input depends on the level of the signal at the detector relative to that of the beat frequency oscillator, as, with a linear detector, it is proportional to the smaller of the two voltages. Thus, when the signal level exceeds that of the oscillator, the output will be constant until overloading occurs.

The noise level in the spaces of the signal is that which is measured with the beat frequency oscillator on, but no signal present. As the R.F. gain control reduces the receiver gain, the noise level is reduced, and the input level at which constancy of output is reached is proportionately increased. The input required for a given output at other frequencies varies, as does the automatic gain control point, since both functions depend on the gain of the receiver preceding the detector. The test should be made at a convenient frequency, say, 1 mc/s, with the R.F. gain control at maximum, and the A.F. gain control at such a setting that overloading of the output stage does not occur. The output for a range of inputs between 1 μV and 100 mV should be measured.

The noise in the absence of an incoming signal should be measured with the signal generator switched off but still connected to the receiver. When the automatic gain control can be on together with the beat frequency oscillator, the output should also be measured in this condition.

Alignment of Receivers

Before carrying out the performance tests just detailed, it may be necessary to check up the alignment of the tuned circuits of the receiver, especially if an appreciable time has elapsed since any previous tests. A brief outline of the general principles will therefore be given as a matter of interest. The actual aligning procedure varies with the different makes and designs of receivers, but it consists essentially of the following:—

Lining up I.F. circuits.

Lining up oscillator circuits, R.F. and aerial circuits.

I.F. Alignment: Band pass I.F. amplifiers require a frequency-modulated signal generator and a cathode-ray tube to ensure correct band pass characteristics. The normal procedure will be described, however. Fig. 15 illustrates the circuit arrangements. The alignment of the I.F. system is carried out by working step by step backward through the I.F. circuits, from the second detector to the first detector, and by always applying the test oscillator to the grid immediately preceding the circuit under adjustment, and adjusting the trimmers on this circuit for maximum output. In carrying out this process, it is, of course, necessary to reduce the output of the test oscillator each time this output is applied to the grid of a tube at a lower power level. It is usually advisable to connect the signal generator output to the receiver, through a condenser of about 0.02 μf. The manufacturers usually recommend the conditions under which alignment should be made if they vary from commonly accepted practice.

The lowest value of signal that will give a reasonable output from the receiver should always be applied in these tests.

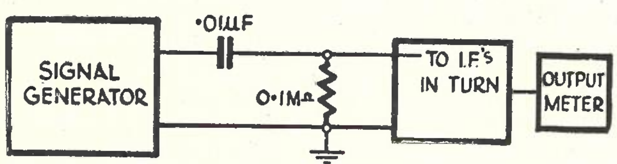

Fig. 15.—I.F. alignment.

Oscillator Circuits and R.F. Circuits: The signal generator is connected to the aerial terminals, as in the sensitivity tests. If a calibrated dial is furnished it is set at a frequency near the high end of the band (or the maker's figure, if given). The signal generator is tuned to the required frequency and controls adjusted for a moderate output at about two-thirds of the output meter scale. The shunt-trimmer on the oscillator is adjusted for maximum output while rocking the receiver tuning dial slightly, in order to take care of any slight interaction between the oscillator and R.F. stages that may be present. After this, the R.F. trimmers of the band concerned are adjusted for maximum output. Then the receiver and signal generator are set to a frequency near the low frequency end of dial, and the oscillator padder condenser adjusted for maximum output of receiver. If the R.F. circuits are provided with inductance trimmers they should be adjusted now for maximum output. If any adjustment has been made at either end, it is advisable to re-check the other end again, and repeat the process until no further adjustments are required. The alignment procedure should be applied to each band of the receiver. In the case of receivers provided with variable selectivity or a crystal filter in the I.F. stage, the necessary tests and adjustments required will be indicated by the manufacturers. Since these will vary according to the individual design, no details of adjustments can be given, except that they are usually carried out at the intermediate frequency.

Receiver with Loop Aerial

For sensitivity and other tests on a receiver fitted with a loop aerial it is necessary to produce over the area of the loop a field of known strength. This can be done by the use of an induction field generator. A convenient loop (as recommended by R.M.A.) has the following dimensions:—

Radius	....	5 cms
Length	....	6 cms
Turns	....	20

The approximate inductance of this loop is 40 μH. It is desirable to shield the loop to prevent electrostatic coupling. The shunt capacitive reactance of the coil and the leads to the signal generator must be large, compared with the inductive reactance of the coil, and the latter should be at least 20 times greater than the attenuator output resistance, so that the output voltage is unaffected by the coil position. The coil and frame aerial are placed coaxially, as in Fig. 16. The input to the receiver is—

$$18800Nr^2E/(r^2+l^2)^{3/2}wL \text{ Microvolts/metre.}$$

where E = signal generator output in microvolts.

N = number of coil turns.

r = radius of coil in cms.

l = axial distance between coil and frame centres in cms (recommended distance, 2 metres).

L = coil inductance in henries.

For the recommended loop dimensions and l = 2 metres, the input is 4670 E/f microvolts/metre where f is in c/s.

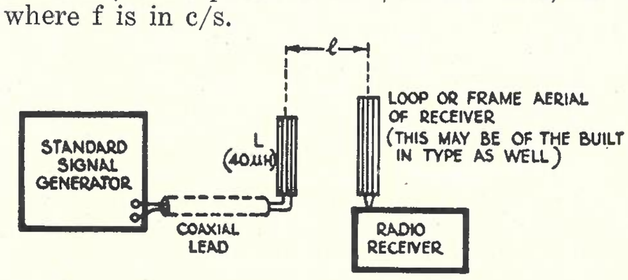

Fig. 16.—Set-up for receiver equipped with a frame aerial.

Fault Location in Radio Receivers

A few points on the general principles of fault localization may be of interest. The remarks apply to most types of receivers, except in such cases as can only apply to the superheterodyne receiver. Fig. 17 shows a typical superheterodyne divided into functional sections. The five general sections are:—

(1) Signal selectivity circuits.
(2) Oscillator sections.
(3) I.F. and 2nd detector.
(4) Audio amplifier and output stages.
(5) Power supply and filter system.

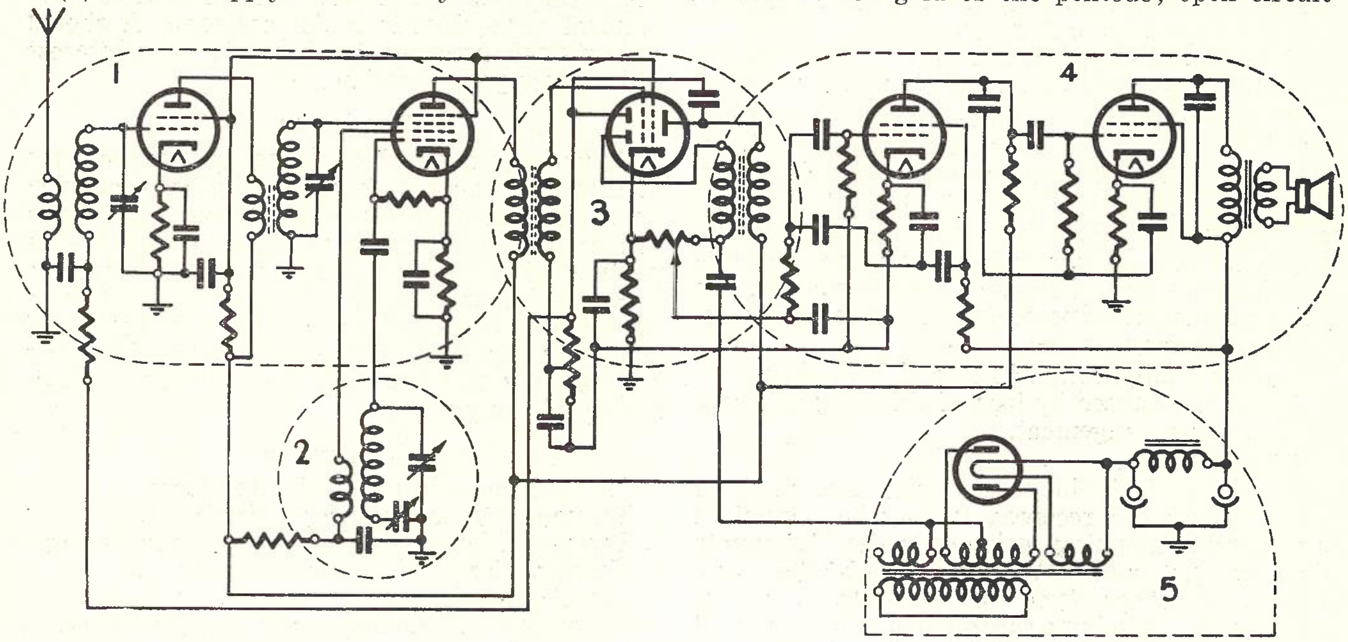

Fig. 17.—Functionalized superheterodyne receiver unit.
1. Signal circuits. 2. Oscillator circuits. 3. I.F. circuits. 4. Audio. 5. Power supplies.

For sections (1) to (3) the signal generator and vacuum tube voltmeter are a useful combination. For section (4) an audio frequency oscillator and vacuum tube voltmeter or other type of audio power meter will be suitable. For section (5) the volt-ohmmeter enables quick checks, and should be used for checking socket voltages of the other stages in a preliminary checking of faulty condition.

Faulty conditions may be summarised under four general headings:—
(a) Complete lack of signals.
(b) Lack of volume.
(c) Distortion.
(d) Crackles and whistles.

It is usually advisable to check all tubes of a receiver for emission, before proceeding with a more detailed analysis.

Typical causes of the fault conditions mentioned above are shown below as a matter of interest.

It is usually a good plan, however, to check the main H.T. points for voltage before commencing other tests.

(a) **Absence of Signals:** These may be caused by:—
Burnt-out rectifier tube.
Broken-down filter condensers.
Open circuit field winding or filter choke.
Short circuit in H.T. by pass condensers.
Open circuit cathode resistors.
High tension supply line open circuit.
Open circuit in R.F. or I.F. coils.
Shield cans shorting to grids.
Open grid resistors, etc.

A short-circuit in the high tension supply circuit (filter, by-pass condensers, etc.) is usually indicated by the plates of rectifier becoming red-hot. An open circuit in output transformer primary circuit, if a pentode is used, shows up by a red-hot screen grid of the pentode; open circuit on the secondary side is sometimes indicated by a faint rattle of the output transformer laminations when the set is tuned to a station.

The oscillator may be roughly checked by touching the oscillator grid with a screwdriver; if operating satisfactorily, a slight click will be heard in the speaker as the blade makes contact with the grid terminal. Touching the grid cap of an audio valve with the grid clip removed will result in a howl if the set is operating satisfactorily following the valve.

(b) **Lack of Volume:** This may be caused by:—
Tubes having low emission.
Low high tension voltage.
Low filament voltage.
Mis-alignment of tuned circuits.
Open circuit R.F. or I.F. coils.
Faulty gain controls.
Open circuit audio amplifier section.

Open circuits generally have to be traced by point to point checking with an ohmmeter or similar continuity meter.

(c) **Distortion:** The main causes of distortion which may occur at R.F. or A.F. may be summarised as under:—
Open-circuited bias or grid resistors.
Oscillator in R.F. or I.F. stages.
Audio feed-back.
Low emission tubes.
Incorrect voltages.
Leaky coupling condensers.

(d) **Crackles and Whistles:** Common causes are:—
Faulty resistors.

Faulty condensers.
Loose contacts at sockets.
Dry soldered joints.
Leaky audio or output transformer windings.
Faulty power transformer.
Outside electrical interference.
Interference coming through the power line.

Whether noise is entering externally is checked by disconnecting the aerial and earth and short-circuiting the corresponding terminals of the set.

If the noise is still present, short-circuit each grid to the chassis in turn until the trouble disappears. Should the noise disappear, examine the resistors and condensers associated with the circuit immediately preceding the valve concerned.

Whistles may be due to:—

Incorrect alignment of I.F. and R.F. stages.
Instability caused by lack of shielding and poor wiring arrangement.
Unstable tubes.

Should the instability be present after checking and aligning the receiver, it may be minimised by inserting stopping resistors in the "B" supply lines to R.F. and I.F. stages (1000-3000 ohms value). Another type is encountered where turning up the volume control causes a succession of howls and whistles. This trouble is probably due to poor layout and too high a gain in mixer and I.F. stages. Suppression resistors in the plate circuits of the mixer and I.F. tubes and in the grid circuits of audio tubes will often remedy this trouble.

This is a necessarily brief outline of some of the principles underlying the diagnosis and removal of troubles in radio receivers. It should be sufficient, however, to stimulate your interest in this intriguing pastime.

Conclusion

Radio is a progressive science, and maybe some of these test methods have already been modified or superseded by other tests. However, the aim has been rather to give as general a picture as possible of the field of receiver tests. There are several opinions regarding the usefulness of some of the tests described, and also in the method of achieving the desired results, and the following bibliography will enable a more detailed examination of the problem.

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THE INTRODUCTION OF DEMAND WORKING AND OTHER FACILITIES AT THE HOBART TRUNK EXCHANGE

J. W. Forster

INTRODUCTION

The object of this paper is to describe extensive alterations which were carried out at the Hobart trunk exchange between August, 1945, and February, 1946. These alterations included the provision of facilities for demand working and other features designed to improve operating efficiency. Fundamental changes in the power supply and distribution were also made.

In dealing with this subject, an account will be given of the historical development of the exchange, especially as regards the switching equipment. The nature of the changes required in circuit and structural design, and the considerations relating thereto, will be indicated, and the method of carrying out the work will be briefly described.

A better appreciation of what follows may perhaps be obtained when it is recalled that Hobart, situated in the south-east of Tasmania, and with a population of approximately 70,000, while considerably smaller than some provincial centres in the Commonwealth, is the administrative centre of the State from both governmental and commercial viewpoints. This, together with the fact that about two-thirds of the population is distributed, with unusual evenness, over the northern portion of the State explains the comparatively large volume of trunk line business handled at Hobart as compared with the other trunk regional centres, Launceston and Burnie, both of which are situated in the northern half of the island. Hobart, with its excellent harbour, will undoubtedly continue to be the principal port, handling an increasing volume of cargo. As the development of new industries proceeds, many of which will be established in the country, an increasing volume of trunk line business at Hobart may be anticipated. It appears certain, therefore, that Hobart will continue to be the key trunk centre, especially as regards intrastate traffic and that its importance as such will be still greater in the future.

HISTORICAL DEVELOPMENT

Original Installation: The Hobart trunk exchange was installed in 1929 in conjunction with the conversion to automatic working of the Hobart

Central exchange area. It was manufactured by Messrs. Siemens Bros. and Co. Ltd., and the switchroom equipment consisted of 11 trunk operating positions, 5 information and recording positions, supervisor's desk and monitor's post. These items were installed on the second floor of the newly erected Telephone Building, the layout (including subsequent additions) being as shown in Fig. 1. A general view of the switchroom is shown in Fig. 2. The associated relay sets, I.D.F., and trunk test boards were located on the floor below together with the automatic exchange equipment.

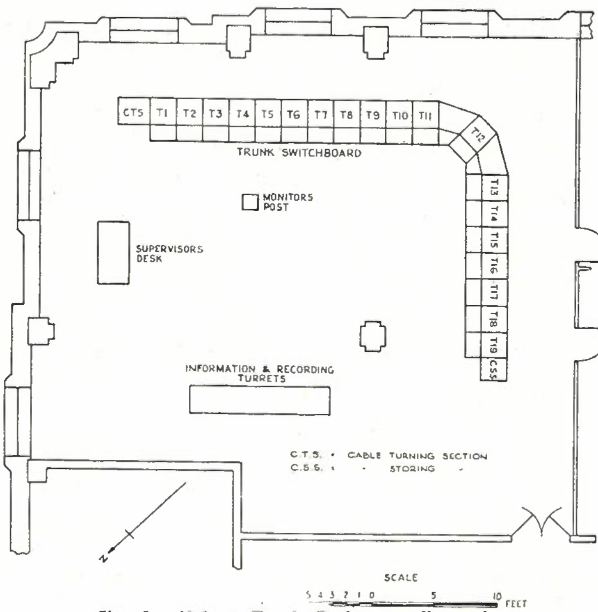

Fig. 1.—Hobart Trunk Exchange—floor plan.

The trunk position suite followed the usual pattern of manual cord switchboard, the frame being of bolted and riveted iron sections. The parts of the front woodwork exposed to wear were faced with fibre sheet, the remainder being highly polished mahogany.

Ten trunk line local jacks and calling lamps were provided in the lower portion of the face of each position, giving a capacity of 110 trunk terminations, approximately 60 of which were in use. The trunk multiple jacks were located in the right-hand panel of each position, the multiple being repeated every two positions. The cabling to both local and multipled appearances was taken from the I.D.F., where jumpering between the line (cabled from M.D.F.) test jacks, relay set, local jack and lamp, and multipled jacks was carried out.

Fifty outgoing junctions were provided, terminated on jacks at the trunk switchboard and on special selector repeaters at the Hobart automatic exchange, through which calls were routed to the metropolitan subscribers. The use of selector repeaters rather than group selectors was necessary in this instance in order to provide full cord circuit supervision. The following method was employed to ensure the efficient and rapid selection of junctions without the provision of multipled appearances of jacks and busy lamps. Ten jacks were provided on each position, making a total of 110, and these were connected to the 50 junctions, via a grading, the first jacks in the strips being connected as individuals while the last jacks were commoned. Below each junction jack was an assignment lamp, and each position was provided with an assignment switch or "junction preselector" under the control of the junction assignment key. This key, when depressed, caused the assignment switch to test the junctions available to the position in numerical order until one was found disengaged, when the appropriate lamp on the position would glow, indicating the junction to be used. In the event of all ten junctions being engaged, the group busy lamp on the position would glow. Two overflow assignment

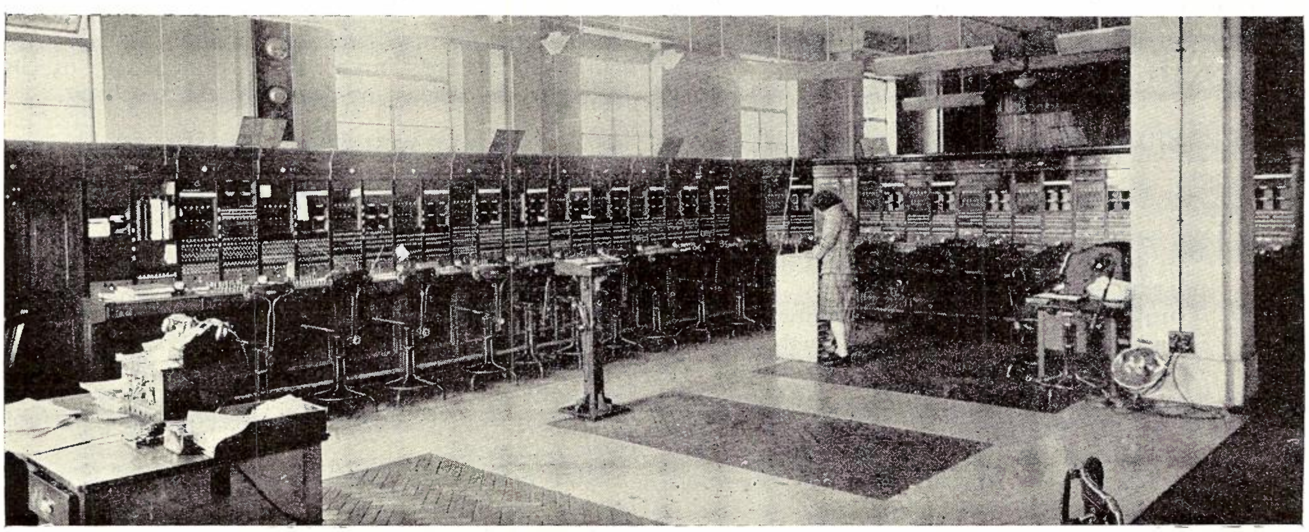

Fig. 2.—Hobart Trunk Exchange—general view.

keys were provided on each position, which controlled the assignment switches of the adjacent positions, thereby permitting selection of junctions terminating on those positions, if necessary.

The incoming junctions, which were used by metropolitan subscribers for booking calls only, were trunked from the "O" level of first selectors in the Hobart automatic exchange. They terminated on three cordless type recording turrets mounted on a long table which accommodated also two similar turret type positions catering for information, complaints, dead numbers, interception, etc.

The cord circuits, of which ten were provided on each position, were of the sleeve control type, positive lamp supervision being given on both answering and calling cords on all types of call. Separate speaking, ringing and dialling facilities were provided on the answering and calling cords, supervision of a call in progress being given by means of a low loss monitoring circuit. The absence of ringing current on the cord circuit is worthy of note, this being applied to line in the trunk line relay set by a marginal relay operated by the application of 50 volts potential at the ringing key. Dialling was over the sleeve of the cord circuit, the speak keys performing also the function of dialling keys. The usual coupling, order wire and engaged test facilities were provided in the operator's circuit.

Each position was provided with a panel of six timing clocks mounted in the switchboard face. The clocks were of the "Zenith" spring-driven type and were fitted with electrical contacts which caused green-capped lamps, mounted in a strip below the clock panel, to glow at 3 minute intervals.

All lamps (24 v. carbon filament), relays, and operators' circuits on the switchboard were fed by means of 24v. D.C. from a tapping on the automatic exchange main 50v. battery, the full voltage of which was used for all auxiliary equipment, including relay sets, assignment switches. 50v. D.C. was also used on the switchboard, but only for ringing purposes as mentioned above. 75v. 17 c/s A.C., from machines direct-coupled to the automatic exchange ringing machines (33 c/s), was fed to the ringing relays of trunk line relay sets.

Subsequent Changes: In 1934 the following alterations were made:—

(a) The trunk line local jack and lamp appearances were dismantled.

(b) Trunk line call lamps were concentrated in a lamp field, above eye level, on the face of positions T.2. and 3.

(c) The incoming junctions were disconnected from the recording turrets and were terminated on a jack and lamp multiple repeated every two positions on the main suite.

Changes (a) and (b) were made in order to concentrate incoming trunk traffic on the early positions of the suite and to eliminate the necessity for operators to move about the suite to answer calls during slack periods. The changes indicated in (c) were intended to enable a measure of demand working to be introduced when light traffic conditions permitted.

It was found, however, that shortage of trunk lines prevented any extensive use of demand working and, as trunk line traffic increased, it became necessary to provide three temporary recording positions to enable all positions on the main suite to be used for switching. The incoming junctions were multipled to these temporary positions.

In 1941 three positions, T.12-14, were added to the main suite, the face layout and facilities on the new positions being similar to the original installation. An additional trunk line call lamp field was provided, however, on positions T.10 and 11 to enable more operators to handle incoming trunk calls.

The abnormal growth in trunk line traffic during the war years made it apparent in 1943 that a further extension of the exchange would soon be necessary to enable the traffic to be handled effectively, especially at the Christmas and Easter periods. It was therefore decided to take the preliminary steps in the provision of five additional positions as soon as possible. This represented a major extension and it was advisable, therefore, that a review should be made of the existing facilities before putting it in hand.

At this time, owing to shortage of channels, delay working was the normal procedure, but the face layout of the switchboard was not entirely suitable even for this method, principally due to the trunk call lamps being dissociated from the line jacks and concentrated in two widely separated fields on the suite, as already mentioned. Moreover, the incoming-junction lamp and jack multiple was entirely superfluous. Some modification of the existing facilities was therefore essential, but a decision was necessary as to whether such modifications should be directed primarily towards improving the efficiency of the exchange for delay or for demand working.

NEW FACILITIES PROVIDED

It was decided that facilities should be such as to permit efficient delay working at any time, whilst also enabling demand working to be utilised in the less busy periods immediately, and in progressively busier periods as additional channels became available. This involved an almost complete re-arrangement of the face layout of the main suite. In order to enable all positions on the main suite to be utilised for switching during delay working, the temporary recording positions were retained.

Main Suite Face Layout: Some idea of the new layout may be obtained from Fig. 3, the principal features being as follow:—

The trunk line multiple has a capacity of 120 lines and is repeated every four panels. Every jack appearance has associated with it a busy lamp, and every alternate appearance has also a call lamp. Busy lamps were considered essential for demand working in order to enable the condition of a group to be ascertained at a glance. The conventional aural engaged test was not only too cumbersome, but would have rendered impracticable any attempt to hold dockets, before passing them to delay, in the hope that congestion on the routes required might soon pass. The generous provision of call lamps would provide a high degree of flexibility as regards method of working.

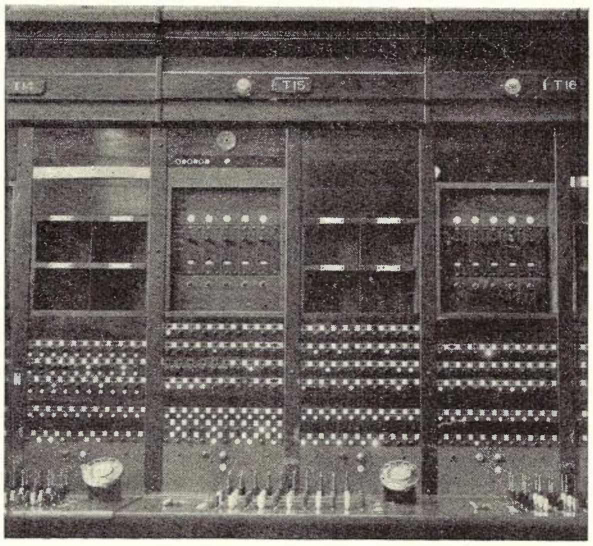

Fig. 3.—Main suite face layout.

A multiple was provided for 20 lines such as Monitor, Supervisor, Trunk Call Cabinets, etc., on which outward calls only are made. This is essentially similar to the trunk line multiple except that there are no call lamps.

No change was made in outgoing junction facilities, there being 10 appearances per position and selection being by means of the position assignment switch. A notable advantage of this arrangement is that it permits the provision of additional junctions without alteration or addition to the switchboard face equipment.

Incoming junction terminations, comprising jacks and call lamps, occupy the same positions on the face as previously, but the provision of 10 additional junctions, making a total of 40, necessitated the multiple span being increased from three to four panels. Space is reserved above the strips for an additional 40 junctions to be provided, if required.

Timing clocks and docket receptacles, which were previously located in the same panel, are located in left and right hand panels respectively. A line of spacing strips of the same height as the equipment strips is provided to separate each class of termination from that above.

Timing Clocks: In 1945, considerable difficulty was being experienced in maintaining spring-driven timing clocks and in providing additional timing facilities owing to scarcity of clocks and parts which were manufactured overseas. In the Melbourne trunk exchange, electrically driven timing clocks, B.P.O. No. 44, had been installed as part of the connecting circuit. Subsequently, a similar type of electrically-driven clock was developed by the Australian Post Office and it was decided that these should be used to replace the existing clocks. The Australian clock, type A.P.O. No. 44A (1), functions on the principle of a subscriber's call register and is similar to the "100A" type meter (2) as regards construction. Whilst it was developed primarily for key-shelf mounting in association with the cord circuit, it is suitable also for panel mounting, this method being adopted at Hobart owing to lack of space on the key-shelves.

Direct Dialling Lines Patching: This facility was included for engineering rather than for operating reasons. Of twenty-five direct dialling lines from country exchanges to the Hobart Automatic exchange, 18 were ordinarily used for dialling-in only. The remainder, having terminations also on the trunk exchange, could be used as dial-in/magneto-out circuits, the two-way function being necessary on small group routes. The 18 one-way circuits served the larger country towns, traffic from which was sufficient to justify the use of some of the channels as one-way circuits, but unfortunately satisfactory dialling was not always attainable, and to enable the circuits to be used when dialling was impracticable each circuit was provided with a change-over key located in the equipment room by means of which the Hobart end could be switched from the automatic termination to a trunk line switchboard termination. This meant that under normal conditions 18 trunk line relay sets, which could well be used for other purposes, and associated switchboard appearances, were idle. The most common cause of unsatisfactory dialling was unbalanced conditions on power supply lines paralleling the trunk routes, exposure being very severe in most parts of Tasmania owing to the small separation between trunk and power routes, consequent upon the tendency of both authorities to hug the narrow roads through the predominantly hilly country. These unbalanced conditions were caused by fault, for example, broken down insulator, tree across line, etc., and rarely occurred on more than one route at a time. Hence, instead of providing each dialling line with its own emergency termination, six such terminations only were installed, provision being made for patching the dialling lines on any route to the emergency terminations, as and when required. The switchboard appearances of these terminations were distinctively designated.

Monitor Call Lamps: On the original installation the attention of the monitor was attracted by an operator throwing a key which brought up an unshaded 50v. lamp. These lamps, which were mounted on top of alternate positions, were not entirely satisfactory for the purpose. It was decided to replace them with a smaller lamp, of the automatic exchange alarm type, mounted inside the position to illuminate plastic caps, one per position, mounted on the polished architrave adjacent to the position designation. The arrangement was rendered more effective by providing for the lamp to flash.

DESIGN

Structural Alteration: In the original installation the multiple shelf at the rear of the suite was 4½ inches above the lower edge of the switchboard face, allowing space for 9 strips of jacks and/or lamps. These were used for terminating non-multiple appearances such as outgoing junctions and trunk locals, which required separate cables from the auxiliary apparatus to each position. Since local trunk appearances had been abandoned and there would be no increase in outgoing junction terminations, it was decided that space for 4 strips would be ample for non-multiple appearances, and that the multiple shelf should be lowered 2-3/8 inches, thereby allowing more space which would be required in the future for the various multipled terminations.

Power Supply: A considerable amount of the design work arose from decisions regarding changes in power supply. These changes were influenced by three major factors:—

(a) The replacement of 24 volt carbon filament lamps with 6 volt metal filament type.
(b) The inability of the existing 24 volt power plant to cope with the increased load, which the alterations would involve, in an efficient manner.
(c) Difficulties associated with the operation of the composite battery arrangement.

As regards (a), it had been determined as a matter of policy that 6 volt metal filament lamps should be used on all new work requiring switchboard lamps. This determination was influenced, no doubt, by the fact that the metal filament type have longer life and lower power consumption than carbon filament lamps and also have been, in recent years, in more plentiful supply. As indicated previously the trunk exchange utilised 50v. and 24v. supply, and hence the use of 6v. lamps would necessitate either the provision of a potential dropping resistance with each lamp, or the introduction of a 6v. supply.

There were serious practical difficulties associated with the use of resistances. The alterations and extension would require more than 3,000 lamps, practically all of which were to be located in strips in the switchboard face. Sixteen lamp strips would be required on each position initially and provision would need to be made for an additional 14 to meet future requirements. Owing to space limitations in the positions, the only practicable method of accommodating the 300 resistances per position was by suspending the mounting from the top of the position. The wiring from the resistances would be taken down each side of the position and thence to the lamp strips. Under such conditions maintenance operations would be rendered more difficult, not only by the greater quantity of wiring connected to the strips but also by the great care necessary to avoid damaging the resistance-to-strip wiring when lifting the multiple.

With reference to (b), it was estimated that the new load on the 24v. section of the main batteries would be 760 Ah. per day, if this supply were used for feeding switchboard lamps. The existing rectifier used for 24v. charging would replace 720 Ah. per day, the deficiency being subject to further increase when additional carrier telephone and telegraph systems were installed within 2 years. This deficiency in charging capacity could have been made up by using, for a period each day, one of the 65v. 300 amp. motor-generators normally used for charging the 50v. batteries, but the poor efficiency of these machines, when giving about one eighth of their rated output, rendered this course undesirable.

With reference to (c), as indicated above, the 24v. supply was derived from a tapping on the automatic exchange 50v. battery, the cells supplying both voltages being 1200 Ah. capacity, while those supplying 50v. only were of 900 Ah. capacity. Experience over 10 years with this composite battery arrangement left little doubt that any saving in capital cost, which it might have permitted, was more than offset by increased maintenance costs. The satisfactory employment of the floating system was found to require constant attention of staff in order to secure voltage regulation within the prescribed limits, and to ensure that each section of the battery received the correct amount of charging. The recent introduction of automatic voltage regulation on one of the 65v. 300 amp. motor-generators for use on the 50v. supply, and an automatically regulated dry-plate rectifier on the 24v. section, has considerably reduced voltage regulation difficulties, but owing to the interaction betwen the two sections as regards load, voltage, and charge, a considerable amount of manual attention is still required to ensure satisfactory charging.

The solution of the difficulties discussed under (b) and (c) above would appear to have been the provision of separate 24v. batteries, together with charging plant of greater output. There were objections to this course, however, from both the immediate and long range viewpoints, since the installation of separate 24v. batteries in the existing battery room would have caused congestion, and the removal of the long line equipment to another room, probably remote from the existing battery room, could be foreseen.

In view of these considerations, the elimination of the use of 24v. supply on the trunk exchange plant was considered desirable, and it was therefore decided:—

(a) To provide a 7v. supply for the 6 volt lamps, thereby avoiding the use of series resistances, and

(b) to convert to 50v. working all other circuits using the 24v. supply.

In examining the method of providing a 7 volt supply, it was considered that, since interruptions to mains supply alternating current (240v. 50 cycle) were both infrequent and of short duration, this source transformed to 7 volts would be suitable for use with lamps such as busy lamps where no special circuit conditions had to be met. Before making this decision, listening tests were made to ensure that there would be no induced hum in speaking circuits. The use of 7v. A.C. was impracticable, however, on cord circuit supervisory lamps owing to the fact that these lamps were required to operate in series with marginal relays in the various line-terminating relay sets. Several methods were examined with a view to using the 7v. A.C. supply for trunk line and incoming junction call lamps, but this idea was abandoned for the following reasons:—

(a) Failure of these lamps could not be tolerated during mains supply interruptions.

(b) Satisfactory operation of pilot relays in series with call lamps by means of alternating current was impracticable.

As regards (b), several methods of overcoming this were examined without success. A pilot relay bridged with a rectifier would have required a 10 ohm holding winding, resulting in excessive voltage drop, whilst the size of a rectifier which would carry current for a panel of lamps would be such as to present a mounting problem. In the absence of a satisfactory solution, it was decided to feed the trunk line and incoming junction call lamps by means of direct current from a suitable dry-plate rectifier with automatic change-over to a 6v. tapping on the main 50v. battery in case of failure of the rectifier output.

Details of the power supply may, therefore, be summarised:—

Circuit	Power supply used
Call Lamps	7v. D.C.
Busy and assignment lamps	7v. A.C.
All other circuits, including operator's circuits, timing, etc.	50v. D.C.

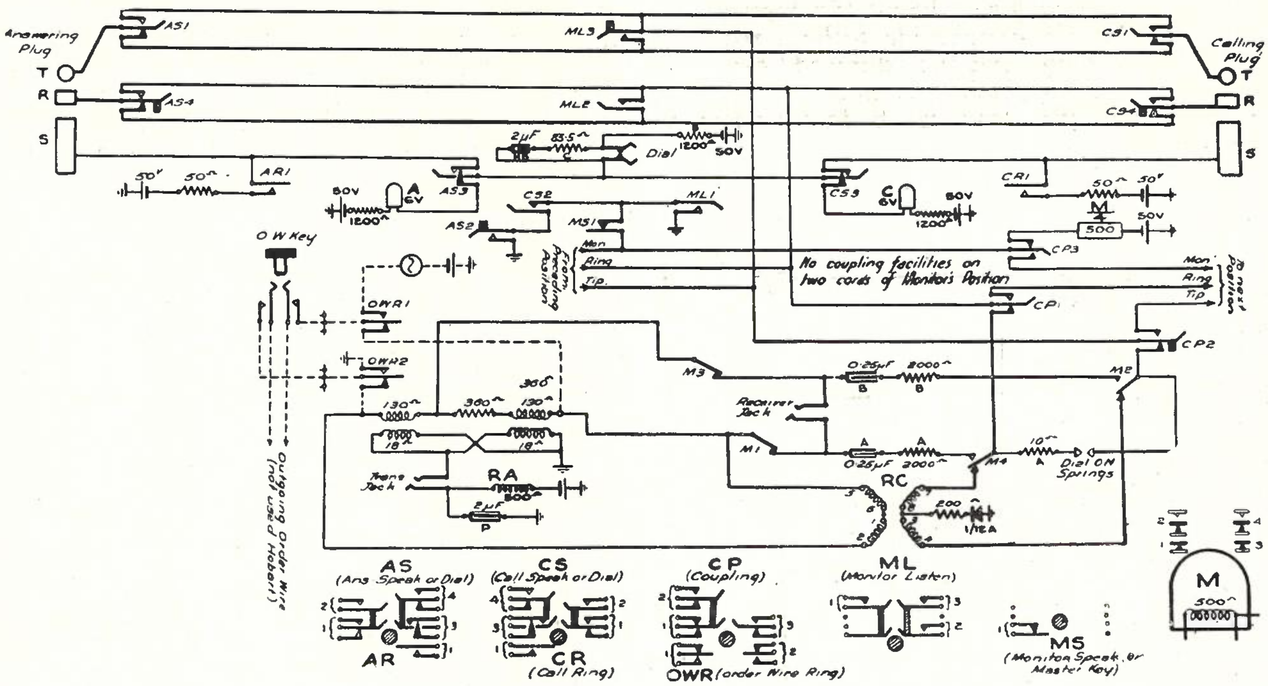

Fig. 4.—Trunk cord and operator's circuit.

Cord and Operator's Circuit (See Fig. 4)

The operator's transmitter battery was previously fed from the 24v. supply via 165 ohms reactances. Transmitter noise had frequently been experienced under these conditions due to excessive transmitter current, and it was found by test that a suitable current value would be obtained by the use of 500 ohms reactances with the proposed 50v. supply.

A number of difficulties had to be overcome in changing to 6 volt supervisory lamps fed from 50v. A cord circuit supervisory lamp was required to be dimmed when in series with the high resistance winding of the sleeve circuit relays of a trunk line relay set (see Fig. 5), an incoming junction relay set, or a selector repeater, and to glow when in series with the low resistance winding of any of these relays. The relays had been designed for use with 24v. carbon filament lamps, and the resistances of the windings were such as to give correct current values for this type of lamp; that is, 100 m.A. normal current when glowing and 50 m.A. when dimmed. The corresponding values for 6v. metal filament lamps, which are set out hereunder, being appreciably lower, it was apparent that some of the sleeve circuit relays would require re-winding.

Condition	Current
Minimum glow	35 m.A.
Maximum glow	47 m.A.
Dimmed	20 m.A.

These values were obtained by experiment, "minimum glow" being taken as the degree of illumination which would be clearly visible when the light intensity at the key shelf was 12-foot candles, "maximum glow" being the highest degree of illumination permissible without reducing the life of the lamp, and the "dimmed" condition being readily recognisable as such under poor lighting conditions, that is, 5 foot-candles at the keyshelf.

the case of the trunk line relay sets this requirement was met by relays A 1000 ohms and B 100 ohms in series reducing the current to 20 m.A. The corresponding relay windings in the incoming junction relay set (C 500 ohms) and the selector repeater (A 300 ohms) gave "dimmed" values of 27 m.A. and 30 m.A. respectively, which values were too high for satisfactory dimming.

It being evident that some increase in the resistance of these two circuits would be necessary for effective supervisory lamp operation, the next step was to ensure that any such alterations would provide also for satisfactory relay operation on the new current values. With these two factors in mind, and in view of the desirability of confining the alterations to the relays concerned, if possible, a summary was prepared of the characteristics to be aimed at in these days. These are set out in Table 1.

In the case of the trunk line relay sets, which constituted the greatest number of the relay sets

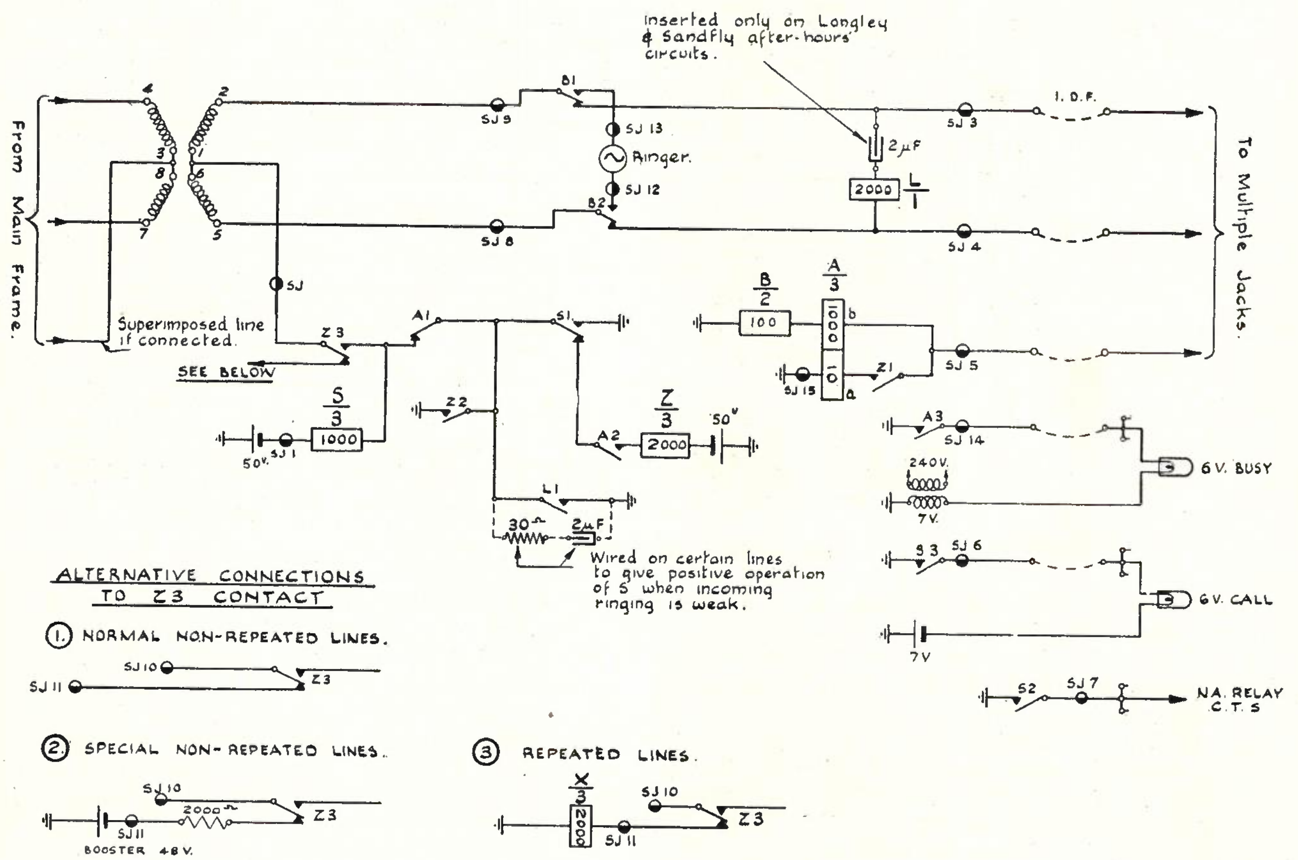

Fig. 5.—Line circuit.

The original values of the low reactance relay windings were all below 60 ohms, and a satisfactory "glow" current for the 6v. lamps fed from 50v. supply was obtainable by the use of 1200 ohms series resistances. The high resistance windings were required to introduce sufficient additional resistance to reduce the current through the lamp to the "dimmed" value, and in

involved, the A and B relays were satisfactory as regards resistance, and it was found that efficient operation was obtainable by minor re-adjustment. Relays C in the incoming junction relay sets were re-wound from 20 ohms/500 ohms to 40 ohms/1100 ohms. A greater number of turns on the low winding and a slight reduction in spring tension were necessary to provide reliable operation. A considerable amount of experimenting was necessary in order to obtain satisfactory re-winding values for the A relays of the selector repeaters. These relays operate initially when the junction is taken, from battery at the supervisory lamp, but while impulsing, battery is fed via a resistance, the operator's dial and the dial-speak key of the cord circuit. In the original circuit the current value for both operating and impulsing was approximately the same, that is, 60 m.A. Under the new conditions 20 m.A. only would be available to operate the relay, and early tests indicated that it would be less difficult to arrive at satisfactory re-winding and re-adjustment data if impulsing also was to take place with 20 m.A. Finally, it was found that satisfactory results could be obtained by re-winding the relay (originally 15 ohms/300 ohms) to 53 ohms/440 ohms + 660 N.I., the new adjustments being quite stable and impulsing performance meeting the usual requirements of routine testing under long and short line conditions. Impulsing current was adjusted to 20 m.A. by replacing the 24v. supply and 85 ohms resistance at the operator's dial with 50v. and 1200 ohms respectively.

Trunk Line Circuit (See Fig. 5): Two alterations were required in this circuit—provision of busy lamps and arrangements for night alarm operation. As previously indicated, a busy lamp (6 volt) was to be provided at each trunk line appearance, alternating current, transformed from the 240v. mains supply, being the power source. Relay A is operated at all times when a trunk line is plugged up and hence this relay was the obvious choice for controlling the busy lamp. A third contact (A3 make) was provided on the A relay for this purpose. Also, it was necessary to arrange for the night alarm relays to be controlled by the S relay which operates when relay L is actuated by ringing current from the line and remains operated until the call is answered. An additional contact, S2, was therefore necessary. Spare switch jack points were available for these alterations, and hence the additional work involved on the relay sets was a small amount of wiring and re-adjustment of the A and B relays referred to previously.

Incoming Junction Circuit: The alterations necessary in this circuit were:—

(a) The replacement of 24v. call lamps and associated power supply by 6v. lamps fed from 7v. D.C. supply.

(b) Re-winding and re-adjustment of C relay as described in the foregoing.

(c) The provision of night alarm control involving the replacement of make contact C2 with a change-over contact, an additional contact on A relay (A3) and associated wiring terminating on spare switch-jack contact SJ7.

With reference to (c), this provision was necessary for similar reasons to those indicated for providing N.A. control in the trunk line relay sets. In the incoming junction circuit, relay A is operated when looped via the preceding group selector and remains operated until the junction is released, while relay C operates when the operator plugs in to answer the call.

Night Alarm Control: Formerly, the N.A. utilised the well known arrangement in which control depends on pilot relays in series with the battery feed to the call lamps, there being one 2 ohm pilot relay per position for incoming junction call lamps and one for each of the two trunk line call lamp

Table 1.

Characteristics to be achieved in re-designing sleeve control relays.

Circuit	Relay	Winding	Characteristics
Trunk Line Relay Set	A	Low	Maximum res.—60 ohms Hold current—37 m.A.
Trunk Line Relay Set	A	High	Approx. res.—1,000 ohms. Operate current—20 m.A.
Trunk Line Relay Set	B	—	Operate current (ringing)—43 m.A. Non-operate current—20 m.A.
Incoming Junction Relay Set	C	Low	Maximum res.—60 ohms Operate current—37 m.A.
Incoming Junction Relay Set	C	High	Approx. res.—1100 ohms Operate current—20 m.A.
Selector Repeater	A	Low	Maximum res.—60 ohms Hold current—37 m.A.
Selector Repeater	A	High	Approx. res.—1100 ohms. Operate current—20 m.A. Must impulse satisfactorily

fields. It was thought desirable to retain this method of control if possible, but it was apparent that much more severe conditions would need to be met than formerly, owing to the replacement of 24v. with 6v. lamps. These conditions were:—

(a) 40 m.A. would be available to operate the pilot relays in lieu of 100 m.A.

(b) Satisfactory operation of the new lamps under heavy traffic conditions placed a much lower limit (0.75v.) on the permissible potential drop in the pilot relay.

It was found that the 2 ohm pilot relays would not operate on the reduced current available and that re-design of these would therefore be required. Also, it was decided that, in order to reduce the effects of (b) above, two pilot relays per position (one per panel) should be utilised.

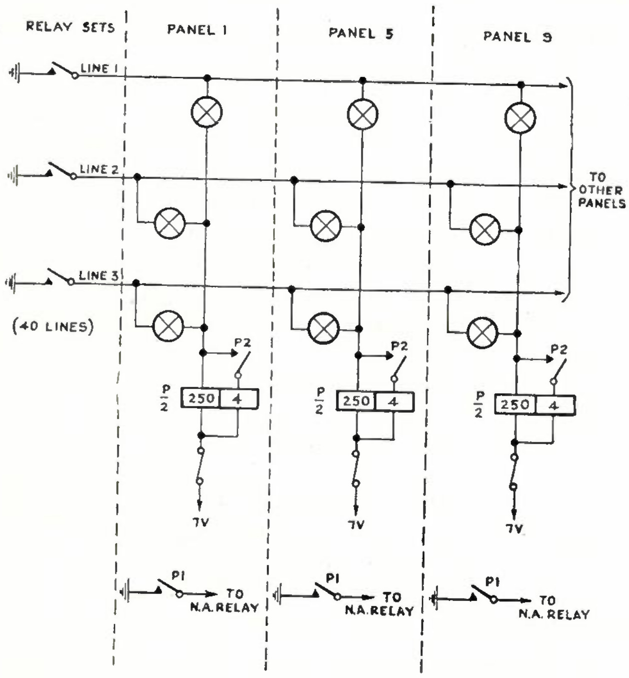

Fig. 6.—Pilot relay arrangement—discarded after trial.

It soon became apparent that single-wound pilot relays would not be satisfactory from the potential drop point of view. Sufficient turns to give reliable operation necessitated a winding of at least 9 ohm resistance which would have caused a poor illumination if the number of lamps alight had exceeded two. 2000 type relay design data was used as a basis for experiments on a double wound relay—one winding of comparatively high resistance for operating the relay and the second—a low resistance winding, normally open circuit, which would be placed in parallel with the operating winding when the relay operated, and would both hold the relay operated and provide a battery feed of low resistance. This arrangement involved the provision of a second contact on the relays, thereby increasing the spring load, and it was found after trying a number of relays re-wound to different values that the most satisfactory combination was 250 ohms/4 ohms.

The scheme proved unsatisfactory, however, as it was found that, due to the impossibility of adjusting all the relays so that the operating times were precisely the same, conditions would be set up whereby the slower relays would be prevented from operating. This can be seen from Fig. 6. Suppose that, as a result of a call on Line 1, earth has been applied at the relay set to the call lamp operating common and that P relays on Panels 1 and 5 have operated, but that P relay on Panel 9 not yet having fully operated, its 4 ohm winding is not yet in circuit. The potential on the battery feed common on Panel 9 will now differ from that on Panels 1 and 5, and current will flow from Panels 1 and 5 via line lamps 2 and 3 on those panels to line lamps 2 and 3 on Panel 9, and thence via line lamp 1 on Panel 9 to earth. For purposes of simplicity the two parallel paths via call lamp operating commons 2 and 3 have been described, but in fact there are 39 such parallel paths in this case (40 lamps per panel) and, therefore, relay P on panel 9 being so effectively shunted will not complete its operation. Moreover, as the number of line lamps waiting attention on a panel fed by an unoperated P relay increased, the brightness of these would diminish, while the current in the remaining lamps in the panel would increase to a stage when they would glow perceptibly, thereby adding to the trouble.

In the circumstances, it was apparent that the pilot relay method of night alarm control could not be used, and the alternative finally adopted was the provision of additional contacts on appropriate relays on the relay sets as already described. Had the impracticability of utilising pilot relays been realised at the outset, arrangements would have been made for trunk and junction call lamps to be fed from 7v. A.C. rather than for the introduction of a 7v. D.C. supply. The installation of the latter was completed, however, before the trouble became apparent and since—

(a) The diversion of the D.C. supply, subsidiary distribution and automatic change-over equipment, etc., to the 7v. A.C. unit would have involved considerable delay; and

(b) It was anticipated that the 7v. D.C. supply would prove useful for secondary cell charging, low voltage testing, etc., the 7v. D.C. supply was retained.

In the night alarm arrangements finally adopted, the switch jacks associated with the new relay contacts were commoned along each relay set shelf and, to permit permanent N.A. faults being readily traced, the shelf commons were each wired to a commoning strip provided for the purpose on each of the three racks. These in turn connected to three night alarm relays mounted in the cable turning section. These relays and the remainder of the circuit were part of the former arrangement and required no alteration.

Outgoing Junction Assignment Switch: (See Fig. 7.) This circuit, which is used to indicate to the operator which junction should be used for a call to the automatic exchange, required minor alteration associated with the change in the type of lamp. The 24v. supply to the assignment and group busy lamps was replaced with 7v. A.C., while that to the junction cut-out pilot lamp, which indicates if, for any reason, a junction has been taken out of use, was replaced by 50v. D.C. fed via a 1200 ohm series resistance. This latter method was adopted since one lamp only was involved and 50v. supply was already available in the cable turning section, on the face of which the lamp was mounted.

Gradings: Alterations were necessary on the gradings serving the first group selector "O" level and the outgoing junction assignment switch outlets.

The outgoing junction assignment scheme has already been described. The scheme depends upon two features (see Fig. 7).

(a) The position assignment switch tests the 10 junctions available to the position in numerical order and assigns the first free junction by lighting the appropriate assignment lamp.

(b) The junction jacks are connected to the selector repeaters via a grading (carried out on the link distributing frame).

At the time of undertaking this project, the efficiency of the scheme was impaired somewhat by defects in the grouping and grading arrangements as follows:—

(a) The junction jacks were arranged in four groups, each group being graded independently of the others, thereby reducing the total traffic carrying capacity.

(b) The four groups were uneven in size comprising jacks on 2, 3, 3 and 6 positions, while the corresponding numbers of junctions available to the groups were 11 to the first group and 13 to each of the others.

In designing the new arrangement, attention was given to the removal of these defects, as also to the need for providing for further development. Each group now contains jacks associated with positions distributed evenly throughout the suite which ensures that, when the operating staff is concentrated on one section of the suite, all junctions will be available to them. This also permits the facility whereby an operator can, if necessary, obtain assignment of a junction on an adjacent position. All of the jacks have been included in one grading, in which a smooth progression from "individuals" to commons has been observed. Additional switches can be readily added to the groups, sufficient space being available for this purpose between the groups of terminal assemblies.

Allocation of Trunk Line Relay Sets: Associated with the use of V.F. repeaters at the Hobart trunk exchange is a pad switching scheme which virtually increases the effective gain of the repeater when the repeated line is connected on a through call to a long non-repeated line. This is achieved by arranging for a 6 db. attenuation pad, which is normally inserted in the repeated line, to be automatically switched out of circuit under predetermined through calling

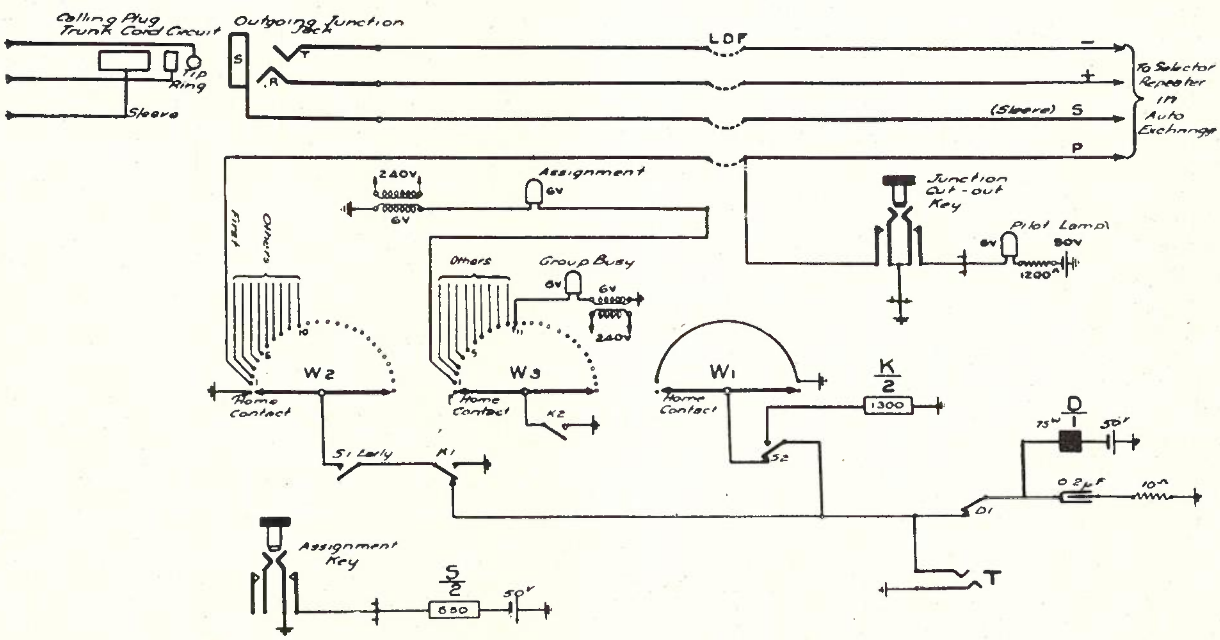

Fig. 7.—Outgoing junction assignment switch.

conditions. The switching is achieved by alternative connections to the Z.3 contact in the trunk line relay set as indicated in Fig. 5. Alternative connection 1 is the condition on lines not equipped with repeaters and having less than 7 db. loss, while connection 2 refers to non-repeated lines having 7 db. or greater loss. Connection 3 refers to lines equipped with repeaters. When a repeated line is connected to a high loss line, relay X associated with the former operates from earth via Z3, transformer centre point, T and R conductors and multiple jack of the repeated line, T and R conductors of the cord circuit, high-loss line multiple jack, T and R conductors of the high-loss line relay set, centre point of transformer, Z3 contact and 2000 ohm resistance to 48v. positive battery. Relay X contacts, when operated, short-circuit the series elements and open-circuit the shunt element of the pad. When the repeated line is connected to a local subscriber's line or to a low-loss trunk line, relay X remains unoperated and the pad remains in circuit. Previously the special connections to the Z3 contacts had been made by altering permanent wiring as additional repeaters were installed. It was now decided that, in conjunction with the other re-arrangements, the relay sets for use with the different classes of lines should be grouped together and that improved facilities for making the Z3 contact connections should be provided. Accordingly, arrangements were made for the 140 relay sets to be divided into two groups as follows:—

Relay Sets 1-40: All lines fitted with V.F. repeaters were connected to sets in this group. The break and change-over springs of Z3 contacts were connected via switch jacks and new cabling to Intermediate Distributing Frame to permit jumpering to X relays and centre point of repeater "back" transformer respectively, when required.

Relay Sets 41-140: All lines having 7db. or greater loss were connected to sets in this group, positive battery being connected to the Z3 contact by means of a single wire jumper from the associated switch jack to a positive battery commoning strip mounted on the relay rack.

Provision was also made for rack positions of non-interchangeable relays sets as also the sets themselves to be numbered in red. Rack positions of other relay sets were designated in black, the interchangeable sets themselves being undesignated.

The use of positive battery, as referred to previously, is worthy of explanation. An increasing number of complaints were being received a few years ago from trunk line users and telephonists, that severe clicks were interfering with calls, and it was found that the trouble occurred on high-loss lines when the operator's monitoring key was thrown or restored. The Z3 contacts of these lines were connected at that time to negative battery, and the clicks were due to the fact that, owing to the operation of the T and R springsets of the monitoring key (ML—see Fig. 4) not being exactly simultaneous, a momentarily unbalanced condition occurred in the circuit from negative battery at Z3, via the transformer, T and R conductors of relay set and cord circuit, monitoring key, coupling key and M relay contacts to earth at the split of the operator's transformer RC. The trouble was overcome by replacing negative battery at Z3 contacts with positive (meter) battery and connecting a suitable metal rectifier in series with earth at the operator's transformer, in such a way as to offer very high resistance to current from the Z3 contact, but to permit, as previously, a satisfactory engaged test being received when the tip of a plug was connected momentarily to negative potential on the jack sleeve of an engaged line.

Direct Dialling Lines Patching: The arrangements decided upon for the provision of this facility are indicated in Fig. 8, which shows the dialling line, under normal conditions, terminating on the "repeater" relay set via an 8-point jack (sleeve not shown), and also one of the emergency trunk line relay sets terminating on a 3-point jack (sleeve not shown). Both sets of jacks were housed in a small patching board designed for the purpose, which permitted any dialling line being connected to any one of the six emergency terminations (Z1-6), by means of a plug-ended cord. The patching board was designed to accommodate 40 direct dialling lines and 10 emergency terminations. It will be noted that the insertion of a plug in one of the 8-point jacks disconnects the dialling lead from the "repeater" relay set, this being necessary to prevent the country station from attempting to set up an automatic connection while the line is switched to the trunk switchboard termination. Flexibility of the scheme was ensured by all components involved being terminated at the I.D.F.

Timing Clocks: The electrically driven A.P.O. No. 44A timing clocks, which were used to replace the spring-driven clocks formerly used, are essentially similar to a subscriber's register except that two indicator wheels or cams only are used, one to show minutes and the other tenths of a minute. The clock requires two series of earth pulses of frequency 6 seconds and 0.1 second respectively. The former is connected by the operation of the control key to "Start" and drives the one-tenth-minute cam which, in turn, drives the minute cam one step at each revolution. The clock will indicate up to 10 minutes, appropriate lamp signals, controlled by the cam-operated springsets, being given preceding the 3, 6 and 9 minute points. The full 10 minute period corresponds to 100 steps of the one-tenth-minute cam. In order to reset the clock, the control key is placed in the "Reset" position, which connects the 0.1 second pulse. This drives the clock rapidly to the zero position, where the drive circuit is opened by the cam-operated springset. Five clocks were required ultimately for each switchboard position, to be mounted in the switchboard face. In order to enable the clocks to be readily dismantled from the switchboard for maintenance purposes, a small panel was designed to carry the clocks and associated circuit components. Subsequent experience proved the value of this arrangement, as maintenance required was rather heavy and wiring would have deteriorated quickly if individual clocks had had to be adjusted at the switchboard. The arrangements adopted enabled the complete panel to be easily disconnected and dismantled from the switchboard and taken to a bench for attention, a spare panel of clocks being fitted in the switchboard in the meantime.

Although bench trials of short duration were satisfactory, it was found after installation that the 6 second relay generator was subject to serious variation in periodicity, which caused the clocks to give inaccurate results as high as 12 per cent. within 24 hours of adjustment of the pulse generator. The variations were mainly due to temperature changes which affected the resistance of the various circuit components and the spring tension of the relays. An accurate electrically driven pendulum clock (B.P.O. No. 1) was therefore provided as the normal 6 seconds pulse generator, the relay type being retained in the circuit for maintenance and emergency purposes only.

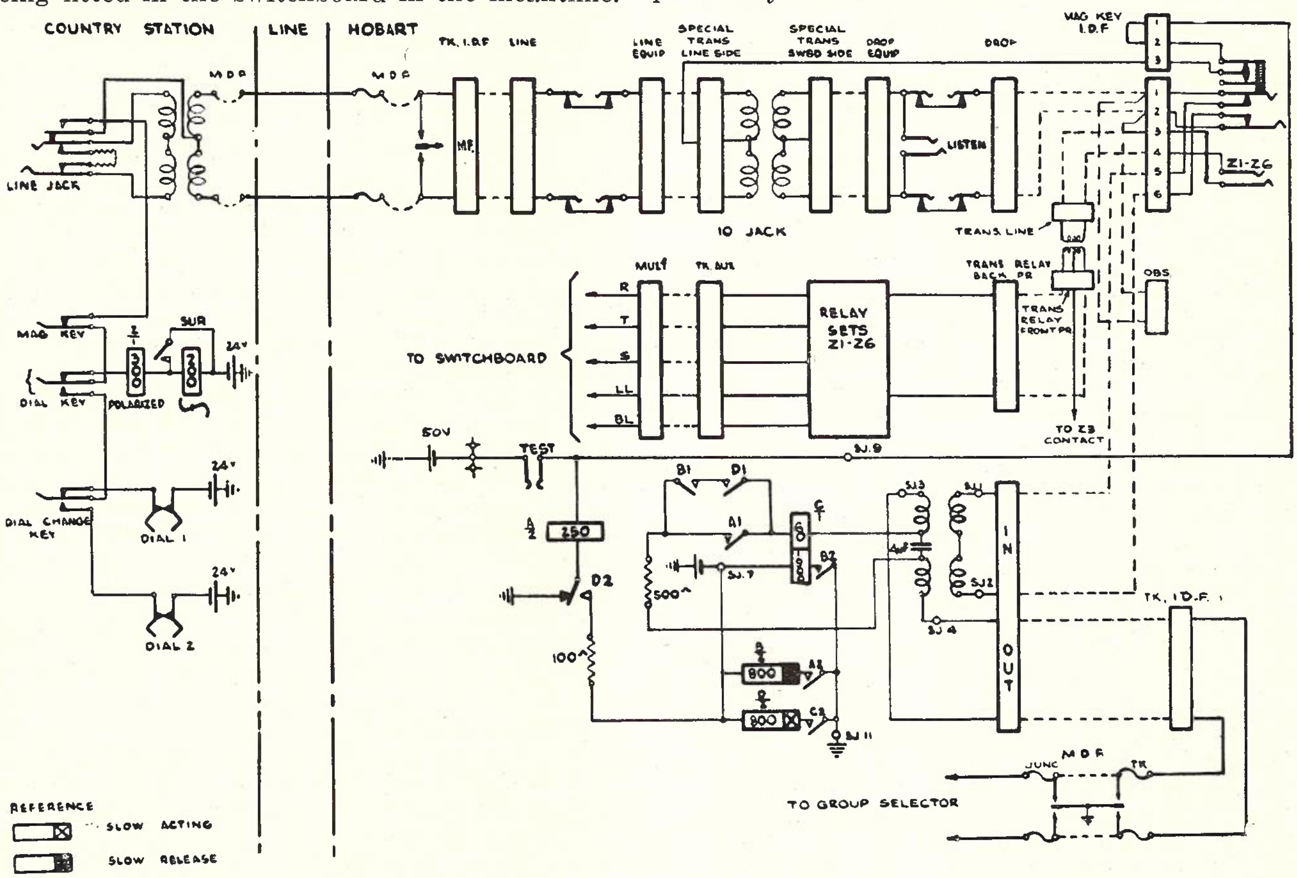

Fig. 8.—Direct dialling circuit—dial in only.

Timing Clock Pulse Circuit: The provision of 6 second and 0.1 second pulse supplies for the timing clocks presented an interesting problem. It was realised that, whatever method of pulse generation was employed, duplicate arrangements would be necesary to ensure continuity of the facility during maintenance operations or possible breakdown periods. Since suitable pulses were not available from the exchange ringing machines or any other existing equipment, it was decided to use relay type generators employing condensers and timing resistances.

Repeating Relays: Since the single contact controlling the output of each of the pulse generators would be rapidly burnt out by arcing and sparking if used to feed the whole 130 clocks ultimately required, arrangements were made for the pulses to be transmitted to the clocks via repeating relays, each of which carried five make contacts. Each contact was provided with a $1\mu F/100$ ohm spark quench and was used to feed two switchboard positions, that is, 10 clocks ultimately.

During the night there would be considerable periods when no timing clock would be in use, and it was decided to provide start arrangements to reduce relay set wear. The ultimate number of switchboard positions was divided into three groups of ten, each group being provided with its own start lead which controlled the repeating relays feeding the group as well as the common pulse generators. This was done to reduce wear on the repeating relays since there would be slack periods, particularly at week-ends, when only portion of the switchboard suite would be staffed.

The timing clock pulse circuit arrangements consisted of the following:—

(a) Two relay sets, each of which comprised a 6 second pulse relay generator, a 0.1 second pulse relay generator, repeating relays and start relays.

(b) A clock type 6 second pulse generator which could be associated with either of the relay sets in (a) above, or with both simultaneously, by means of keys.

(c) A group of six change-over relays controlled by a key for switching all start and distribution leads from one of the relay sets in (a) above, to the other.

(d) Test keys, etc., to enable the pulse generators to be connected to a test timing clock for check of performance and accuracy.

Monitor Call Lamps: On the former installation, one monitor call lamp was provided for each two positions, control being by means of the monitor call key on either position which, when thrown, connected earth to the lamp. This circuit was retained except that a separate lamp was provided for each position and steady earth at the monitor call keys was replaced by interrupted earth to give a flashing signal. Interrupted earth, 0.75 sec. on, 0.75 sec. off, was available from the automatic exchange and was fed thence to a terminal block in the trunk exchange cable turning section, from which it was distributed to the positions via individual leads. The moulded caps used on the lamps were clamped to the suite architrave, which was drilled to permit the lamps being mounted with the bulbs partially inside the caps. The lamps were mounted on specially designed brackets which would enable the lamp-holders and lamps being readily removed at the rear of the switchboard. Ready access to the lamp, etc., for maintenance purposes was thereby afforded without the necessity of removing the lamp caps, which was undesirable, both because it would have to be done at the front of the switchboard, and because of the risk of mutilating the screws, mounting ring and adjacent polished woodwork.

50 Volt Power Supply Distribution: Power supply to the switchboard was previously fed via two panels fitted with 1.5 amp. alarm type fuses and located in the exchange equipment room. The larger of these carried 440 fuses and was used for the 24v. supply. Fourteen fuses were cabled to the miscellaneous block in each position and used as follows:—

1 fuse for each of 10 cord circuits.
1 fuse for call, etc., lamps on each of the two panels.
1 fuse for operator's circuit (transmitter, dial, etc).
1 fuse for pilot lamps and O/G junction group busy lamp.

The second panel—a small one fitted with the same type of fuse—was used for feeding 50v. supply to ringing keys and monitor call lamps. Since, with the exception of the call lamps, the circuits fed from the 24v. panel were to be converted to 50v. working, arrangements were made for the 24v. panel to be disconnected from the 24v. battery and connected to 50v. supply via a new cable to the automatic exchange main distribution panel. Two of the fourteen fuses per position were thrown spare since call lamps now used 7v. supply, and these were used for ringing potential and monitor call lamps (thereby enabling the small 50v. panel to be dismantled), and also for the new timing clocks. These alterations involved a minimum of alteration to power cabling, wiring and designations.

7 Volts D.C. Supply: Since all call lamps were to be supplied by means of 7v. D.C., it was essential that this supply should be completely reliable. This could have been achieved by providing a three-cell secondary battery or alternatively by means of a tapping on one of the main 50v. batteries. In either case, 7v. charging arrangements would have been required, but since the mains power supply was very reliable it was decided to feed the circuits directly from a dry-plate type rectifier and to provide for automatic change-over to a tapping on one of the 50v. batteries, in the event of the rectifier output failing. Provision was also made for:—

(a) Facilities for testing the automatic change-over;

(b) Operation of the exchange non-urgent alarm in the event of change-over taking place; and

(c) Operation of the exchange urgent alarm in the event of the supply failing, due, for example, to failure of the change-over to take place after the output of the rectifier had failed.

The supply was fed from the exchange power room, in which the rectifier was located, to a new alarm type fuse panel with capacity for 90 fuses and mounted in the equipment room above the 50v. supply panel. Provision was made for two feeds from the fuse panel per switchboard position (one per panel), distribution to the lamp strips being via screw type commoning strips to facilitate maintenance.

Potential drop is a fundamental consideration in any power supply system, but in designing a system for 6 volt switchboard lamps it becomes a vital factor. This is especially the case in a large installation. In the present instance, the go and return distance from the power unit to the furthermost lamp approximated 500 feet, and included about 200 feet of small gauge (9.25 lbs. per mile) conductor in the relay set to switchboard, and switchboard multiple cabling. Only by the use of power cabling much heavier than that usually found in telephone installations of comparable load, was it possible to ensure satisfactory lamp voltage. Table 2 indicates the basis on which the maximum current load was estimated, provision being made for 30 per cent. of all call lamps being operated simultaneously, and for the exchange having reached its ultimate stage of development (in the present switchroom), that is, 30 positions terminating 240 trunk lines.

D.C. supply, the calculation of the maximum load was based on the anticipated development of the suite to 30 operating positions. While O/G junction assignment lamps were to be fed by 7v. A.C., this load would be negligible compared with that taken by the trunk line busy lamps. The estimate, which is set out in Table 3, provided for 80 per cent. of busy lamps being lit simultaneously.

This load was four times as great as that for the 7v. D.C. supply, but the conditions to be met were eased somewhat by the fact that emergency supply arrangements were unnecessary for the trunk busy and junction assignment lamps since, in the event of supply failure, the normal engaged test could be utilised to carry on service. This meant that the power unit—a step-down transformer connected to 240v., 50 cycle mains supply—could be located in close proximity to the equipment.

Table 2
7 Volt D.C. Supply— Maximum Load

Circuit	Lamps per position	Lamps lit per position 30%	Load per position (amps.)	No. of positions	Total Load (amps.)
Trunk Line (Call)	120	36	1.44	16	23.0
Incoming Junction	20	6	0.24	30	7.2
Total	140	42	1.68	—	30.2

The maximum load capacity of the rectifier (30 amps.) having been established, the maximum (no load) voltage of the rectifier was arrived at as follows:—

Potential drop in each trunk circuit call lamp wire between relay set and first switchboard position at present stage of development, that is, 19 position (5 lamp appearances per circuit) ...... 0.3 volt
Maximum permissible voltage at 6 volt lamp consistent with reasonable life 7.0 volts

Maximum (no load) voltage of rectifier 7.3 volts

The minimum voltage of the rectifier on full load was specified as 6.8v. Rectifier input was listed as 200/250v., 50 cycle, single phase.

The power cable sizes were based on a maximum permissible potential drop in the power distribution cabling of 1.3v., derived as follows:—

P.D. = a — (b + c).

where a = minimum (full load) voltage of rectifier = 6.8v.

b = potential drop in each trunk circuit call lamp wire between relay set and last switchboard position at ultimate stage of development, that is, 30 positions (8 lamp appearances per circuit) = 0.5v.

c = minimum permissible voltage at 6v. lamp for satisfactory glow. = 5.0v.

7 Volts A.C. Supply: As in the case of the 7v.

Details of the transformer are as follow:—

Input—240v. 50 cycle, single phase.
Output—840 v.A. (14v. 60A.) Regulation 0.4v.
Core Section—5.1 square inches.
Turns per volt—1.55
Primary—372 turns of No. 16 S.W.G.
Secondary—22 turns of No. 2 S.W.G., Centre tapped.

The 14v. centre-tapped secondary, used as two 7v. windings, facilitated manufacture of the transformer by permitting the use of a lighter gauge conductor than if a single 7v. 120 amp. winding had been used.

As already mentioned, the permissible voltage range at the lamps was fixed at 5-7v., but owing to the small regulation of the transformer (0.2v. per 7v. winding), and the short supply cables involved, it was practicable to reduce the range to 5-6.5v. The lower maximum was desirable in the case of busy lamps, which would receive very heavy use. The lower voltage limit of 5v. was subject to a maximum permissible potential drop in the supply cables of 0.7v. derived in a similar manner to that shown above.

From the fuse panel one heavy lead was taken to each position, final distribution to the lamp strips being via screwed commoning strips, one per panel. Feeds were taken from the two halves of the transformer secondary to alternate switchboard positions, thereby ensuring that the loads would be kept even as additional positions were installed. The busy lamp operating circuit was completed by connecting the appropriate "earth" tags of the trunk line relay set switch jacks to commoning strips on the relay set racks whence connection was made to the centre point of the transformer secondary, by means of heavy cables. These cables were to carry also operating earth for the trunk call lamps (fed by 7v., D.C.) and were of sufficient cross-section to comply with the potential drop limit of the combined load. The 7v., D.C. earth circuit was completed by means of a cable to the exchange main earth system, to which the positive terminal of the rectifier was also connected.

EXECUTION

It is not proposed to describe in detail the execution of the work. In exchange installation works the procedure followed normally comprises mounting and erecting equipment, cabling and wiring, connecting, testing and adjusting, final test and cut-over to service, in that order. In many cases, such as the installation of a new exchange, this order will be applied to the installation as a whole, but since the project now under discussion consisted of a series of more or less independent alterations to a working installation, the efficiency of each of which could be judged only by the performance of the plant after its incorporation in the working system, it was preferable to complete each alteration separately as far as practicable. While this subdivision tended to simplify the work, there were two factors which complicated it considerably. These were:—

(a) The necessity to ensure that satisfactory service facilities would be available throughout the course of the work.

(b) The necessity to re-use in the new work practically all of the existing material components in the sections of plant to be altered.

With reference to (a), it will be apparent from the foregoing description of the design work that alterations were required in practically all circuits and that a substantial amount of structural alteration was also involved. Since all portions of the plant were heavily loaded during the busy periods of each day, the procedure adopted was to carry out as much preparatory work as possible and then to cut out of service and alter portion of the circuits during the less busy traffic periods. In the case of jack-in equipment, such as trunk line relay sets, use was made of a number of spares, manufactured for the purpose and with considerable difficulty owing to the shortage of components. In some instances, particularly as regards power supply, temporary duplicate wiring was provided. As regards (b), this was brought about by the acute shortage of many items of material owing to wartime conditions of supply. It applied particularly to switchboard components such as jack and lamp strips, keys, lamp caps, etc.

Table 3
7 Volt A.C. Supply—Maximum Load

Circuit	Lamps per position	Lamps lit per position	Load per position (amps.)	No. of positions	Total load (amps.)
Trunk Line (Busy)	130	104 (80%)	4.16	30	124.8
O/G Junction Assignment	10	Negligible	—	30	—

Cabling: The circuit alterations, re-arrangement of the switchboard face layout and provision of additional facilities as described in the foregoing, necessitated a substantial amount of re-cabling, much of which terminated at the trunk exchange intermediate distributing frame. This frame was originally designed to cater for the cross-connecting of the trunk lines to the local and multiple switchboard appearances via 6 and 10 jack testing circuits, but, subsequent to the original installation, the local appearances had to be abandoned and a considerable quantity of long line equipment had been installed and terminated on the I.D.F. Since the new arrangements involved considerable variation, both as regards the number of circuits to be provided for and the number of terminations per circuit, re-arrangement of the I.D.F. was essential. An ideal arrangement would have involved an extension of the I.D.F. which, however, was impracticable owing to the restricted floor space and the necessity to replace the heavy cabling running to the trunk test boards and the exchange M.D.F. Nevertheless, it was found possible by re-arranging some of the long line terminal blocks and by removing some non-essential miscellaneous terminations to provide all circuits proper to the trunk switchboard equipment with sufficient terminating space to allow for development to the ultimate capacity of the exchange in its present location.

CONCLUSION

Experience at the trunk exchange since the completion of the alterations has been generally satisfactory from both traffic and engineering points of view. Demand working, while still severely limited by shortage of channels, is now used to a much greater extent than previously, and its use will be extended further as additional trunk lines are constructed. The rate of failure of the 6v. lamps, which it was thought might be somewhat high pending the installation of additional appearances which would reduce the slack period voltage, has been low, replacements having approximated only 5 per cent. per annum. Maintenance attention required by the timing clock pulse relay sets has been reasonable considering the heavy use to which they are subjected but the timing clocks themselves have required more attention than was anticipated. Maintenance attention otherwise has been very satisfactory.

The work was carried out by the Hobart exchange installation staff, whose valuable assistance in bringing the project to a satisfactory conclusion, the author wishes gratefully to acknowledge.

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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. 2721—ENGINEER—TELEPHONE EQUIPMENT GROUP 3

W. B. Wicking

Q. 7.—(a) Explain the reasons for providing a test desk at an automatic exchange of the 2,000 type.

(b) Enumerate the facilities provided at the test desk [referred to in (a) above] to allow subscribers to be connected to the test desk.

(c) Explain, by reference to a schematic circuit diagram of the essential circuit elements, the procedure when an impulse ratio test of a subscriber's dial is carried out from an automatic exchange test desk.

A.—(a) Test desks are provided at 2,000 type automatic exchanges primarily to simplify the testing of subscribers' lines, junctions and individual items of exchange and substation equipment. Facilities are provided for determining readily the loop resistance between positive and negative lines, the resistance from positive or negative line to ground, insulation resistance from wire to wire or from either wire to ground, capacitance and foreign battery, positive or negative, on either leg. Special tests are provided also for dials and include measurement of speed, ratio and the counting of impulses. All the tests utilise the voltmeter as the testing instrument with high, medium and low scales, and are sufficiently accurate for general purposes.

(b) Subscribers' lines may be connected to the test desk by any of the following methods:—

(i) Dialled up by the desk attendant via the test distributor and test final selectors.
(ii) Connected via the test lines from the exchange or protector side of the M.D.F.
(iii) Connected via the test lines from the fuse or cable side of the M.D.F.
(iv) Connected via the test and plug-up lines from the M.D.F.
(v) Connected via the hospital circuits.
(vi) Connected via the trunks in and out through the normal exchange equipment.

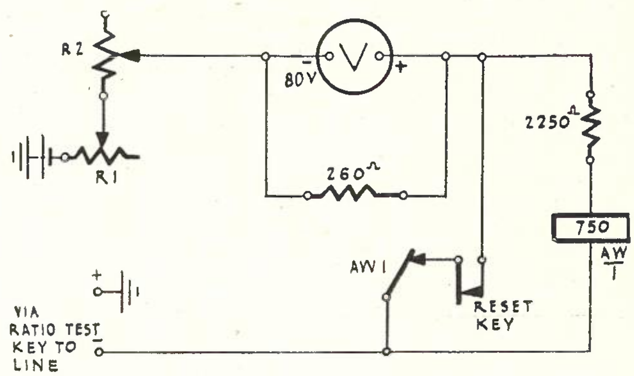

Fig. 1.

(c) The preliminary tests of the lines for insulation resistance, loop resistance, etc., having been completed, the test desk technician operates the dial ratio test key connecting the ratio test circuit to the subscriber's line, as in Fig. 1. He then adjusts the variable resistance R1 to give a deflection of 75 scale divisions with the subscriber's receiver off and the dial off normal. Next he operates the reset key and observes that the voltmeter shows a deflection of 25 scale divisions equal to the deflection for a normal dial unshunted. He now has O dialled three times, operating the reset key between each impulse train, and observes the reading indicated by the voltmeter during dialling. The voltmeter scale is calibrated to read direct in percentages, and any variation from normal is therefore read direct from the meter. A normal dial in a telephone should register approximately 36% on the meter during impulsing.

Q. 8.—A subscriber in a metropolitan area is connected to a main automatic exchange of the 2,000 type and dials B071 to gain access to the demand positions of the trunk exchange serving the area. The actual trunk positions are of the sleeve control type, and the junctions incoming from the main automatic exchange

referred to above are jack-ended with ancillaried lamp appearance.

(a) Enumerate the facilities which must be provided by the relay set associated with the junctions incoming to the demand trunk position to meet the conditions above envisaged.

(b) Explain, by means of a diagram of the relative circuit elements in both the trunk junction relay set and the operator's cord circuit, the operation of the circuit between the time the telephonist actually plugs in to answer the subscriber's call and then first commences to converse with the subscriber.

A.—(a) The facilities to be provided by the relay set at the manual end of the junction are as follow:—

(i) Light the calling and pilot lamps on the ancillary positions and operate the night alarm (if switched on).

(ii) Extinguish the supervisory lamp in the cord circuit when the operator inserts the plug to answer the call.

(iii) Operate relay TA in the cord circuit via the sleeve conductor to disconnect the test path and connect the speaking path of the operator's circuit when the speaking key is thrown.

(iv) Light the supervisory lamp in the cord circuit when the junction is released at the automatic end.

(v) Return the battery via the negative leg of the junction to give supervision, meter operation, etc.

(vi) Maintain a busy condition on the repeater at the automatic end of the junction until it is finally cleared.

(b) The simplified connections are shown in Fig. 2. On insertion of the answering plug 210 ohm battery via the answering supervisory lamp and sleeve circuit operates relay S on its 85 ohm winding. S1 operates SS, contacts of which open the lamp relay circuit, extinguishing the calling lamps, removing the short circuit from the 2nd winding of S and increasing its resistance by 5,000 ohms. Connect battery via 200 ohms and the A leg of the juncton to give supervision, metering, etc. SS locks via a contact of L.

The telephonist throws the speak-answer key KSA, operating SKA, which locks at SKA1, short circuiting its 1500 ohm coil and preventing a second SK relay from operating should another key be thrown.

SKA2 operates CK, disconnecting the calling side of the cord circuit.

SKA3 and SKA4 connect the tip and ring of the answering cord to the operator's circuit.

SKA5 disconnects the supervisory lamp and connects FA and TA in series to the sleeve circuit.

SKA6 prepares an alternate path for the supervisory lamp, while the cord circuit is connected to the position circuit.

SKA7 operates DS in preparation for dialling.

TA operates and switches the connection from the test path of the operator's circuit to the speaking channel, permitting the operator to converse with the subscriber.

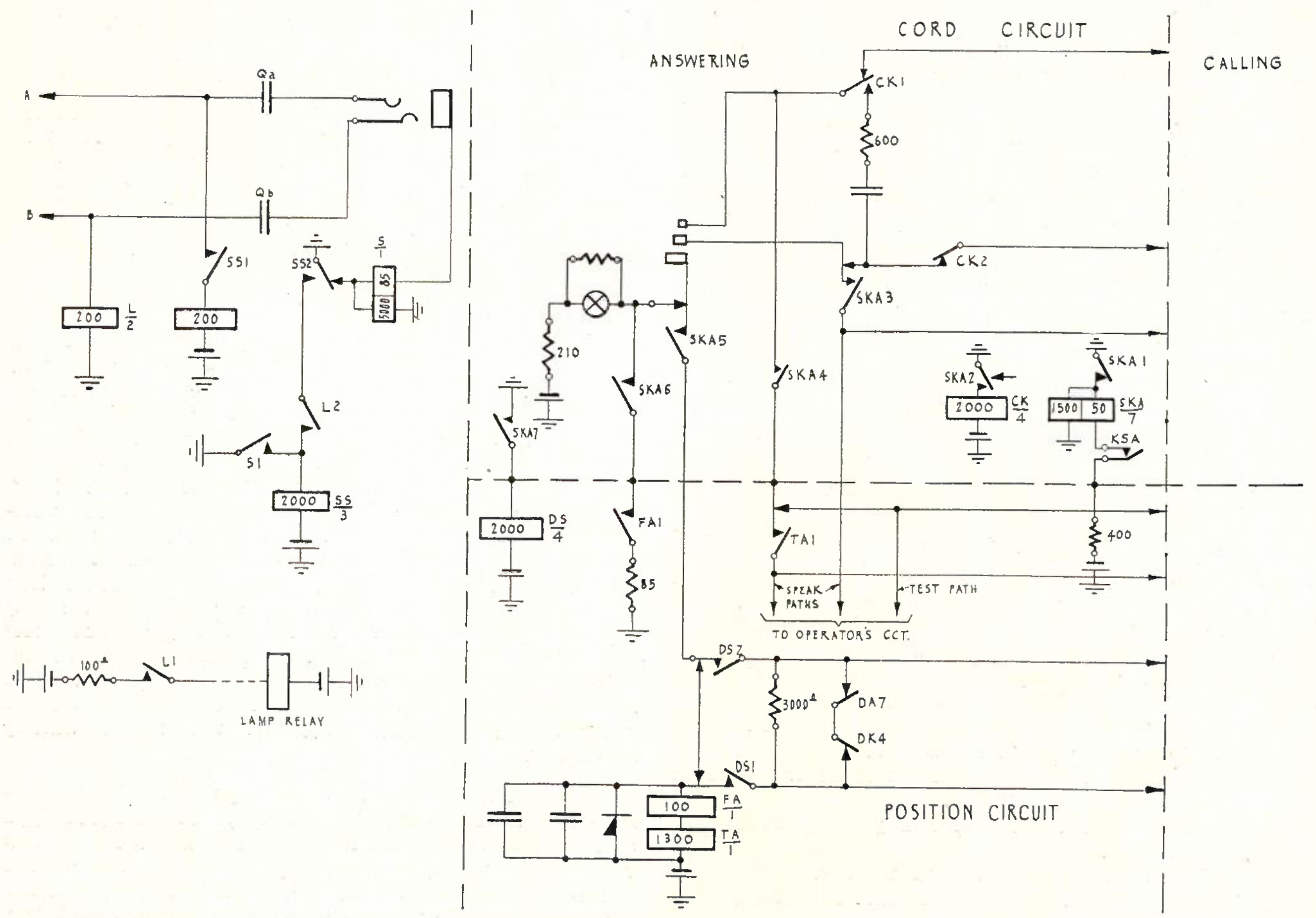

Fig. 2.

Q. 9.—(a) Enumerate the facilities provided by the latest Departmental standard pattern C.B. lamp signalling cord type P.B.X. designed for operation on 37-50 volts.

(b) Explain, with reference to a simplified circuit diagram of the relative circuit elements, the operation of the exchange line circuit provided at the above type of P.B.X. when an incoming call is received from any 2,000 type automatic exchange.

A.—(a) The facilities provided are as follow:—

(i) 6-volt lamp signalling for exchange and extension calls.
(ii) 6-volt lamp signalling for supervision on cord circuits.
(iii) An audible alarm with key control on exchange and extension call lamps.
(iv) Independent battery feed coils and positive lamp supervision on each side of the cord circuit.
(v) Night switching of all cords with any line.
(vi) "Call back" facility with both inward and outward exchange calls.
(vii) Through calls cannot be interfered with by telephonists.
(viii) No overhearing between cord circuits when two speak keys are operated simultaneously.
(ix) Trapping of following on calls on exchange or tie lines.
(x) Provision of holding and transferring on inward and outward exchange calls.
(xi) V.F. termination during switching.
(xii) Provision of tie lines from P.A.B.X. and C.B. or magneto P.B.X's.
(xiii) Tie line (restricted service) relay sets interchangeable with exchange line relay sets.
(xiv) Through dialling from extensions with switch hook supervision.
(xv) Positive supervision on tie lines.
(xvi) Battery is disconnected from cords and plugs when the cords are normal.
(xvii) Supervision of the progress of an outgoing exchange call during the dialling period is provided.
(xviii) Connection of an exchange line to another exchange line or tie line is prevented.

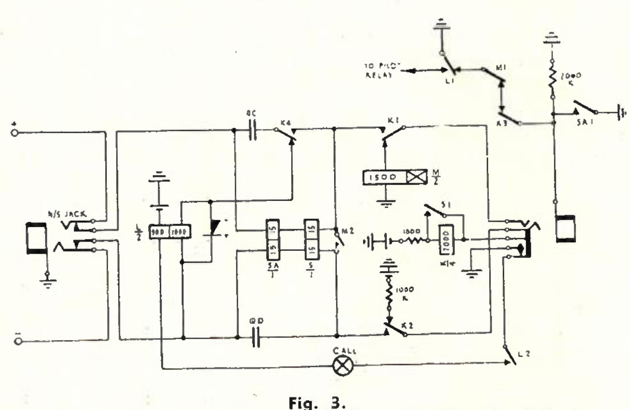

Fig. 3.
Errata.—Contact S1 should be shown as a break contact.

(b) Fig. 3 shows the elements of the exchange line circuit which, during an incoming call from a 2000 type exchange, functions as follows:—

On an incoming ring from the exchange, final selector L operates via its 1000 ohm coil and locks via its 900 ohm coil, calling lamp, contact L2 to ground at the extra springs on the answering jack. Contact L1 operates the pilot relay and night alarm. The telephonist inserts the front plug in the answering jack, extinguishing the call lamp, and throws the speaking key providing a loop via the A relay in the cord circuit to operate M in the line circuit. From ground, M relay, K1, tip of cord, A relay cord circuit, ring cord circuit, K2, 1000 ohm battery to ground. M2 closes a loop to the automatic exchange via S and SA, tripping the incoming ring and operating S from battery over the exchange line. SA does not operate, as its windings are conected in opposition. S1 breaks the short circuit on K, which operates to ground at the extra spring on the answering jack. Contacts K1, K2 and K4 connect the exchange line to the cord circuit, at the same time disconnecting M, L and 1000 ohm battery. K3 prevents the short circuiting of the 2000 ohm earth K on the sleeve circuit. The telephonist ascertains the required extension and completes the connection by means of the rear cord. The exchange loop is then extended by the cord circuit to the extension which has full switch hook control, only the 15 ohm windings of S and SA being connected in series with the positive and negative side of the line. The supervisory lamps in the cord circuit are connected in series from battery on the sleeve of the extension jack to the 2000 ohm ground on the sleeve of the exchange jack. On completion of the call the extension receiver is replaced, breaking the loop and releasing S. S1 short circuits K, which releases K3, short circuits the 2000 ohm resistance K connected to the sleeve and lights both supervisory lamps in the cord circuit. K1, K2 and K4 disconnect the exchange line from the cord circuit. K4 reconnects L to the exchange line. Should a follow-on call be received at this stage, L responds to the ring current but does not lock, and a flashing signal is given by L1 at both supervisory lamps. Normally, this does not occur, and the plugs are withdrawn by the telephonist.

The attention of the telephonist may be attracted by an extension either by intermittently operating a special recall button, where this is provided, which grounds the tip side of the line, unbalancing SA, which operates and, by short circuiting the 2000 ohm resistance A in the sleeve circuit, causes both supervisory lamps to flash. Where a special button is not provided, this effect can be produced by operating the switch hook, causing the release of S and the short circuiting of the 2000 ohm resistance K at K3. Relay M is made slow to operate so that it will saturate and ensure that contact M2 will remain closed long enough to trip the ring and prevent ringing current passing to the telephonist's receiver.

EXAMINATIONS No. 2822, 2823 and 2824—SENIOR TECHNICIAN, RADIO AND BROADCASTING, TELEPHONE AND RESEARCH ELECTRICAL THEORY AND PRACTICE

N. S. Smith, A.M.I.R.E. (Aust.).

Q. 5.—(a) What do you understand by the term electrical resonance? How is the impedance of a circuit at the resonant frequency affected when the inductance and capacitance are connected (i) in series, (ii) in parallel?

(b) An inductance of 4 henries is connected in series with a capacitance of 1 microfarad. Calculate the fre-

quency at which resonance occurs. If the resistance of the circuit is 20 ohms, what is the impedance at the resonant frequency? ($\pi = 3.14$).

A.—(a) In a circuit containing inductive and capacitive components, electrical resonance is said to exist when the reactive voltages developed across these components are equal in magnitude and opposite in phase. The net effect of these voltages will thus be zero. This condition only occurs at one particular frequency determined by the values of the inductance and capacitance.

(i) In the series case Z becomes equal to the ordinary effective resistance of the circuit and is a minimum.

(ii) In the parallel case Z is theoretically infinite, but in the practical case the impedance is a maximum, and sufficiently approximates $\frac{L}{CR}$ for most purposes, where:

L = inductance of circuit in henries.
C = capacitance of circuit in farads.
R = effective resistance of circuit in ohms.

(b)

$$f_{res} = 1/(2\ \pi\ \sqrt{LC})$$

where L and C are as above

substituting $f = 1/(2 \times 3.14\ \sqrt{4 \times 10^{-6}})$
$= 10^3/(6.28 \times 2) = 79.6$ cycles/sec.

At resonance the inductive and capacitive reactances are equal and opposite. They cancel leaving the impedance at resonance equal to 20 ohms.

Q. 6.—(a) Describe with the aid of a sketch the construction of a typical directly-heated three-electrode thermionic valve, and indicate the purpose of each of the elements.

(b) Describe the construction when indirect heating is employed, and state the advantages and disadvantages of this method of heating.

(c) Sketch typical characteristic curves showing the relationship between grid voltage and anode current for a three-electrode valve for two values of anode voltage. Use this diagram to explain what is meant by the amplification factor of a valve.

A.—(a) Fig. 3a is the conventional representation, 3b a plan view and 3c a cut-away section of a three-element valve or triode. The elements are the filament, grid and anode.

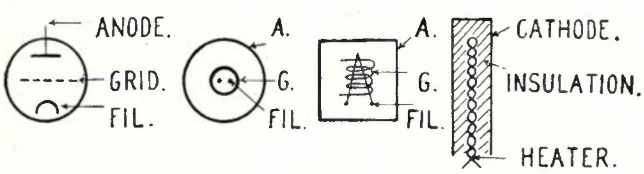

Fig. 3.

(i) **The filament** is the source of electrons by virtue of which the valve functions.

(ii) **The grid** is a spiral element close to the filament and acts to control the magnitude of the electron stream by varying the voltage impressed on it. When the grid is positive it assists the electrons on their path to the anode, when negative it retards them, and, if sufficiently so, blocks them entirely. The grid usually functions as the input circuit element.

(iii) **The anode** is a plate surrounding the above two elements and, when given a positive potential, attracts electrons emitted from the filament. Variation of the magnitude of this positive potential controls the number of electrons reaching the anode, but the grid plays a more effective part in controlling the electron flow.

(b) When indirect heating is used, the filament is enclosed by, but insulated from, an oxide-coated element which functions as the source of electrons after being heated by the filament or heater (see Fig. 3d).

Advantages:

(i) Enables A.C. to be used for cathode heating for valves, irrespective of their place in the circuit.
(ii) The emitting surface is unipotential.
(iii) A single source of power may be used to heat a number of cathodes between which a difference of potential exists.

Disadvantages:

(i) Appreciable time required to "heat" the cathode to its emitting temperature.
(ii) Slightly more complex design adds to production costs.
(iii) Heater power requirements relatively great, which reduces their usefulness in portable applications.

(c)

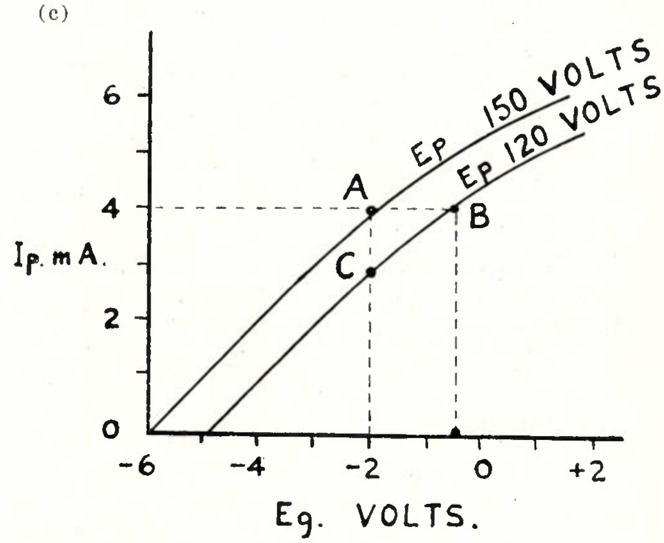

Fig. 4.

The amplification factor is a measure of the relative effectiveness of the grid and plate voltages in controlling the plate current. It is determined from the ratio, Small change in plate volts/Small change in grid volts, with the requirement that the plate current be kept constant. From the figure, with $I_p = 4$ ma, change the plate volts from 150 to 120 (A.C.). Now, in order to restore the plate current to 4 ma, we must change the grid volts from —2 to —0.5 (C.B.).

From the definition

Amplification factor =
(150—120)/(2—0.5) = 30/1.5 = 20

Amplification factor = 20.

Q. 7.—Describe the principles of operation of the Bridge Megger and state the purposes for which it is generally used. Draw a schematic diagram of the connections.

A.—The bridge megger is a development of the ordinary megger, the functions of which it combines with those of a Wheatstone bridge. The principle of the megger function of the instrument is indicated in Fig. 5.

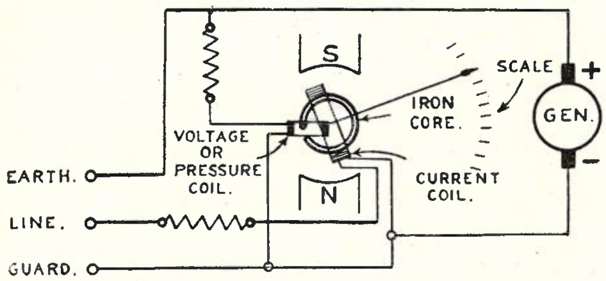

Fig. 5.

The movement of the needle is governed by the difference in currents through the voltage and current coils. The former is connected across the generator output, and the latter in series with the line or item being measured. The torque resulting from the current through the current coil is opposite in direction to that due to the current through the voltage coil, so the needle deflection is proportional to the algebraic sum of these currents.

The bridge condition, illustrated in Fig. 6, is obtained by altering the internal connections by means of a switch, thus bringing in the ratio arms and the associated ratio switch. An external calibrated resistance box is connected to terminals on the instrument.

It will be noticed that the two windings of the generator are connected in parallel to reduce the voltage and increase the current.

The pressure coil supplies a controlling force which tends to keep the needle on "Infinity," and this is the case when there is no current in the current coil (galvanometer equivalent), i.e., when the bridge is balanced. Balance is obtained by adjusting the ratio arms and calibrated resistance box for the above condition.

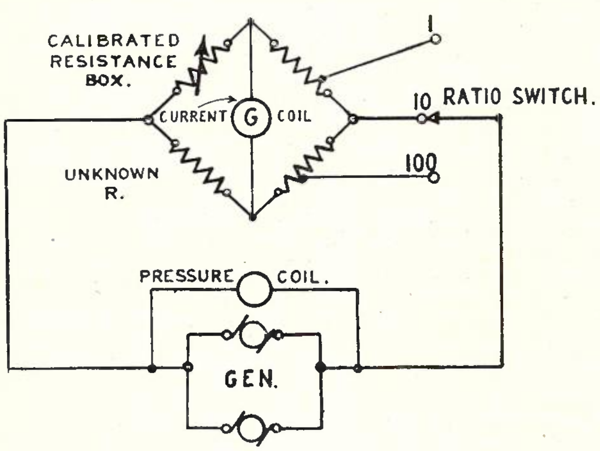

Fig. 6.

Typical Measurements:

Insulation of lines, apparatus and office wiring.
Conductor resistance of above.
Localisation of earth, contact and high resistance faults.
Measuring insulation and/or resistance of components used in communication services.

Q. 8.—(a) A motor-generator set is to be brought into operation. What precautions should be taken (i) before starting, (ii) after the machine has been running for a short time?

(b) If the machine fails to generate the required output voltage, what would be the most likely causes and what tests would you apply to locate the trouble?

A.—(a) (i) Precautions before starting:—
Check the machine for the following—
(a) cleanliness;
(b) brushes and brush-holders free from bind;
(c) brushes seating correctly;
(d) condition of commutator;
(e) bearing lubrication;
(f) armature turns freely by hand;
(g) tightness of all electrical connections;
(h) ensure that all switches, rheostats or starters are in the "off" position.
(ii) After the machine has been running for a short time, check the following—
(a) bearings of machine for overheating;
(b) brushes for sparking or other irregularity;
(c) voltmeter and ammeter readings.
(d) Failure to generate the required output may be due to—
(a) faulty commutation;
(b) disconnection in field circuit, armature or external wiring;
(c) loss of residual magnetism in field magnets.
To locate the trouble—
(a) check brushes for condition of contact face and seating; examine commutator for high micas;
(b) lift brushes from armature, connect E.M.F. to field circuit and test with voltmeter. Connect E.M.F. to armature at points 180° apart (using brushes) and test each side of commutator for continuity by bridging adjacent segments in turn with a suitable measuring instrument;
(c) if tests (a) and (b) prove satisfactory, suspect no residual in the field magnets. Connect source of low potential to the field coils for a short period, making sure that the polarity is correct.

EXAMINATION No. 2817—ENGINEER—LINE CONSTRUCTION

F. L. C. Taylor, B.Sc., A.M.I.E. (Aust.)

PART A—GENERAL

Q. 1.—Explain the objections to low or medium pressure electric power wires crossing under telephone wires. Under what circumstances might you permit such under-crossings?

When and in what manner should strain insulators be inserted in stay-wires where electric power and telephone wires are adjacent? Give reasons.

A.—(a) The lighter Departmental wires are much more prone to breakage than electric power wires. If the power wires pass below Departmental wires the possibility of contacts due to breakages is greatly increased. The presence of power under-crossings may also obstruct the erection of additional telephone wires. There may be insufficient clearance to allow provision of additional arms, and the erection of wires on existing arms would be rendered more difficult and possibly dangerous.

Under-crossings of power wires carrying voltages not exceeding 650 volts might be permitted if the power wires would not pass within 8 feet of a telephone pole. The neutral wire must be run vertically above the live wire or wires. No exceptions to these rules should be allowed, and the authority of this Department must be given in writing before the under-crossing is carried out. The existence of all under-crossings must be noted in the field book for the route and listed on Form LM2.

(b) Where a stay wire from a telephone pole passes under or close to electric mains at higher pressure than 650 volts, or in any case where the electric mains are likely to come into contact with a Departmental stay-wire, two strain insulators should be fitted in the stay-wire, one 6′ to 8′ from the telephone pole, and the other at an intermediate point between the first and the line of crossing with the electric mains, say, 6′ to 8′ distant. The installation of strain insulators ensures that in the event of a contact between the power wires and a Departmental stay, the pole or other telephone plant remains at normal potential, and does not provide a path to earth for the power currents. The provision of two insulators is a safeguard should one become defective.

Two strain insulators should also be fitted by the power authorities in stay and suspension wires attached to electric supply poles when there is a danger of contact between stay or suspension wires and telephone wires.

There are two standard types of strain insulator. Type No. 1 is used with stay-wires up to 7/14 when the power supply does not exceed 11KV. A No. 1 insulator is designed to withstand 11KV. Type No. 2 is used with 7/12 and 7/10 stay-wire for all voltages to 22KV. If the voltage exceeds 11KV., it is necessary to use No. 2 insulators with all sizes of stay-wire. If the voltage exceeds 22KV., it is necessary to provide additional No. 2 insulators in series. For example, in insulating against a 66KV. line, four No. 2 insulators would be installed. In the event of one insulator becoming defective, the remaining three would still provide effective insulation, each No. 2 insulator being designed to withstand 22KV. As a general rule strain insulators are only installed with new stays, and existing stays are not altered for the sole purpose of installing insulators. Advantage is usually taken during reconstruction work or alterations to fit strain insulators where required. There may, however, be special cases where it is desirable to insulate existing stays, for example, where small separations exist or arise, where the power contruction is below standard, or on routes subject to frequent lightning disturbance. Strain insulators should also be installed during new construction in those cases where it is known that the power authorities are likely to construct a contiguous route at a future date. It is much cheaper to instal the insulators during new construction than to equip existing stays.

Q. 2.—Enumerate the various factors which give rise to breakages in aerial copper wires and briefly indicate the aspects of construction and maintenance to which you would give particular attention with a view to limiting faults of this nature.

A.—The chief factors which give rise to breakages in aerial wires, listed in their approximate order of importance, are:—

(i) Wire fatigue due to wind sway and vertical (aeolian) vibrations. Experience has shown that these "aeolian" vibrations which cause the characteristic humming of a telephone line are the main source of wire fatigue. Failures through fatigue usually occur at terminations, ties or joints, where the bending stress is greatest.

(ii) Insufficient clearing allowing falling boughs or trees to foul the line.

(iii) Overtensioning.

(iv) Chafing against insulators and ties.

(v) Inadequate maintenance or staying, permitting marching or rocking of poles, or arms turning.

(vi) Extreme weather conditions, storm and lightning hazard.

(vii) Other forms of mechanical hazard, vehicular traffic, etc.

Careful attention to tensioning, both during erection and subsequent maintenance, is an effective means of reducing wire breakages. The number of faults due to both excessive tension and fatigue increases with tension, and it is therefore desirable to allow the maximum sag that is possible without undue danger of the wires contacting during high-velocity wind-gusts. Sag tables for copper wires, which affect this compromise for local climatic conditions, appear in Lines Engineering Instructions, Aerial W.2010, and should be closely followed. As a general rule, overtensioning is a greater fault that undertensioning, particularly in areas subject to extreme cold.

Particular attention should also be paid to joints, ties and terminations, broken or chipped insulators, the general state of the wire, particularly if second-hand wire has been used, leaning or sinking poles and turning of arms. Incorrectly-made joints, ties and terminations are more prone to act as reflecting points for aeolian vibrations, with consequent wire fatigue at those points. It should be ascertained that they are being made correctly, particularly that line wires are not being weakened in the process by the use of pliers, excessive heat, bent sleeves, too many turns in sleeves, etc. Use of the standard type tie without binding tapes can result in chafing of the line wires against binding wires or insulators, particularly if an insulator is broken or chipped. Care should be taken that tapes are the correct size and fit firmly around the wire. Movement between tapes and line wire can also result in abrasion of the wire. Any worn sections of wire or damaged insulators should be replaced without delay. In the case of a new route, care should be taken to provide sufficient staying, particularly over exposed sections. If wire breakages are prevalent on an existing route, the staying should be carefully checked, as lack of staying or looseness in existing stays may be allowing poles to lean. If poles are found to be leaning, every effort should be made to determine the cause and apply remedial measures. Poor holding ground should be securely rammed, if possible with rock filling around the butt, and stays fitted where necessary. If arms have turned, they should be straightened and squared with braces and combiners securely fitted. If the turning has been due to an unbalanced load, action should be taken to balance the load or support the arm against the unbalance. The beat method might be employed to check any irregularities in tension.

Trees, limbs and branches are a prolific source of interruption to open-wire lines and a major cause of wire breakages. Constant attention to clearing is essential. On major routes, it is desirable to remove all trees within 40 feet of the line, and any taller timber that may fall and foul the wires. Less important routes should be cleared for 20 feet. If clearance to these distances is not possible, sufficient lopping of limbs should be carried out, to minimize the danger of interference, but complete clearance for the distances specified is much to be preferred.

Q. 3.—Briefly indicate the main specification requirements of porcelain and glass insulators. What are the relative merits of each type? Explain the effects of the dimensions and shape of an insulator on its insulation resistance.

A.—Porcelain insulators should be of highly-vitrified, glazed porcelain, ivory white in colour, non-porous and free from cracks, nodules, blowholes, etc. The glazing must be uniform and present a regular surface free from crazing. The thread should be clean-cut, smooth and well-centred, of uniform pitch and free from glaze and cracks. After immersion in water for 12 hours a trunk P.L.S. insulator should have an I.R. not less than 100,000 megohms between internal and external surfaces when tested at 500 volts. The insulator is inverted and partially submerged in a water bath for this test. The cup of the insulator is filled with water and the test conducted between electrodes placed in the water inside and outside the insulator. Porcelain subscribers' type insulators must show an I.R. not less than 10,000 megohms. Porcelain insulators must withstand the following loads, applied laterally by a wire passing around the wire groove of the insulator:—

Tk. P.L.S.	1500 lbs.
Subs.	500 ,,
Terminal	1500 ,,

After three hours in an autoclave at 150 lbs. per square inch, porcelain insulators should show no sign of cracking, crazing or loss of I.R.

Glass insulators should be of transparent, colourless glass, of good quality and homogeniety, free of chips and cracks and of foreign bodies greater than $^1/_{32}$ inch in diameter. They should be reasonably free from holes, air bubbles, surface roughness and stains, and should not contain excrescences, fins or sharp edges which might injure the hands during handling. The wire groove must be free of irregularities which might damage the conductor. The thread should be smooth, well-centred and of uniform pitch. Glass insulators must have similar I.R. values to the corresponding porcelain insulators, the test being conducted between a metal spindle and a wire wrapped around the wire groove. The power factor of the glass used must not be greater than 0.009 at 100 kc per sec. Trunk and sub-type insulators must withstand lateral loads of 1000 lbs. and 350 lbs. respectively. Glass insulators must also be capable of withstanding a temperature shock test. In this test, insulators are immersed for 10 minutes in water at 120°F., then immediately for 10 minutes in water at 32°F. They are then allowed to return to room temperature and the process is reversed. During this test there must be no sign of cracking or chipping.

Porcelain insulators are less prone to breakage and show a better I.R. than glass insulators, particularly during wet weather. Because of the greater liability of breakage, current practice is to use glass insulators only on straight sections. Porcelain insulators are preferable at terminations, angles and transpositions where the working stress is greater. The poorer I.R. of glass insulators under wet conditions is due to the presence of surface alkalis which absorb moisture and form a leakage path over the surface. This may be accentuated by pitting of the alkali, allowing dirt to accumulate on the surface, or the presence of cracks in the glass.

The better class glasses, such as boro-silicate, have a very low alkali content, but are not yet available at reasonable cost in Australia. It is necessary to subject glass used locally to a special skin treatment during the manufacture of insulators, to reduce the alkali content. Transparency is one important advantage possessed by glass over porcelain, in that it discourages spiders from spinning webs inside the insulators. Leakage through spiders' webs can be very serious, particularly in wet weather, and the trouble can be

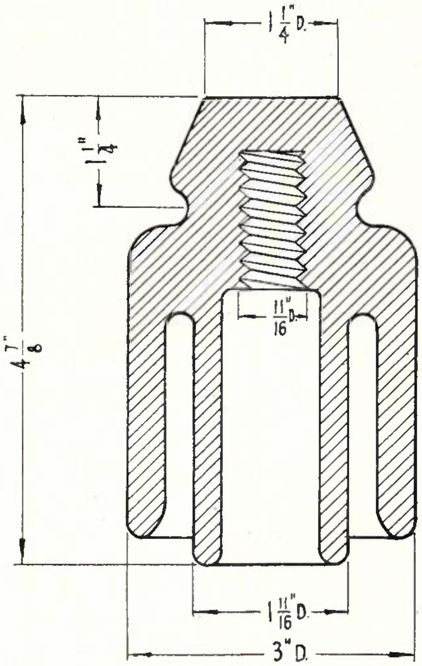

Fig. 1.

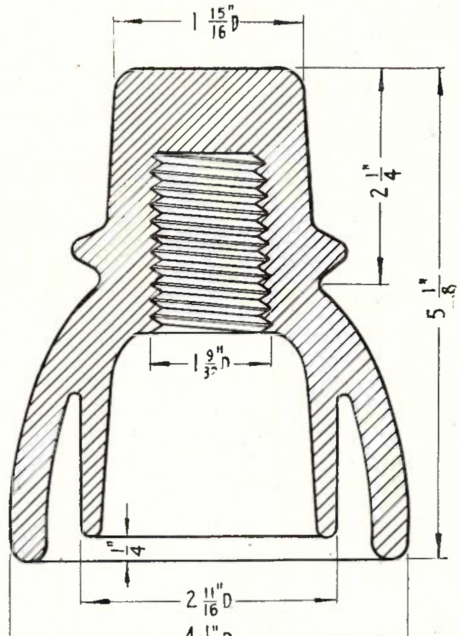

Fig. 2.

largely overcome by the use of glass insulators. On current prices, glass insulators are approximately 33% cheaper than the corresponding porcelain insulators.

As in the case of any other conductor, the I.R. shown by an insulator between wire and spindle depends on the length, cross-sectional area and conductance of the leakage path. Thus the ideal insulator should have a leakage path as long as possible and of as small a cross-sectional area as possible, with minimum conductance. The total path length may be increased by using two skirts, as in the B.P.O. type trunk insulator (see Fig. 1), and in the old Australian standard trunk insulator (see Fig. 2).

The present Australian standard trunk long-skirt insulators have a single skirt only, giving a smaller overall leakage path than either of these, but are of narrower cross-section and have a larger proportion of the path exposed to the cleansing action of rain. Tests have shown the porcelain trunk insulator P.L.S. (see Fig. 3) to have an I.R. comparable with that of the B.P.O. type insulator, which is designed for use with steel spindles, and much superior to that of the old Australian type shown in Fig. 2.

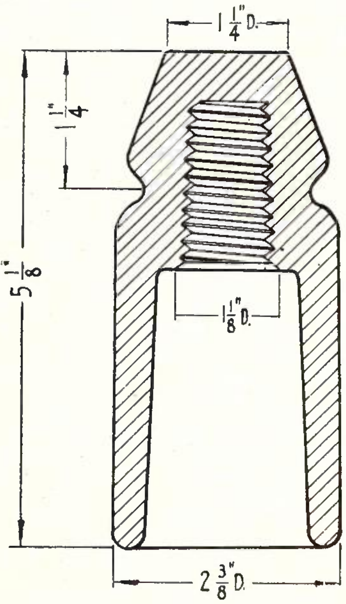

Fig. 3.

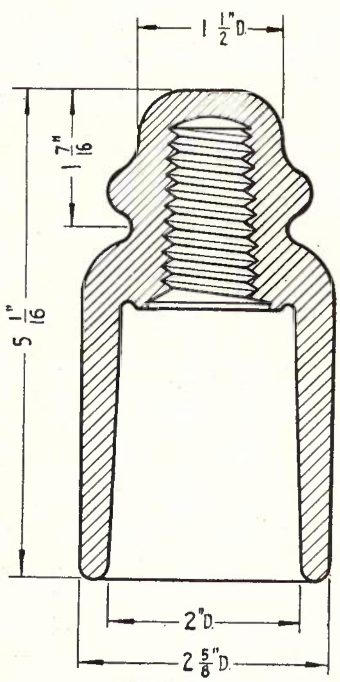

Fig. 4.

Fig. 4 shows the standard trunk glass L.S. insulator. This insulator has the same leakage path as the porcelain insulator, but, in general, provides a lower I.R., for reasons previously mentioned. The slight alteration in shape is designed to decrease the effect of cooling stresses in the glass.

EXAMINATION No. 2823—SENIOR TECHNICIAN—BROADCASTING RADIO I.

N. S. Smith, A.M.I.R.E. (Aust.)

Q. 1.—What is meant by low level and high level modulation as applied to a broadcasting transmitter? Give a block schematic of a broadcasting transmitter employing high level Class "B" modulation, and indicate the function and operating conditions of each stage.

A.—Low level modulation of a transmitter means that the process of modulation occurs at some stage preceding the final power amplifier, i.e., where the radio frequency carrier is at a relatively low level. High level modulation usually indicates modulation of the final amplifier, that is, where the radio frequency power has reached its final value. (Occasionally in a high-

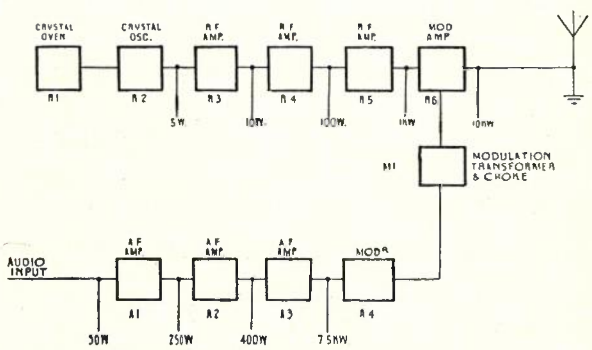

Fig. 1.—Typical high-level modulated transmitter.

power transmitter the term is used when the penultimate stage is modulated, the audio signal being at a relatively high level.)

Stage R1

The oven housing the frequency control crystal. Temperature control serves to maintain the operating frequency within the tolerance required by international regulations.

Stage R2

The oscillator valve and associated circuit operating under low load and stabilised conditions to ensure a high degree of frequency stability.

Stage R3

An R.F. amplifier stage mainly serving to isolate the crystal oscillator from succeeding stages of transmitter. It is usually operated Class A so that a constant load is presented to the oscillator stage, although Class B or C conditions may be used, provided the amplifier is not driven to grid current.

Stages R4 and R5

These are R.F. amplifying stages operated under Class C conditions for high efficiency and serve to build up the R.F. carrier level.

Stage R6 is a plate-modulated Class C power amplifier (usually termed the "modulated power amplifier") delivering 10 kW of unmodulated power to the aerial.

Stages A1 to A3 are speech amplifiers, A1 and A2 generally operating under Class A conditions. A3 may be Class A, AB or B, depending on requirements.

Stage A4 is the "modulator," in this case an audio amplifier operating under Class B conditions and delivering 7.5 kW of power to modulate Stage "R6" via the modulation transformer and choke M1.

Q. 2.—What is meant by carrier noise of a broadcasting transmitter and how is it usually expressed? What are the main causes?

Describe the principle of a method of measuring carrier noise.

A.—Carrier noise is a term used to indicate noise introduced into a broadcast programme by some condition associated with the generation and amplification of the radio frequency carrier wave. It is thus distinguished from noise due to static, radio receivers, man-made interference, programme circuits and associated equipment, etc.

It is usually expressed in decibels below 100% modulation. This will be further referred to in the description of testing.

The main causes of carrier noise are associated with the power supplies to the valves, i.e., anode and bias rectifiers, and filament supplies.

Adequate filtering of anode and bias rectifier outputs minimises trouble from these sources, but there are usually several low frequency (50, 100, 200, etc., cycles) components present when A.C. filament heating is employed, the actual frequency of the noise component depending on the particular circuit design. Modern practice is to reduce noise by a large amount of negative feedback.

Testing:—

One method of testing requires the following:—

(a) A diode coupled to the final output of transmitter.

(b) A measuring set containing a variable calibrated attenuator and an indicating meter.

The principle of testing is then:—

The transmitter is modulated to a depth of 40% with a sine wave tone of 1000 c/s. The demodulated output of the diode is fed into the measuring set and the meter adjusted for a convenient deflection with at least 60 db in the attenuator.

The 1000 c.p.s. tone is then removed and the transmitter audio input terminated in its correct impedance. The attenuator is then adjusted until the meter gives the same indication as before. The difference in the attenuator settings represents the number of decibels below 40% modulation of the audio noise components.

This value is corrected to decibels below 100% modulation by the addition of 8 db.

Representative values are 42 db below 40% modulation or 50 db below 100% modulation.

Discrimination is sometimes made between frequencies below and above 250 c/s., but the above illustrates the general procedure.

Q. 3.—What do you understand by the terms, primary service area and secondary service area of a medium frequency broadcasting station? What are the main factors affecting propagation from such a station? Distinguish between day and night transmission.

A.—The primary service area of a medium wave B/C station is usually considered as that area in which the degree of fading or presence of noise is such that reception is not noticeably degraded. It is the area served by the ground wave. Fading is not considered as being serious until the interfering signal approaches or exceeds 50% of the ground wave value. Arbitrarily selected values of field strengths required to provide a primary service area are:—

City business or factory areas	10 to 50 mV/metre
City residential areas	2 to 10 mV/metre
Other population centres	0.5 to 2 mV/metre
Rural summer	0.25 to 1.0mV/metre
Rural winter	0.1 to 0.5mV/metre

The unit mV/metre represents millivolts-per-metre and is the voltage induced in every metre of effective length of the aerial.

The secondary service area is the region served by the reflected sky wave alone, it being beyond the influence of the ground wave and thus free from the fading due to inter-action between ground and sky waves. Fading is experienced, however, due to ionosphere variations. The secondary service area exists only after sunset.

The main factors affecting propagation from a medium wave B/C station may be considered as being:—

(i) Ground conductivity and dielectric constant of soil.

(ii) Radiation characteristics of aerial system.

(iii) To a certain degree, the transmitter power.

(iv) The operating frequency.

(v) Topographical character of various reception areas, and whether city, residential, industrial or rural, etc.

(vi) Situation of transmitter site, whether in city or in open country.

In the medium frequency band it is not possible to confine radiation to paths parallel to the earth, therefore there is always a certain amount directed at various angles above the horizon.

This radiation travels upwards until it encounters an ionosphere layer (known as the "E" layer) with the following results:—

Day Suffers practically entire absorption by the ionised layer.

Night Is reflected back to earth from the layer with only moderate absorption.

Thus in daylight there is only the ground wave present, while at night both ground and reflected waves are present giving rise to fading in certain areas.

A secondary service area exists also at night as mentioned earlier.

Q. 4.—A coil of 80 microhenries inductance and 3 ohms effective resistance is connected in series with a condenser of 600 micro-micro farads capacity and negligible resistance. What is the resonant frequency of the circuit? If across the terminals of the combination a sine wave of 75 volts peak value is impressed at the resonant frequency, how much current flows and what is the voltage drop across both coil and condenser?

What is the power factor of the coil and of the whole circuit at resonance?

A.—

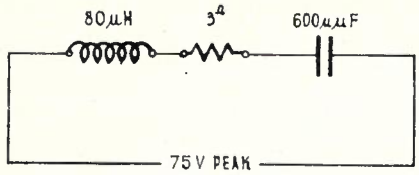

Fig. 2.

The resonant frequency of the above circuit is determined from the formula:—

$f = 1/(2\pi\sqrt{LC})$ where f = freq. in c/s. L = induct. in henries. C = cap. in farads. π = 3.14

R is small enough to be neglected in the general case.

Substituting: $f = 1/(6.28\sqrt{80 \times 10^{-6} \times 600 \times 10^{-12}})$

$= 10^{8}/(6.28\sqrt{480})$

= 727 kc/s .... (f)

At resonance Z = R = 3 ohms

∴ I = 75/3 = 25 amps. peak.

= 25 × .707 = **17.68 amps R.M.S.** .... (I)

Volts across coil $= X_L I = 2\pi fLI$

$= 2 \times 3.14 \times 727000 \times 80 \times 10^{-6} \times 17.68$

= **6450 volts** .... (E_L)

At resonance voltages across coil and condenser are equal in magnitude ∴ volts across condenser = 6450 volts .... (E_c)

Power Factor

At resonance the current and voltage are in phase and the power factor is 1.

PF of a coil equals $\cos\theta$ where θ is the phase angle between current and voltage in a coil.

$$\theta = \tan^{-1}\frac{X}{R} \text{ or } \tan\theta = \frac{X}{R} = \frac{\text{reactance}}{\text{resistance}}$$

As the current in all parts of a series circuit is the same, and as the voltage across the reactance (product of reactance and current) and the voltage across the resistance (product of resistance and current) are available from the preceding calculations, the expression

$$\tan\theta = \frac{\text{reactance}}{\text{resistance}} \text{ may be written—}$$

$$\tan\theta = \frac{\text{reactance} \times \text{current}}{\text{resistance} \times \text{current}}$$

$\tan\theta = 6450/(3 \times 17.68)$

$= 6450/53.04 = 121.7$

and $\theta = 89° \, 32'$ approx.

power factor $= \cos\theta = 0.00814$

Answers—

Frequency = 727 kc/s.

Current = 17.68 amps. R.M.S. or 25 amps. peak.

Volts = 6450 across both coil and condenser

Power factor =

(a) of coil = 0.00814

(b) of circuit = 1

Q. 5.—Explain briefly the difference between C.W., I.C.W., and speech modulated methods of radio communication. When a superheterodyne receiver used for telephony is tuned to a radio telegraph station transmitting C.W. signals, a series of clicks only is heard. Why is this, and what would be necessary to give intelligible audio frequency signals?

A.—

(a) C.W. is short for "continuous wave" and is used to indicate radio-telegraphy in which the code signals are transmitted by short and long impulses of pure carrier wave.

(b) I.C.W., "Interrupted Continuous Wave" indicates that telegraph signals are sent as in (a) but the carrier wave is broken up at an audio frequency rate. The name originated with the use of a rotating wheel with alternate conducting and insulating segments around its periphery. The R.F. carrier was transmitted during the conducting period by means of a brush contact. It is more usual to use an audio oscillator or the 50 cycle mains to provide the interruptions, the object being to enable a simple receiver to be used.

(c) Speech modulated transmission requires the **continuous radiation** of the carrier wave which is modulated as required by the speech channel input.

C.W. being a series of pure carrier wave impulses occurring at a rapid rate (radio frequency) the inertia of the diaphragms of head phones or loudspeakers prevents their responding to these impulses (apart from other characteristics of the receiver). A click is heard due to the spacing between the code elements.

To render these signals intelligible it is necessary to introduce a modulation component at the receiver, this component being at an audio frequency. After rectification, this audio frequency provides the necessary low frequency impulses to operate the phones, etc.

Two methods of providing this tone are:—

(1) Positive feed back from output to input of detector stage.

(2) In a superheterodyne receiver it is conveniently accomplished by providing an extra oscillator operating at the I.F. frequency (± several Kc). This oscillator is adjusted to beat with the normal I.F. to provide a suitable audio frequency component.

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