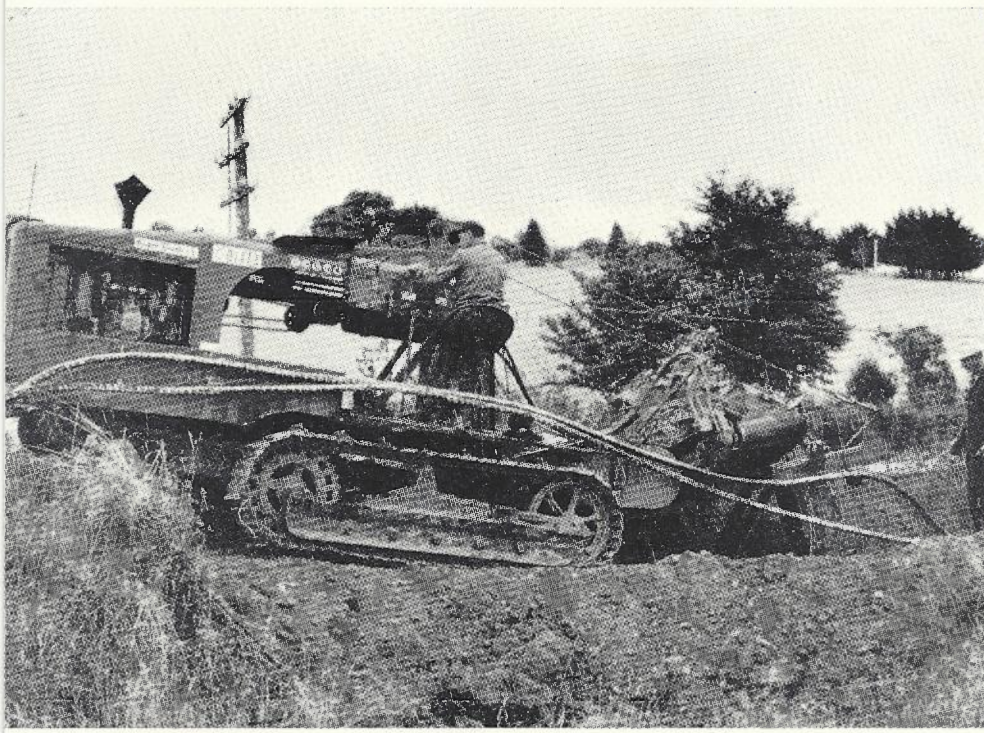
THE

Telecommunication Journal OF AUSTRALIA



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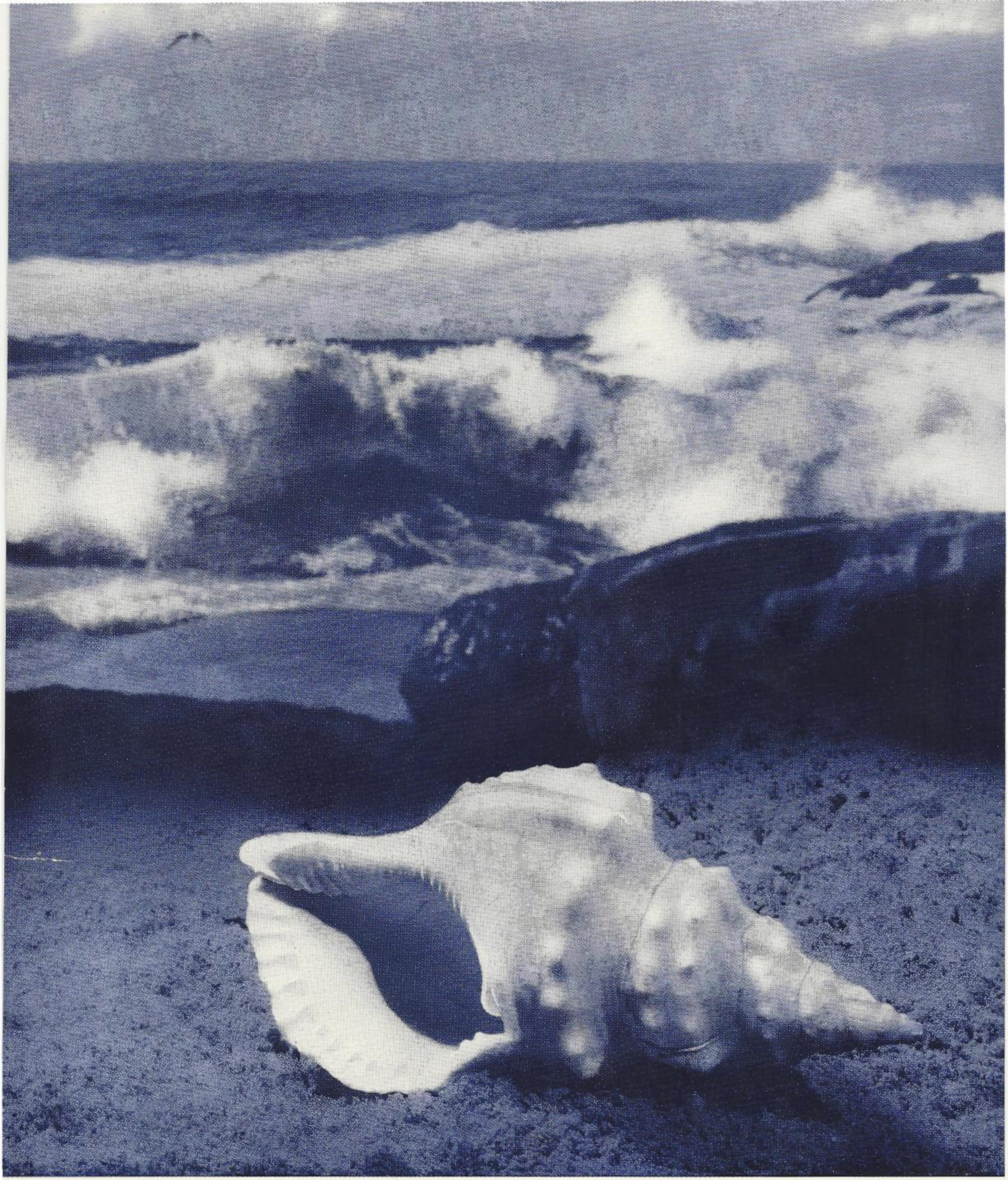

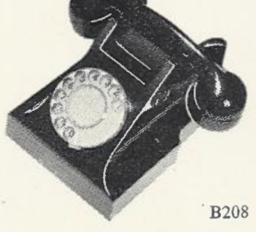

The
TELECOMMUNICATION JOURNAL
of Australia

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CONTENTS

This Journal is issued three times a year by the Telecommunication Society of Australia. A year's subscription commenced with the June issue; succeeding numbers are published in October and February. A complete volume comprises six numbers issued over two years, and a volume index appears in No. 6 of each volume.

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*For addresses see page 467

MR. N. J. McCAY, B.Sc.

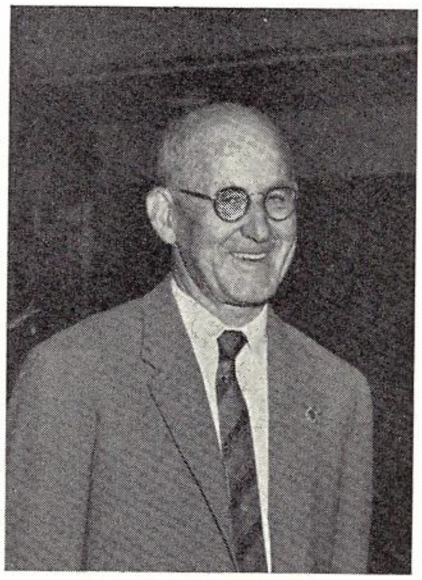
On the 1st January, 1961, Mr. Norman J. McCay retired from the position of Supervising Engineer, Research, on the Postmaster-General's Department Central Staff. Mr. McCay has had a most varied and distinguished career, not only within the Department's Engineering Division, but also in the Australian Imperial Forces during both World Wars.

Mr. McCay joined the Department in 1913 as a Clerk in the then Chief Engineer's Branch. After service in the Victorian Stores' and Accounts' Branches and a break of five years war service, he was transferred as an Engineer-in-Training in Victoria in 1921. From 1924 to 1931 he was an Engineer in the Victorian office where he worked mainly on transmission and carrier equipment. This type of equipment was first introduced into Australia during that period and Mr. McCay was one of the few engineers who installed the first Type B 3-channel carrier telephone system between Sydney and Melbourne in 1925. With this valuable background of pioneering work, he was transferred to the Central Office Transmission Section in 1931. He was promoted in 1934 to Divisional Engineer and in 1938 to Assistant Supervising Engineer in that Section.

Following his return to the Department at the end of the Second World War, Mr. McCay became the first Supervising Engineer of the newly established Long Line Equipment Section. The formation of the Section coincided with the start of a period of rapid growth in the trunk line field, and apart from the staff training difficulties normally associated with the introduction of a new organisation, Mr. McCay was confronted with many problems such as the establishment on a sound basis of the local manufacture of carrier equipment, the introduction of many new types of systems and difficulties in obtaining equipment supplies. He attacked all these problems with his characteristic energy and determination and was largely responsible for laying a proper foundation for the present large Australian carrier network.

After a short period as Supervising Engineer, General Works, Mr. McCay was promoted in 1953 as Supervising Engineer in charge of the Department's Research Laboratories. From then until his retirement, he devoted most of his time and considerable energy to building up the status of the Laboratories and its staff. Mr. McCay was responsible for effecting many improvements in the accommodation and facilities of the Laboratories and many important new developments were introduced during the period in which he was in charge. He was the Department's representative on a number of scientific and research bodies and he was well-known and respected in scientific circles.

During the First World War, Mr. McCay served in the Infantry from August 1914 to March 1920 and was commissioned in the field in France. In 1942 he joined the Australian Corps of Signals as a Lieut.-Colonel at the request of Major General Simpson, Signals Officer in Chief. His duties were "Civil Communications" which, inter alia, included liaison work with the Postmaster-General's Department who, at that time, constructed almost all of the fixed type of telecommunication services for the Armed Forces in Australia. As time went on, the Corps of Signals developed into a strong group for line construction and maintenance and long line equipment installation and maintenance. His title was changed to Staff Officer, Grade 1 (Lt.-Col.), Fixed Signals Services, and his activities covered all of the South West Pacific operational area.



MR. N. J. McCAY, B.Sc.

One of his main activities was Australian Army representative on Committee H, which was the communications committee responsible for planning fixed services for all the Armed Forces. Represented on this committee were American Army and Navy, Australian Navy, Army and Air Force, Postmaster-General's Department and Department of Munitions. Among other things, they planned and had approved by War Cabinet an Australian trunk line service strengthening and supporting the service then in existence. New routes or major extensions were planned on all main routes from Cape York through to Perth and on the Adelaide-Darwin and Brisbane-Darwin routes.

By joint effort of the Postmaster-General's Department, Australian Corps of Signals and U.S. Army Signals Corps, about half of this plan was completed and the remainder has since been completed, almost exactly as planned, by the Postmaster-General's Department. As the war centre moved north in the South-West Pacific area, Lt.-Col. McCay's group planned and executed under his personal direction a number of important new trunk routes and cables in the New Guinea area, including a submarine telegraph cable from Cape York to Port Moresby and a tree sling three-channel carrier trunk route over the precipitous Owen Stanley Ranges from Moresby to Inonda (near Buna) and later to Salamaua and Lae. Sundry local fixed type communication services in New Guinea, New Britain, Bougainville, Morotai and Borneo were also provided by his group.

In the four years in which he was associated with this work he developed the technical sophistication in the Army on fixed signals services from the Fullerphone D VIII cable stage to one on a par with the regular civil communication authorities. This, in the face of died in the wool tradition and extreme shortage of people with the necessary background and even less authority, was a tremendous feat. His application to the cause and unswerving single purposeness won him some very loyal supporters and extracted admiration from even the bitterest of his critics.

For much of the latter part of his career, Mr. McCay did not enjoy good health, but this did not deter him from entering fully into many activities outside his profession. He has been for many years a member of the Naval and Military Club, the Brighton Bowling Club, Kingswood Golf Club, and on the Council of the Brighton Technical School. He is also an enthusiastic photographer and is addicted to classical music. The Society and the Board of Editors join in wishing Mr. McCay a very happy retirement and have no doubt that with his many interests, he will have no difficulty in enjoying his new-found leisure.

REVIEW OF TELEPHONE TRAFFIC ENGINEERING – PART I

*I. A. NEWSTEAD, B.Sc., B.A., D.I.C., A.M.I.E.Aust**

INTRODUCTION

All utilities which provide services to meet a fluctuating level of demand face the fundamental problem of achieving an acceptable compromise to the conflicting requirements of plant economy and customer service. Public transport, gas, electricity and water authorities as well as telephone administrations must provide plant in sufficient quantity to meet reasonable standards of service during the busiest demand periods, even though much of it will be idle for the majority of the total service period.

These considerations arise in a telephone system in the provision of exchange common switching equipment, external trunk-lines and junctions.

Telephone Traffic Engineering is concerned with the design, dimensioning and interconnecting of these plant items from the viewpoint of securing the most economic disposal of telephone traffic, consistent with satisfactory service. This includes—

(i) The design of optimum trunking methods for inter-connecting separate switching stages to form an exchange, and exchanges to form networks.

(ii) The measurements and prediction of telephone traffic flow at all points of the switching system.

(iii) The calculation of the number of connecting circuits and switching and control devices required throughout the system to carry the telephone traffic at prescribed standards of service.

The tables against which the number of circuits required and their traffic capacity are assessed, are derived by the application of Probability theory and Statistics to form mathematical models of the appropriate telephone traffic distributions.

Despite its mathematical basis, traffic engineering demands a sound and practical knowledge of the trunking and switching detail of telephone systems. With a manual system, the control of traffic depends essentially on the control and organisation of telephonist staff. With automatic operation however, the economic disposal of telephone traffic becomes inextricably tied to switch and system engineering. Circuit provision, both internal and external, depends not only on traffic flow, but on considerations of switch outlet capacities and their allocation, the design of gradings and interconnecting schemes, the exchange and network trunking, and the digital translation and routing facilities of control equipment. Likewise, the observational and docketing routines by which traffic data is acquired in a manual system must be replaced by electrical traffic-recording equipment of various types. With electronic techniques it is now possible to achieve a high degree of automation in this work.

The importance of Telephone Traffic Engineering increases continuously with the expansion of the telephone system. In large networks the investment in common switching equipment and circuits not including subscribers plant, is of the order of £70 per line, representing in the Melbourne network, for example, capital assets of over £20M. Obviously even small increases in the traffic efficiency of circuits through improved common trunking can yield large financial savings. With refined methods of traffic measurement and supervision and more accurate bases for calculating circuit requirements, further savings could result, since it would be possible to reduce the traffic capacity margins that are normally imposed at switching stages as a service safeguard. The planned extension of subscriber dialling to national and international networks and the new types of switching equipment being introduced, poses a host of further problems, whose economic solution lies with the development of new theory and techniques in Telephone Traffic Engineering.

The value of this work is well acknowledged by the leading telephone administrations of the world. In the American Bell System, the British Post Office, in Germany and in the Scandinavian countries particularly, considerable attention is given to Traffic Engineering at the Research as well as the Operative and Administrative levels.

THE SCOPE OF TELEPHONE TRAFFIC

The activities of Traffic Engineering may be classified as follows:

(i) Traffic Measurements
(ii) Traffic Data Processing
(iii) Circuit Requirement Calculations
(iv) Trunking Design
(v) Traffic Development Work

(i) Traffic Measurements. One class of traffic measurements is made at prescribed regular intervals in order to obtain traffic data for telephone planning purposes. The most important of these is the Erlang occupancy of all circuit groups. This is usually recorded at prescribed intervals which may vary from 6 months to several years depending on the conditions of growth and stability. Other measurements in this class include holding-times and traffic dispersion data which, being more stable, need to be recorded less frequently.

The second class of measurements is used for supervision of circuit adequacy, or Congestion Supervision. These are made more frequently, say weekly or monthly, but are far less extensive and less accurate. Measurements of this class may be overflows, call-counts and particular-circuit occupancies (last-choice occupancy), or full occupancy if suitable traffic recording equipment is permanently installed.

(ii) Traffic Data Processing. This covers—

(a) The operations performed on the raw observational data to convert it into present traffic statistics.

(b) The forecasting of future traffic data, based on present traffic data and growth information, which includes subscriber growth and network trunking developments.

(iii) Circuit Requirement Calculations. The calculation of equipment and circuits required to carry known traffics at prescribed standards of service. This involves a knowledge of the switching equipment used and the trunking conditions prevailing.

(iv) Trunking Design. The design of gradings and interconnecting schemes to connect together switching stages so as to achieve an optimum economic disposal of traffic.

(v) Traffic Development Work. Theoretical and experimental investigations into the nature of telephone traffic, the performance of interconnecting schemes and gradings, etc. This includes work on analysing the traffic characteristics of new switching systems and new trunking situations.

PROBLEMS OF DEFINING SERVICE OBJECTIVES

The initial problem of prescribing standards of service on which to base common plant provision is a complex

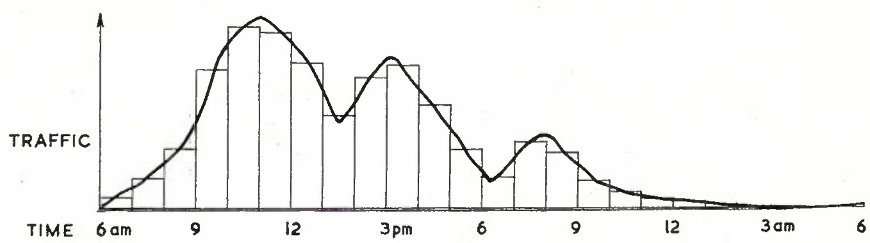


Fig. 1.

* See page 466.

Editor's Note: This article, which is a review of current world practices and theories in telephone traffic engineering, originally formed part of the report prepared by Mr. Newstead following his term of post-graduate study overseas in 1958/59 under a Public Service Board Award. The article will appear in two parts. Part I covers the background to traffic engineering, basic traffic theory, busy-signal systems and gradings. Part II will include basic theory of link systems, delay operation, traffic measuring and forecasting techniques, and will provide background information to a number of traffic problems arising from the introduction of link trunked crossbar equipment into our networks.

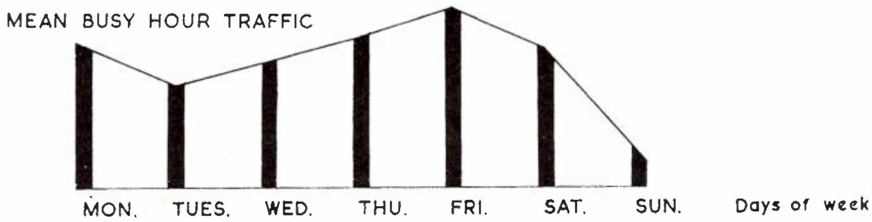


Fig. 2.

one which is receiving renewed attention in C.C.I.T.T. as well as in major telephone administrations.

Busy Hour. If the mean traffic intensity on a large group of circuits is recorded separately for each hour of the day, the form of the resulting histogram is shown in Fig. 1. If this were done as a continuous process the corresponding curve would apply. From experience, the busiest period for most circuit groups occurs between 9 and 11.30 a.m. Afternoon and evening peaks of reduced magnitude are usually found, and in cases where the traffic concerned is predominantly social in character (e.g. between exchanges in purely residential areas) the evening peak may even exceed the day peak—this effect is often due more to the longer holding times of evening calls, than their increased number.

In the past, circuit provision has been customarily based on a "busy hour" traffic. The principle of using a period of one hour is widely accepted and arises partly from convenience. There is however a more important reason in that it has been found to be a period sufficiently long to embrace a substantial sample of traffic yet sufficiently short that the average traffic load will remain sensibly constant. This constancy of load is fundamental to the traffic theories normally employed for circuit provision.

Although the idea of a busy-hour is used, there has been inadequate definition regarding:—

(i) what constitutes the busy-hour?
(ii) which busy-hours should be selected for prescribing service objectives?

As an example of the results of different interpretations of (i), simultaneous traffic measurements by two European administrations on a particular group of international circuits gave figures for "busy-hour traffic" which differed by more than 10%. Further definition is needed. In particular, should the busy-hour traffic for a number of days be:

(a) The average of the busiest-hour traffics for each of the separate days, or
(b) That traffic which, averaged over the same hour of each day, gives the highest value. This is the concept of a "time-consistent" busy hour.

Further specifications must be made as to the accuracy in placing a particular busy-hour. The C.C.I.T.T. has now adopted as a standard for international circuits the "time-consistent" busy-hour, time-located correct to the nearest quarter-hour.

Seasonal Variations

Having defined "busy-hour" traffic, question (ii) remains of selecting appropriate busy-hours from the total array of busy-hours presented over the yearly cycle.

The mean busy-hour traffic for each day of the week displays variations of the type indicated in Fig. 2. For each particular circuit group the general shape of this pattern is recurrent week by week, although the magnitude of the respective traffics will vary, since each represents a sample from an infinite population of days of that class. In estimating traffic flow it is clearly essential to include in the measurements, samples from each class of day which is to be covered in the specification of the equipment performance.

If the average busy-hour traffic for each separate week is recorded over a year, the pattern of seasonal variations is found to be of the form represented in Fig 3. Unless special conditions apply, the "week" is normally taken as the five working days, and the smooth curve is obtained by taking moving averages. The general pattern of this curve is also recurrent year by year, with a slowly increasing yearly mean, reflecting the increased telephone consciousness of subscribers.

Since the average level of traffic is undergoing continuous seasonal change, as well as the characteristic hourly and stochastic variations, a comprehensive description of the system performance would require the specification of a very large number of constraints—the service standard for the worst busy-hour of the year, second worst, etc., together with average service standards over continuous periods of various lengths; worst week, worst month, etc.

For limited traffic reading and administration cost, the problem is to seek out the minimum number of parameters, which will give an adequate description of the service to the subscribers. Parameters which are being examined include:—

(i) Average Service During the Year. This is a very difficult and costly measurement and in any case would not be adequate where there is a marked seasonal peak.

(ii) Busy Season. This is attractive in concept but is difficult to define in practice because of variability of its duration from place to place.

(iii) Busiest Week. This would be a convenient design period but it is difficult to predict in advance exactly when it will occur.

(iv) Busiest Hour. This is too short a period to engineer reliably for and in any case would result in an uneconomic provision of equipment. It is also recognised that congestion can increase for isolated periods without causing undue subscriber inconvenience.

The current practice with most administrations is to design for average busy-hour conditions during the busy season—the busy season itself is somewhat arbitrarily defined and of duration from two to six weeks. If only one parameter is to be adopted then there is little doubt that this is the one best suited to the majority of exchanges. There are some however where the seasonal peak is rather short and a very high level. An average busy season approach here results in considerable overprovision for the rest of the year. Likewise there are exchanges where the busy season is long and there is the danger that for periods within that time the service may be degraded well below the average busy season level.

An attempt is being made by A. Jensen of the Copenhagen Telephone Company to sharpen the approach to congestion specification by investigating the distribution of the busy-hour traffics throughout the year.

Fig. 4 represents the frequency distribution of the busy-hour traffics A taken over a year. Above the A-axis, the frequency f(A) is shown representing the proportion of days with busy-hour traffic in the interval $A \pm \Delta$. Below the axis is shown the corresponding congestion function E(A) for the given traffic A and a fixed number of circuits.

Although this distribution would completely describe the system performance throughout the yearly cycle, a large number of parameters would need to be specified unless the shape of the curve were known and uniformly applicable to different traffics. Statistical data so far collected suggests that exchanges might be grouped into one of a number of classes, the distribution characteristics being fairly uniform over the traffics

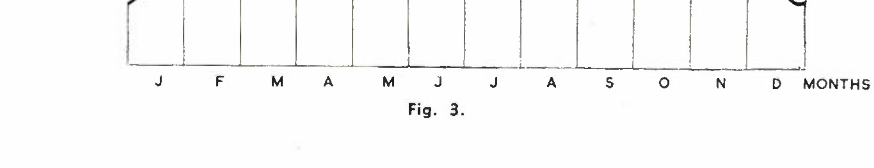


Fig. 3.

within any one class. Parameters which could be used for performance specification would be:

(i) The average busy-hour congestion experience throughout the year

$$= \sum_{A} f(A).\ E(A).$$

(ii) The risk f(r) of exceeding some critical congestion value E_c.

Practical objections to this approach are that it requires measurement throughout at least one complete year, and implies the constancy of the frequency distributions between years. Further studies on the method are being made in Denmark and Sweden.

CONGESTION STANDARDS

Having selected one or more time-parameters (e.g. average busy-hour, busy season) as the most suitable for specifying system performance, it remains to determine appropriate quantitative congestion standards. The form in which the standard is specified, depends first of all on the type of switching system.

For traffic purposes, systems are classified according to the conditions which apply when all circuits are occupied:—

Busy Signal Systems. Calls arriving at a congested switching stage receive a "busy" tone, and switching cannot take place even when circuits subsequently become free. A new call attempt must be made.

Delay Systems. Calls arriving at a congested switching stage enter a queue and are subsequently switched when a free circuit becomes available. Calls may be selected from the queue either in order of their arrival, at random, or by some form of gating procedure—e.g. the queue is divided into a number of sub-queues, each of which is dealt with in order, but selection from the sub-queue is at random.

Under manual telephony the operator effectively performs the function of a delay system. In automatic telephony, most switching stages operate as busy-signal systems since:—

(i) The provision of automatic queue-seats and queue control equipment is complex and costly.

(ii) With the larger values of traffic normally encountered in automatic operation it is practicable to engineer for low probabilities of congestion whilst still retaining high traffic efficiencies.

Automatic delay working is therefore used only when the volume of traffic concerned is small and the cost of the associated outlets high, for example, the provision of markers and common translator equipment in register controlled systems. Although the number of calls to this type of equipment will be high, the traffic is small because of the very short holding time necessary to perform the function. With increased use of fast common-control equipment in electronic and semi-electronic switching systems, delay theory will assume an increasing importance.

Congestion Standards for Busy Signal Systems. With busy-signal systems, the congestion standard is specified by the probability of a random call finding all circuits occupied in the particular section of trunking concerned. This probability is known as the "Grade of Service". Experience has shown that, for the larger traffic groups in local networks, busy hour grades of service in the range .01 to .001 at each switching stage provide a sufficiently low probability of congestion to be accepted as a reasonable service by subscribers and at the same time ensure an economic traffic loading on switching plant. On more expensive trunk circuits, the circuit provision is less liberal, with grades of service typically in the range .03 to .01.

Various attempts have been made to establish a sounder economic basis for the selection of congestion standards. An early approach was to provide switching equipment until the revenue lost by calls meeting congestion was just balanced by the marginal cost of providing and maintaining an additional circuit. However, unless congestion is severe, calls are rarely "lost" (i.e., abandoned) but generally repeated. Thus the marginal switch costs must somehow be equated to the subscriber inconvenience in having to repeat calls. The difficulties in assigning a quantitative measure to an "inconvenience function" which would also be highly subjective, have prevented an analytical solution of these lines.

Rapp of L. M. Ericsson Company Sweden, recently outlined an approach covering wider economic considerations in system administration. He defines two cost functions, F and G.

$$F = f\,(A.\ E,\ \ldots). \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

where A is the traffic and E the congestion standard. This represents the cost to the administration in handling traffic. It consists of internal and external plant costs as well as "action costs" as a result of congestion, faults or subscriber complaints.

$$G = g\left(\int_{A} E.\ dA\right) \quad \ldots\ldots\ldots\ldots \quad (2)$$

This represents the costs to the subscriber in not getting his connection when required, due to congestion or fault. The objective should be to minimise the total cost function (F + G.) This would require, not only a detailed analysis of telephone administration costs, but far greater knowledge than is at present available of subscribers' behaviour under fault and congestion conditions. However, these investigations could be well worth while in determining a sounder economic basis for the telephone policy of an administration.

Variable Grade of Service. If the average **overall** loss for the system is specified, it is then practicable to apportion this so as to provide the optimum economic grade of service at each of the separate switching stages. This optimum is attained when the cost of achieving a fixed incremental improvement in the grade of service is the same for each stage.

This approach can readily be extended to determine optimum economic grades of service on small circuits. A constant grade of service criterion leads to very low traffic capacities on groups of only a few circuits. It is generally agreed that a less liberal grade of service is reasonable on these small circuit groups in the interest of economy. Traffic capacity tables which provide for an equal marginal traffic efficiency at all points achieve this effect. They also ensure that, for any arbitrary break up of a given number of trunks, the total traffic carried will be maximised.

These principles were first established by K. Moe of the Copenhagen Telephone Company and were subsequently expanded by A. Jensen (1). Traffic tables of this type are used in Denmark and in a modified form in Sweden. The paper by B. Marrows for the Second Teletraffic Congress (The Hague 1958) further develops these concepts with particular reference to circuit provision on small groups, and shows that upper and lower bounds to the slope of acceptable traffic capacity tables are given by the two criteria,—equal grade of service, and equi-marginal utility, (2).

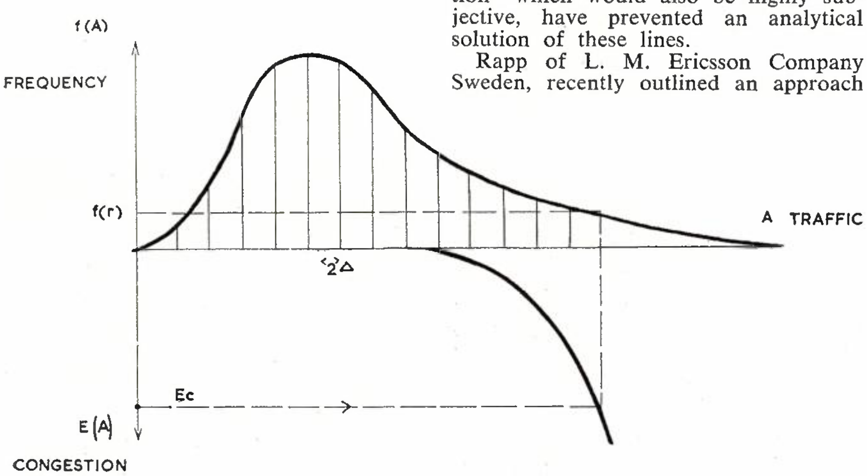


Fig. 4.

SUMMARY OF OVERSEAS STANDARDS (Local Networks)

British Post Office. Standards are based on busy season conditions, but busiest hours are used. This results in a higher level of measured traffic (5% to 15%) than for a time-consistent busy hour.

There is a current campaign in the British Post Office to cut the costs of the automatic service, and attention is being focussed on the question of reducing the grade of service provided at various switching stages. A "Grade of Service" committee has been formed whose terms of reference are "To determine what further reduction in grade of service can be made to achieve economy of operation consistent with satisfactory service to the public". An important change made so far has been to reduce the grade of service from one in 500 (.002) to one in 200 (.005) for all switching equipment in linked-numbering schemes. Whereas the .002 standard contained an overload provision—that a further 10% increase in traffic would not degrade the service below .01, the proposed .005 standard does not. However, a similar safeguard may be introduced if it is considered necessary after further operational experience at the new level. They also consider that Erlang-based traffic tables tend to over-provide, particularly at final selectors. (This fact was appreciated some years ago in the Australian Post Office and a .005 table has been used for final selector provision for some time). The B.P.O. are undertaking tests in which the number of final selectors is systematically reduced in controlled groups, whilst simultaneous traffic and overflow records are taken. They hope by this way to establish what is a workable minimum grade of service. Although early thoughts were that a 1 in 50 Erlang-table might be used, the results so far indicate that any reduction below about 1 in 200 can be dangerous because of the rapid build-up of repeated attempt calls with further traffic increase.

Holland. Present standards are based on a time-consistent busy hour during the busy season. However, they intend to adopt a two-hour period, rather than a single busy-hour, in local networks. They believe that the traffic intensity over this longer period will still be relatively constant and that the extra advantage of doubling the amount of traffic data for the same traffic reading cost outweighs the loss of an identifiable busy hour.

Germany. Present standards are related to average busiest-hour conditions during a week selected to lie near the middle of the busy season. The busiest hour of each day is determined to the nearest quarter hour. Erlang loss probabilities of .01 are used for primary equipment and .02 for most other switching stages in local networks. For small circuit groups the grade of service is increased to .05. Compared with other countries these losses are high, but the use of the busiest hours rather than a time-consistent busy-hour leads to inflated traffic figures.

They propose however to change to the time-consistent busy-hour taken over two weeks in the busy season. With the changed time-parameter there will be an adjustment to the grades of service adopted.

Denmark. Standards are based in the busy week of the year, using a time-consistent busy-hour. In Copenhagen a fixed hour 9.30-10.30 a.m. is used for all circuit groups, unless there is known to be a significant departure from this period.

Studies have shown that, due to the presence of slow variations in the traffic intensity, a 90-minute period would provide a more accurate measure of average congestion when used in conjunction with Erlang theory, but they do not consider that the difference is sufficient to justify a departure from the concept of the busy-hour.

Sweden. Here a time-consistent busy-hour is also adopted, but extending over the busy season. Grades of service of .002 are used for trunking within an exchange and .01 for junctions.

The L. M. Ericsson Company which is prominent in the traffic research field also supports the approach of Jensen (Copenhagen Telephone Company) in attempting to arrive at a traffic density distribution function to cover the cyclical seasonal variations and is assisting in this work.

U.S.A. Service standards vary widely in the U.S.A. not only between the Bell System and the Independent Companies, but also between the Bell Companies themselves. In the past, the majority have attempted to provide for average busiest-hour conditions over the three busiest months of the year. Traffic measurements over such a long period are necessarily based on sampling and are subject to large sampling errors.

A new approach being introduced through the A.T. & T. headquarters organisation is to adopt a time-consistent busy hour for the 10 high days during the busy season. Although this will be the principal parameter, they are also studying the effects on the average busy season conditions, on the busiest day conditions, and on the average service throughout the year. It may be that a second parameter is needed to specify congestion standards adequately.

This applies particularly to final routes in an alternate routing system where the daily variations in average traffic can be such that any statement about the average service will not give an indication of the very much poorer service which will result on the few heaviest days. An additional service criteria for these days seems to be necessary.

Although the time consistent busy-hour will be applied in local networks, the principle of the busiest hour of each day will probably be retained for toll circuits where the daily variations in the busiest hour tend to be systematic—this is mainly because toll traffic characteristics are dominated by relatively small group of calling sources with definite trunk call patterns. With larger local network traffic, the variations of busiest hour traffic about the mean busy hour are more the normal statistical fluctuations associated with sampling from a population of this type.

The present service objective with step-by-step equipment is for an overall loss of 4% on Poisson theory, not including line-finders. This corresponds to about .01 grade of service at each switching stage. The line-finder standard is for not more than 1.5% of calls delayed more than 3 seconds in receiving dial tone. Similar standards apply to cross-bar systems with a further specification that the matching loss (internal congestion) in link trunking shall not exceed 2%.

With the new approach of circuit provision based on the 10 high days, these standards will be revised to provide for somewhat greater losses, e.g. line-finder delays will be of the order of 5-8% exceeding 3 seconds. Special attention will be needed to the specification for the markers in the No. 5 crossbar system which are operated at a high occupancy on a delay basis. It follows that their overload capacity is small and the service rapidly deteriorates in a non-linear fashion with increasing traffic. If there are any significant peaks over the 10 high days, the average service given can therefore be very much worse than the service under (fictitious) conditions of average traffic.

Looking further ahead, projects at present in the research stage offer the future means of continuous traffic measurement and supervision. When these facilities are available there could well be a completely revised approach to congestion service objectives, possibly along the lines being examined by Jensen in Denmark.

CONGESTION STANDARDS FOR DELAY SYSTEMS

In delay systems the congestion standard is expressed by the probability of exceeding a delay of specified duration. This is the delay distribution function $\Phi(t)$ where $\Phi(t) = P\ (D > t)$ .... (3).

In practice however, only one or two points are selected from $\Phi(t)$ for specification. Parameters commonly used are $P\ (D > o)$ and $P\ (D > kh)$; these are respectively, the probabilities of delay, and of a delay exceeding k times the mean call duration h. The average delay on all calls, and on calls experiencing delay, are also useful parameters. It should be noted that, for a given delay distribution $\Phi(t)$, the specification of any single parameter automatically determines all the others. However, with different trunking situations the emphasis will change as to which is the more important service criterion—some trunking demands that the probability of *any* delay be of a specified low value, in other cases a fair percentage of delayed calls is of no consequence, the important criterion being the proportion for which the delay exceeds some critical maximum period.

Practical delay standards vary widely depending on the type of circuit and the method of traffic disposal. The Bell System engineer manually controlled toll circuits for an average delay of specified duration, either 8, 15, 30, 60 or 120 seconds. On the majority of toll groups the standard is 30 seconds, or 1/10 of average call holding time of 5 minutes. On the other hand, with electronic common control equipment where the holding time may be only of the order 20-50 milliseconds, delays of several times this figure can be tolerated.

BASIC TRAFFIC THEORY

Although the foundations of modern telephone traffic theory were laid in the early 1920's the scope and importance of this work has expanded with the evolution of the telephone service. The development of traffic theory is an integral part of telephone development and arises from a continuous need to:

(i) Achieve greater accuracy in circuit provision as the amount of capital investment in telephone plant increases.
(ii) Maintain the service standards of congestion as the network grows in size and complexity.
(iii) Develop means for improving the traffic efficiency of existing trunking.
(iv) Achieve an optimum design of new types of switching equipment for the economic disposal of traffic.
(v) Assess the traffic capacities of new trunking arrangements and for telephone traffics of different characteristics.

In meeting these requirements Traffic Research Engineers are aided by:—

(a) The availability of new and more powerful mathematical techniques in the joint fields of Probability and Statistics.

(b) The development of electronic analogue and digital computers for the solution of mathematical problems and for the direct simulation of traffic engineering problems.

(c) Acquisition of additional knowledge concerning the practical behaviour of telephone traffic through experience of existing networks.

All the major telephone administrations and manufacturing companies employ traffic research engineers. L. M. Ericsson Telephone Company, Sweden, and the Bell Telephone Laboratories, U.S.A., are leaders in this field, both having active teams of traffic research engineers who work in close liaison with the telephone operating companies as well as the equipment designers. The British Post Office also has a team of five engineers devoted to traffic research in the Telephone Development Section of the Engineering Department.

As an example of the type of investigations made, the following summarises present projects being undertaken by the L. M. Ericsson group.

(i) Congestion and traffic capacity studies on link-trunked crossbar switching stages. These include traffic simulation trials using the high speed digital computer BESK in Stockholm.
(ii) Studies on marker provision under conditions of delay working and limited access.
(iii) Observation and measurement of subscribers' behaviour under various congestion situations. This is being carried out in collaboration with the Swedish Royal Board.
(iv.) Studies of the economics of congestion supervision both from the equipment and administrative viewpoints.
(v) Congestion studies of networks with alternate routing and crossbar switching.

The Stochastic Nature of Telephone Traffic

Telephone traffic arises from the occupancy of circuits in carrying telephone calls. The state of occupancy of a particular group of circuits will vary with the interplay of new calls arriving into the group, and the termination of existing conversations. This process forms a series of discrete states in continuous time. This is represented in Fig. 5 where n(t) is the instantaneous circuit occupancy.

Although the precise moments at which call arrivals and departures will occur cannot (in general) be specified, it is possible to describe these events in terms of probability distributions and the process is termed "stochastic". The basic task of telephone traffic theory is therefore to formulate probability models appropriate to the particular traffic situations encountered, from which may be deduced the essential properties of the processes taking place. In telephone traffic engineering, the most important properties to be described are the probability function for the states of occupancy of the system and the probability distribution of the times spent in these states.

Since we are normally concerned with system behaviour over some finite period of time, the telephone traffic on a group of circuits is defined as their mean occupancy over a specified interval T.

$$A = \frac{1}{T}\int_{t=t_o}^{t_o+T} n(t)\,dt \quad \ldots \ldots \ldots \ldots (4)$$

where the telephone traffic A is measured in Erlangs. The Erlang was adopted as the unit of telephone traffic at the 1948 Plenary Congress of the CCIF in Geneva. The name was given in honour of A. K. Erlang, a pioneer worker in the field of telephone traffic engineering. The previous unit was the "Traffic Unit" which is identically equal in magnitude to the Erlang.

If P(n) is the probability function for the states of occupancy n(t) during the interval t_o, $t_o + T$, it follows that the traffic is also given by

$$A = \sum_{n=o}^{N} n\,P(n) \quad \ldots \ldots \ldots \ldots \ldots (5)$$

where N is the upper bound to n(t), in practice, the total number of circuits provided.

It follows from the definition (4) that the traffic in a given period will depend not only on the number of calls handled during the period, but also on their durations.

$$\text{Hence } A = C\frac{\bar{h}}{T} \quad \ldots \ldots \ldots \ldots \ldots (6)$$

Where C is the total number of calls handled in time T and $\bar{h}$ is their mean holding time.

BUSY SIGNAL SYSTEMS—FULL AVAILABILITY

In recent years there has been considerable development in the theory of stochastic processes and its application to a vast range of basically similar problems arising in widely differing fields. These include problems in genetics, nuclear physics, chemistry, queueing, service and storage schemes. Stochastic process, particularly those of a type known as Markovian, are also applicable to the description of a number of fundamental problems in traffic engineering. There has therefore been a re-examination of the earlier work of A. K. Erlang and others, and several writers, notably A. Jensen (3) and R. Syski (4), have shown that the early results were special cases of a much more generalised theory of congestion.

Erlang's Solution

Erlang's well-known equation for busy-signal systems relates the grade of service B to the number of trunks N and the offered traffic A:—

$$B = \frac{A^N}{N!} \Bigg/ \sum_{y=0}^{N} \frac{A^y}{y!} \quad \ldots \ldots \ldots (7)$$

This result is derived from a number of basic assumptions regarding the characteristics of both the originating traffic and the switching system. The main underlying assumption are:

(i) Calls arrive individually and collectively at random. The probability of a call arrival during time $\Delta t = \lambda \Delta t$ where λ is a constant, termed the birth coefficient.

Hence it follows that the call arrival distribution follows the Poisson Law

$$P(\gamma) = \frac{1}{\gamma!}(\lambda t)^{\gamma} e^{-\lambda t} \quad \ldots \ldots \ldots (8)$$

where $p(\gamma)$ is the probability of exactly γ calls arriving in time t.

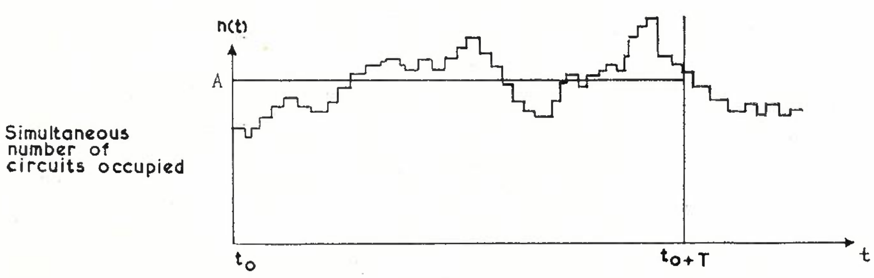


Fig. 5.

(ii) Calls leave the system at random. It follows that the probability of a conversation terminating in the small time interval Δt is independent of the previous duration of the call, and equal to $\mu \Delta t$ where μ is a constant, termed the death coefficient; μ is equal to the reciprocal of the mean holding-time of calls, h. This assumption leads to a (negative) exponential distribution of call holding-times.

$$P(T>t) = e^{-\frac{t}{h}} \quad \ldots\ldots\ldots (9)$$

(iii) Calls which arrive when all circuits are busy are 'lost', and cleared from the system.

(iv) The system is in Statistical Equilibrium. This implies that there is a stationary distribution P(j) of the probability of being in any prescribed state of j circuits occupied.

(v) Full availability trunking applies. That is, every calling source has access to every outlet.

With these assumptions, the realisations of the possible states of occupancy 0, 1, 2, . . . j, . . .N of the system form a Markov process, since the probabilities of transition from state j at time t depend only on j and t and are independent of the previous history of the system. The equation of state is then—

$$P(j, t + \Delta t) = P(j-1, t)\lambda\Delta t + P(j+1, t)(j+1)\mu\Delta t + P(j, t)(1-\lambda\Delta t - j\mu\Delta t) + 0(\Delta t)^2 \quad \ldots\ldots\ldots (10)$$

Rearranging (9) gives the partial differential equation—

$$\frac{\partial P(j,t)}{\partial t} = \lambda P(j-1, t) + (j+1)\mu\, P(j+1, t) + (1-\lambda - j\mu)\, P(j, t) \quad \ldots\ldots (10a)$$

There are also two boundary equations for the special states O and N.

By assuming statistical equilibrium, the left hand side of equation (10a) becomes equal to zero and a simple recursive solution is possible, giving the familiar Erlang result.

It is possible however to obtain a more general solution using probability Generating Functions which enables the transient behaviour prior to equilibrium to be examined.

By suitable modification of the birth and death coefficients and the equation of state, other mathematical models may be constructed describing telephone systems with different underlying assumptions.

DEPARTURES FROM ERLANG CONDITIONS

Although in many situations the Erlang assumptions provide a reasonable description for telephone traffic, there are others in which the conditions are very different. The resultant level of congestion in these cases can differ significantly from that predicted by Erlang theory. New assumptions are needed and it is the work of traffic theorists to develop more realistic stochastic models for the changed traffic situations that can arise in practice. Current work in this direction is discussed in the following paragraphs.

Limited Number of Sources. The Erlang assumption (i) requires that the probability of a further call is independent of the number of calls in progress. This implies an infinite number of calling sources. In practice, where the number exceeds about 200, there is little error introduced by assuming it to be infinite, but where the traffic originates from only a few sources—subscribers, or selectors at a previous stage, the actual congestion will be considerably less than predicted by Erlang theory. Some administrations use a distribution due to Engsett in these cases, but the expression is complicated and tedious to evaluate. Moreover, there is known to be a marked divergence in intensities between the calling sources, whereas Engsett theory assumes a uniformity in calling strengths. Work in the French administration and the Bell Laboratories has shown that the distribution of calling strengths is approximately exponential. There is also a reduction in effective calling sources due to the fact that some subscriber will be receiving calls and therefore not in a position to originate them. In accounting for these effects in practice, Bell Laboratories Traffic Engineers use a uniform strength theory but with an effective number of subscribers equal to one-half of the actual number.

Similar considerations apply to traffic which terminates on small groups of subscribers (final-selector traffic), where the limitation in terminating sources will also modify the probability distribution of the states of occupancy.

The effect of a limited number of sources is to cause a progressive reduction in the value of the birth coefficient λ as the occupancy j of the circuit group increases. If the S calling sources have uniform intensity there will be a linear decline in λ as indicated in Fig. 6a. If the calling strength distribution is exponential, the variation in λ will be of the form of Fig. 6b.

Where the calls originate, not from subscribers, but from the N switches of a previous stage, the mechanism is rather different. Here the switches act as pseudo-sources, but there is no marked reduction in λ until all switches are occupied, at which point $\lambda = 0$ (See Fig. 6c).

Effects of Congestion. Congestion at a previous stage will modify the call arrival distribution at the subsequent stage. This has the effect of 'smoothing' the traffic, that is, reducing the ratio of variance/mean below the value of unity which applies to pure-chance traffic. There will also be a modification to the call arrival distribution at the congested stage itself due to the presence of repeat-attempt calls. Although the effect is small for normal levels of circuit provision, it builds up rapidly as the grade of service exceeds a critical region at values around .05. Beyond this point the actual congestion experienced can be very much worse than that predicted by Erlang theory due to the positive feedback of repeat-attempt calls. J. W. Cohen (6) has investigated this effect for the Netherlands P.T.T. together with the subject of non-uniformity in calling strengths.

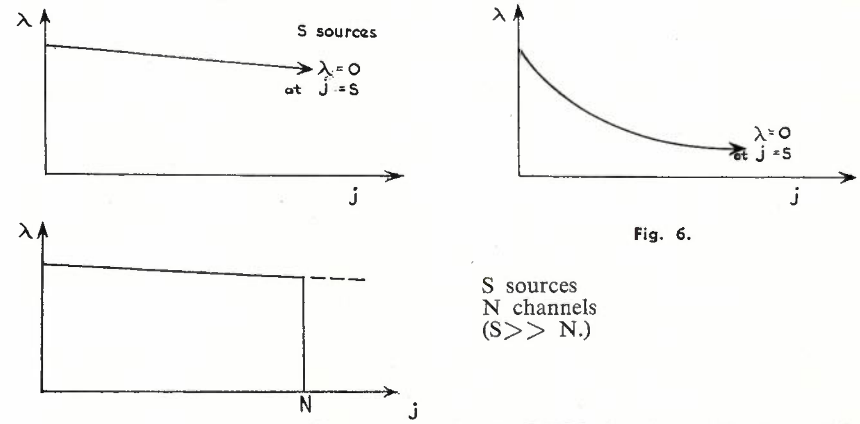


Fig. 6.

S sources
N channels
(S>> N.)

In investigating these questions the Bell Laboratories have also studied the effect of repeated calls under conditions of both exponential and constant return times and are gathering data to verify the results of their calculations.

Re-entrant Traffic. In small isolated exchanges where a combined primary (line-finder) and final selector stage is used, some account must be taken of the auto-correlation of the traffic on local-local calls, e.g., on an Erlang basis 10 circuits can carry 3.4E of pure chance traffic at a grade of service of .002. If, however, this traffic is made up of 2.4E outgoing and .5E local-local as illustrated in Fig. 7, it can be shown that the grade of service on external calls is .0047 but on internal calls is .015.

Although the effect is slight in large groups, account must be made in smaller exchanges of this type. The Bell Laboratories are developing modified tables and are checking their results against simulation trials. In Sweden also this effect is being studied in connection with their crossbar R.A.X.

Disposal of Lost Calls

Under Erlang assumption (iii), calls which encounter congestion are either

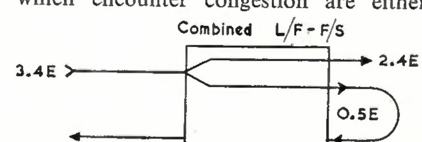


Fig. 7.

cleared from the system, or else repeated only after a sufficiently long interval that that they may be regarded as another random call.

The Bell System favours an alternative approach known as "lost calls held". It is assumed that the calling source continues to demand service and seize the first free channel. In practice this would correspond to repeated attempts being made at very close intervals. In assessing the lost calls however, only the first attempt is included. This assumption carries with it the further condition that the duration of the call is considered to commence at the instant that the first attempt was made. Although an artificial condition, this simplifies the analysis, and corresponds to a compromise between "lost calls cleared" and "delay" modes of operation.

The 'lost calls held' assumption leads to an expression of Poisson form for the grade of service;

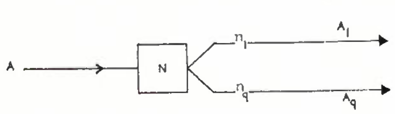
$$B = \frac{A^N}{N!} e^{-A} \quad \ldots\ldots (11)$$

Congestion occurs not only in the state j = N, but also in the hypothetical states j>N which are inadmissable in Erlang theory.

Since $\lim_{N \to \infty} \sum_{y=0}^{N} \frac{A^y}{y!} \longrightarrow e^{A}$, it is clear that the Erlang expression converges with the Poisson for good grades of service. The typical Bell System standard of congestion of .01 (Poisson) corresponds roughly to an Erlang .004 provision. Most traffic capacity tables used in the Bell System are based on the 'lost-calls held' assumption.

Tuncation & Partitioning of Telephone Traffic

Whereas early traffic theory was concerned with the congestion in a single full-availability group of circuits, recent research (7) has examined the interaction effects of other groups trunked from the same switching stage. Assume that traffic A is offered to a switching stage of N circuits, thence it divides amongst q outgoing levels equipped with $n_1 \ldots n_q$ circuits respectively, the traffic offered to these levels being $A_1 \ldots A_q$.



The state of occupancy on any particular level is influenced by the occupancies on the other (q–1) levels. Using essentially combinational methods expressions for the traffic capacity of a group of circuits may be developed as a function of q, the total number of levels in use. Assuming that the partitioning of the total occupancy amongst the various levels follows a hypergeometric distribution an approximate result for the grade of service on level i is given as

$$B_i = \frac{E_n(A)}{E_{n-n_i}(A)} \quad \ldots\ldots (12)$$

where $n = \sum_{x=1}^{q} n_x$

and terms of the form $E_n(A)$, represent the Erlang loss expressions. (Ref. 7).

The general effect obtained is that for a fixed grade of service, the traffic capacity of a particular group of n circuits increases as q increases. This trend however has not so far been substantiated in traffic trials, and is contrary to the general opinion amongst traffic engineers that the capacity of the group would decrease with additional levels in use—this may be explained in general terms as follows—The congestion introduced by the N circuits removes the peaks of the compound input traffic distribution. With only one or two outgoing levels in use, the peaks of the input traffic will usually coincide with the peaks of the traffic of a particular level. This traffic is therefore smoothed by congestion when it appears at the level. As the number of levels in use is increased however, the peaks of the compound traffic less often coincide with the traffic peaks of any particular level and hence the level traffic will be closer to pure-chance character.

More analytically, the system can be described by a q-dimensional random walk, with a general continuity equation and boundary conditions.

Two-Level Case. For the special case q=2 the system can be represented in the diagram below. If the level occupancies are designated by variables y and z, the continuity equation becomes.

$$P(y, z).\ [\lambda_y + \lambda_z + \mu\,(y + z)] = \lambda_z\, P(y, z-1) + (y + 1)\mu\, P(y + 1, z) + (z + 1)\,\mu\, P(y, z + 1) + \lambda\, y,\ P(y-1, z) \quad \ldots\ldots (13)$$

Boundary conditions are:—

$$\left.\begin{aligned} 0 &\leqslant y \leqslant m \\ 0 &\leqslant z \leqslant n \\ 0 &\leqslant y + z \leqslant N \end{aligned}\right\} \quad \ldots\ldots (13a)$$

where λ_y and λ_z are birth efficients and μ is the death coefficient, (equals the reciprocal of the mean holding-time h.) and m and n are the numbers of circuits provided on the two levels.

It follows that—

$$A_y = \frac{\lambda_y}{\mu};\ A_z = \frac{\lambda_z}{\mu} \quad \ldots\ldots (14)$$

The diagram of Fig. 8 defines all possible states of the system. Transitions can only occur within the enclosed region and the directions of the transitions are indicated with their respective transition probabilities. Congestion on the y level is the sum of probabilities represented by points existing in the boundary y = m, and on the z level by points in the boundary z = n. Congestion at the previous stage is represented by points in the oblique boundary y + z = N. By solution of the transition probability matrix it is possible to evaluate these congestion levels. It can be shown that the joint probability density function P(y, z) has a solution of the form

$$P(y, z) = k.\ \frac{A_y^{\,y}}{y!} \cdot \frac{A_z^{\,z}}{z!} \quad \ldots\ldots (15)$$

where k is the normalising constant.

$k = \dfrac{1}{P(o, o)}$. Hence the congestion on level y is given by

$$B_y = \frac{\displaystyle\sum_{z=0}^{N-m-1} \frac{A_y^{\,m}}{m!}\,\frac{A_z^{\,z}}{z!}}{\displaystyle\sum_{z=0}^{n} \sum_{y=0}^{m} \frac{A_y^{\,y}}{y!}\,\frac{A_z^{\,z}}{z!} \quad (y+z \leqslant N)} \quad \ldots\ldots (16)$$

This process may be extended to obtain an exact solution for level congestion with any number q, of levels in use. However, the computations soon become excessively large, and could best be performed by using an electronic computor to prepare tables for practical use.

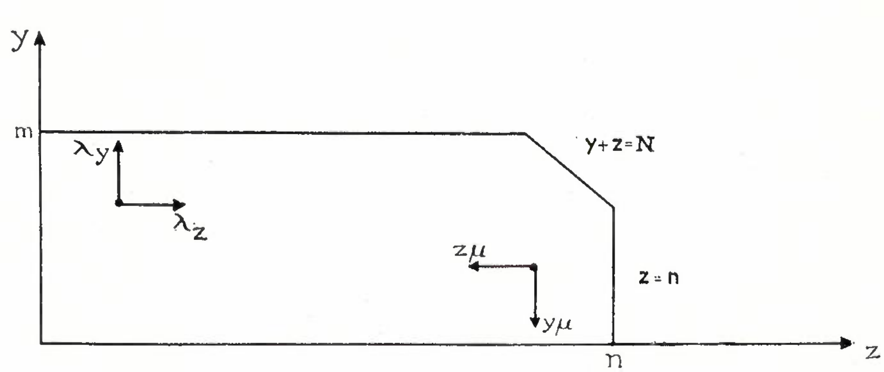


Fig. 8.

Statistical Equilibrium

The Erlang assumption of statistical equilibrium implies the existence of a limiting probability distribution $P(j) = \lim_{t \to \infty} P(j, t)$ so that the state probabilities become independent of time. Under this condition,

$$\left.\begin{aligned} \frac{\partial P(j)}{\partial t} &= 0 \\ \text{and} \sum_j P(j) &\equiv 1 \end{aligned}\right\} \quad \dots\dots\dots\dots\dots (17)$$

The concept of statistical equilibrium can be made more rigorous through the theory of Markov chains (8).

Because in practice the mean level of traffic is undergoing slow continuous change, conditions of statistical equilibrium are never completely obtained. However, during the busy hour, the traffic intensity passes through a maximum value and the variations of the mean intensity within that hour are usually sufficiently small that there is insignificant error in assuming that the distribution is stationary. Palm (9) and more recently Von Sydow (10) have investigated these effects.

Palm replaces the constant traffic intensity A by a time-dependent function A(t). He assumes that the variations in the mean intensity are sufficiently slow that at any point of time the traffic conditions will be the same as if the intensity were constant but with an actual value A(t). This implies that the intensity changes with a certain inertia, and slow variations of this type are termed 'inert' variations.

The value of A(t) over a period is described by the probability distribution function

$$G(x) = P\,[\,A(t) \leqslant x\,] \quad \dots\dots\dots\dots (18)$$

The mean value of the intensity over the whole period is given by—

$$\bar{A} = \int_0^\infty x \, d\,G(x) \quad \dots\dots\dots\dots\dots\dots (19)$$

Any traffic quantity F(x) which is determined by the intensity x will have the mean value

$$\int_0^\infty F(x) \, d\,G(x) \quad \dots\dots\dots\dots\dots (20)$$

In particular, the time congestion over a period will be given by

$$\int_0^\infty E_N(x) \; d \; G(x) \quad \dots\dots\dots\dots (20a)$$

where $E_N(x)$ is the usual Erlang congestion expression.

If the distribution function G(x) can be obtained by measurements it is then possible to assess congestion over periods during which the traffic is not in statistical equilibrium. However, the process is complex, and administrations have not found it necessary to apply it in general practice. The theory will probably become more important in the future since it provides a means of making calculations for longer periods than the busy hour.

Although the level variations within the busy hour are small, this may not be true of the day to day variations which also represent departures from statistical equilibrium since measurements extend over a number of days. In general, no special theory is applied but care is taken to ensure either that 'representative' days are used for measurements, and that they extend over a sufficiently long period to include one or more days of each class where the daily characteristics change.

There is however one situation in which the day to day variations become most important. This occurs on the final or backbone routes of alternate routing systems. The final route is extremely sensitive to variations in the offered traffic on the high-occupancy direct route. E.g., a variation of 20% in the offered traffic on a direct route can change the overflow component from that route by as much as 200%. The effect of daily fluctuations of overflow traffic is being studied in the Bell System Laboratories and a paper on this subject was presented at The Hague (11).

INTERCONNECTING SCHEMES AND GRADINGS

Many administrations are carrying out investigations to improve the efficiency of the inter-connecting schemes and gradings used in inter-stage trunking.

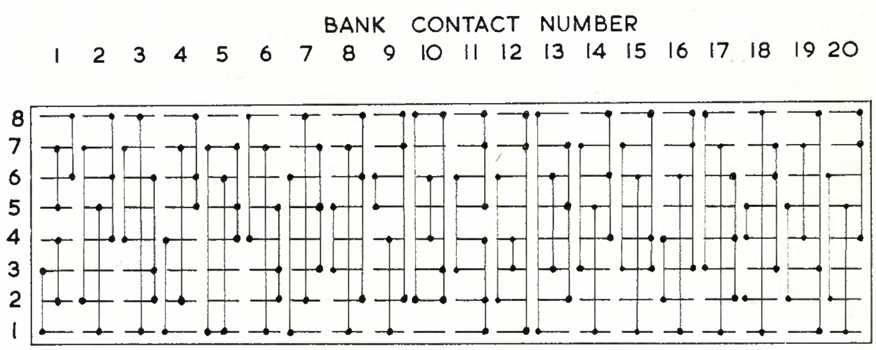
This work includes:—

(i) Effect of variations in the grading pattern on the total traffic efficiency.

(ii) Performance under conditions of input traffic unbalance.

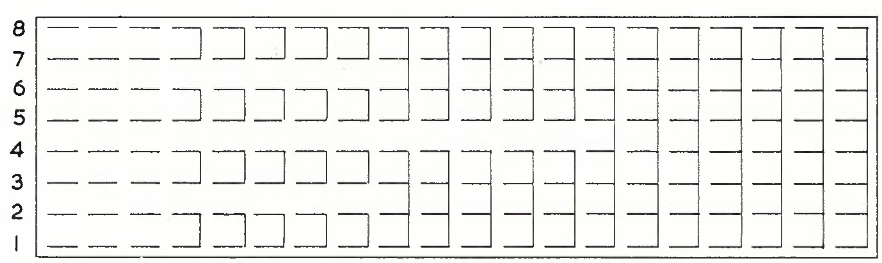
(iii) The accuracy of existing traffic capacity tables.

Grading Design (Homing Switches). It is now generally accepted that the homogeneous interconnecting scheme has an improved traffic efficiency compared to the 'straight' gradings used in B.P.O. and A.P.O. practice. When the magnitudes of the separate grading-group input traffics are balanced this advantage is slight, but it becomes significant under conditions of input unbalance. Straight gradings however, have advantages of simplicity in installation and maintenance (call-tracing) and they are generally easier to modify.



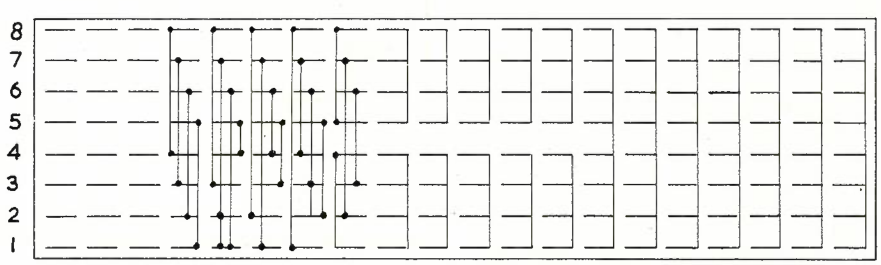
BALANCED INTERCONNECTING SCHEME 8 GPS. 61 TRUNKS

Fig. 9.



STRAIGHT GRADING 8 GROUPS 61 TRUNKS

Fig. 10.



PARTIAL—SKIPPED GRADING 8 GROUPS 61 TRUNKS

Fig. 11.

It appears that these advantages could be largely retained, and yet an improvement achieved in the unbalance tolerance by introducing a limited amount of dispersed or skipped commoning into the grading pattern. With homing-switches, the early outlets are heavily loaded and insensitive to traffic unbalances, so that there is not much to be gained by skipped commoning in this region. Similarly the final commons are shared by all groups. It follows that there is probably some optimum stage along the outlets where skipped commoning would have the most effect—this could be amongst the penultimate commons, and it should be possible to achieve a worthwhile improvement in the grading performance with a minimum of alteration. Figs. 9, 10 and 11 illustrate respectively a balanced interconnecting scheme of 8 groups and 61 trunks, and the equivalent straight and modified straight gradings.

Achieving Grading Balance. In addition to improving the performance of trunking under conditions of traffic unbalance it is important to reduce to a minimum the extent of the unbalances themselves. At switching stages other than the primary, this can be achieved by attention to traffic mixing and outlet allocation procedures. At the primary stage however, unbalances will exist between the traffics offered by the various grading groups of subscribers' line equipment. These are the normal statistical variations associated with the random sub-grouping, and their relative magnitude will increase as the size of the basic sub-group decreases. Thus the extent of group-group unbalance between the traffics from groups of say 200 uniselectors, will be far less severe than if the subscribers were trunked in groups of 20. With crossbar primary finders the smaller sub-groupings demand a greater attention to sub-group traffic balance if the grade of service is to be reasonably uniform over all groups and the total traffic carried is to be maximised. In the Bell System the question of primary traffic balance both with step-by-step and crossbar equipment is receiving a great deal of attention, and comprehensive traffic recording equipment is being developed to supervise this stage continuously. Statistical methods (12) have also been developed in which unbalance criteria are applied to determine the extent of corrective action necessary. Depending on the severity of the unbalance this may be either:—

(1) Non-allotment of further new lines in the group.

(2) IDF transfers of 'outgoing only' lines—e.g. P.T's., P.A.B.X.

(3) IDF transfers of subscribers.

The allotment procedure for new lines is also carefully controlled to maintain the best possible traffic balance. This applies not only to the Bell System but also to the other companies—e.g. A.E.C. (General Telephone Company), Bulletin 512 "Telephone Number Assignments for Strowger Automatic Office", deals extensively with this subject.

Grading Theory and Traffic Capacity Tables. The first theory for limited-availability trunking was developed by Erlang (3). He envisaged an 'Ideal' Interconnecting Scheme in which the input traffic was divided into a number of sub-groups such that each sub-group has access to 'k' trunks selected at random out of the total of N. With this arrangement he showed that the grade of service would be $\left(\frac{A}{N}\right)^k$ where A is the total traffic carried by the assembly. Such a scheme cannot be realised in practice because of the enormous number of sub-groups that would be needed to meet the conditions specified. G. F. O'Dell of the B.P.O. however adapted Erlangs ideas to practical gradings in the late 1920's, and the O'Dell traffic capacity tables have been widely used by administrations in calculating the circuit provision from gradings.

O'Dell derived an expression for the

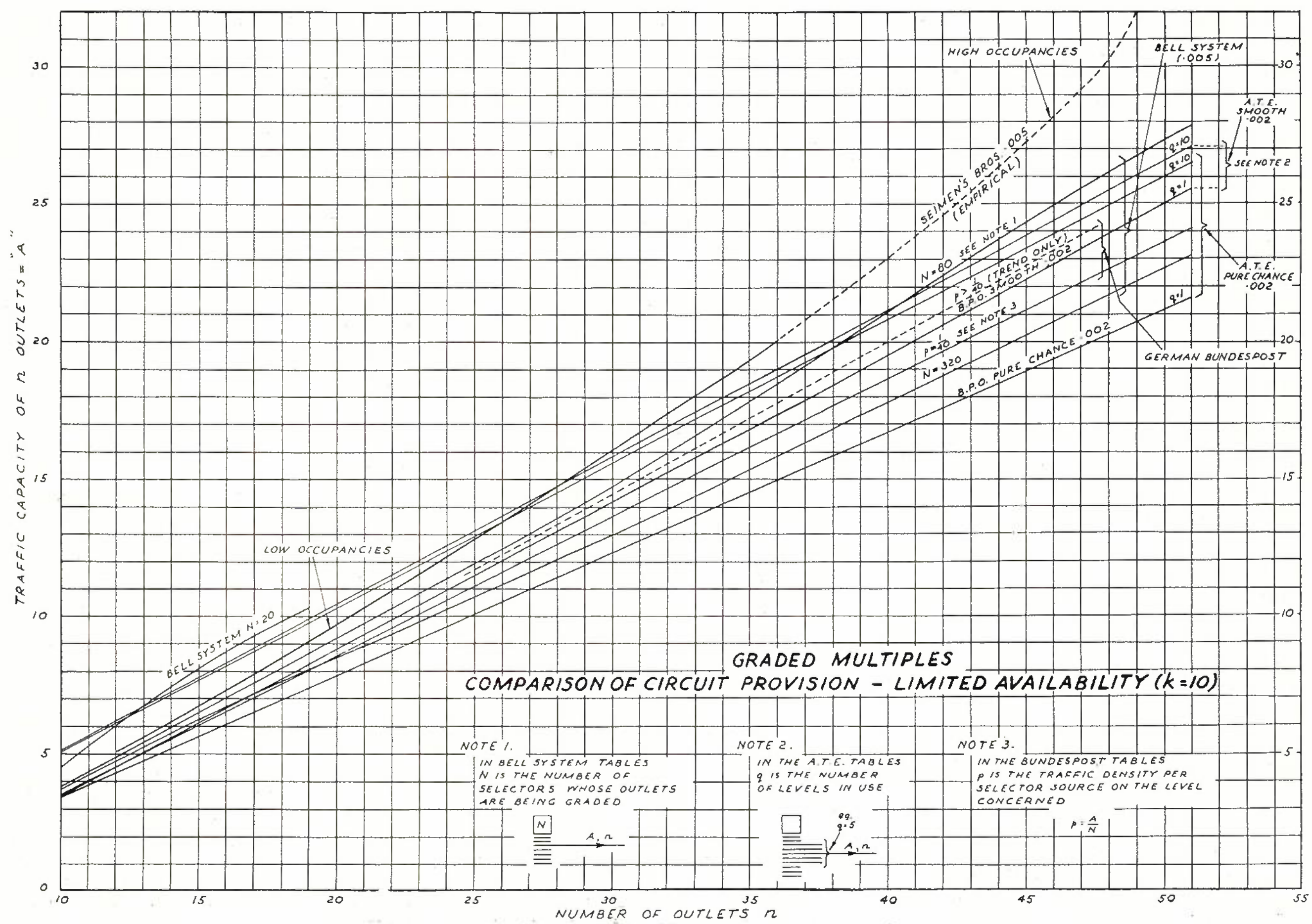


Fig. 12.

number of circuits N required in a grading with availability k in order to carry a total traffic A at a grade of service E

$$N = k + \frac{A - Ao}{(E)^{\frac{1}{k}}} \quad \ldots\ldots\ldots\ldots\ldots (21)$$

Ao is the traffic capacity of a full-availability group of k trunks with grade of service E according to the usual Erlang expression.

Limitation of B.P.O. Tables. The tables themselves are largely based on the extension of semi-empirical data and have no strong theoretical foundation. Moreover, traffic is classified rather arbitrarily as either 'Pure Choice' or 'Smooth' with a considerable difference in resultant circuit provision. Traffic smoothing in gradings is a complex process and arises through several mechanisms:—

1. Truncation of the traffic distribution by the limitation in switches at the previous stage. This effect, which is usually slight, reduces the variance/mean ratio of the traffic as a whole. It is not accounted for in the O'Dell tables.
2. The formation of grading groups by the amalgamation of selectors operating at a high average occupancy. This is a function of the size and efficiency of the trunking from which the grading is being made, and is the main justification for the B.P.O. Smooth Traffic Tables.
3. The method of selector allocation from the previous grading so as to ensure that traffic peaks occurring in a particular grading group are distributed widely amongst the switches at the next stage. Mechanisms (2) and (3) cannot affect the variance/mean ratio of the traffic as a whole but will cause a reduction in the ratio applying to the traffics of the individual grading groups. This could be termed 'Internal traffic smoothing'.

It is clear that since these effects depend on a number of factors, their extent in practice can vary over fairly wide limits. It would be desirable therefore to introduce further parameters to specify the traffics characteristics more closely than do the present 'Pure-Chance' and 'Smooth' classifications. It should be mentioned that the differences in circuit provision (for the same traffic) between these two tables is as high as 15% and the decision as to which is applicable has large repercussions on the cost of switching and junction plant.

Overseas administrations and companies have therefore sought to improve the accuracy of circuit provision from gradings, and a number of new theories and practices are emerging. The nature of gradings and the additional complications mentioned makes exact solutions, through the equations of state, impossible. The theories must therefore resort to approximations and the results must be tested extensively by simulation trials. A major difficulty here is that present analogue traffic devices have not the resources to simulate adequately the effects of non-random traffic, large trunking, or selective outlet allocation. However, much work has been and is being done.

Fig. 11 compares the traffic capacities of 10-outlet graded tables used by various administrations. These are:—

B.P.O. The O'Dell Pure Chance and Smooth traffic tables.

German Bundespost. These are based on the work of Rohde and Stromer (13). In this theory, combinational methods are used to evaluate passage probabilities through the grading. The tables introduce a new parameter 'p', being the traffic efficiency of the selectors on the level concerned.

Bell System. Based on the early work of E. C. Molina, modified to account for the finite number of selectors N, at the preceding stage, which now appears as a parameter.

A.T.E. Liverpool. (Manufacturing Company). These tables introduce the parameter q, the number of levels in use at the stage. This approach was discussed in the section on full-availability trunking and the grading tables are an extension of these ideas. The trend of increasing traffic capacity with increase in the value of q, contradicts the trends expressed in both the Bundepost and Bell System tables.

Siemens Bros. (Manufacturing Company, United Kingdom). Results based on early empirical studies by Dumjohn and Martin (14). These show an extreme range of traffic capacities depending on the average selector occupancy at the previous stage.

These tables cover a wide range of circuit provision for a given level of traffic and it is apparent that a greater knowledge of the underlying conditions and characteristics of the traffic is needed before it can be determined which are most applicable under various trunking situations.

SUMMARY OF GRADING PRACTICES

British Post Office.

Only straight gradings are used and their traffic capacity is assessed with the B.P.O. Smooth (B) and Pure Chance (C) tables based on O'Dell theory. However, work with their electronic traffic analyser has shown that the 'C' tables overprovide by about 3-4% with balanced inputs and pure-chance traffic. No results can be obtained for the Smooth tables as the artificial traffic equipment cannot simulate this type of traffic. They propose to issue revised traffic capacity tables for Pure Chance traffic based on their findings. They are also considering standardising on a reduced number of grading patterns, using only multiples of two in the commoning. The grading would then be designed to the five year requirement and cut back to the two-year, if necessary retaining a slight asymmetry in the pattern. Traffic balance in gradings is achieved by the selective allocation of outlets, and of new subscribers for balance at the primary stage. Subsequent changes at the subs. I.D.F. are made if traffic analysis or overflow readings show that there is significant residual balance. Tests on grading performance with input traffic unbalances have also been made.

Holland.

In their step by step systems, the Dutch administration are in the process of changing from the standard or "straight" type of grading to a standard system of inter-connecting based on patterns of basic 3's and 7's. They believe that this provides better mixing between grading groups and is less sensitive to input traffic unbalances. Patterns are always made up for racks of standard sizes and they claim that the system employed makes subsequent modification easier. The O'Dell formulae are used, but smooth traffic tables are applied at all switching stages using a grade of service of .001, except at line finders, final selectors and outgoing junctions where .01 is used.

In the Philips UR49A Non-homing Uniselector System, homogeneous interconnecting schemes are used. This provides for the approximate equal traffic loading of all outlets to the next stage. Traffic mixing is virtually performed within the gradings they claim that the traffic unbalance of this type of arrangement is much better than can be tolerated with normal gradings. Artificial traffic studies have shown that the O'Dell smooth traffic tables would be applicable with this type of inter-connecting scheme provided that the stages from which the trunking is made is large, that is, exceeds about 80 switches. Some adjustment however must be made because of the use of common controls which apply artificial 'busy' to all circuits which they serve when any one common control is in use. Rodenburg has modified O'Dell's formula to take account of this effect and the modified tables are used to determine switch provision in the UR49A system.

On the question of traffic balance, they are considering taking subscriber meter readings at the same time as the grading analysis readings are being made. The meter readings could then be correlated with the actual traffic measurements to provide a basis for interpreting subsequent meter readings in supervising future traffic balance.

Belgium.

Homogeneous interconnecting schemes are used in most of their power driven systems. Traffic tables are based on the work of Kruitof and Rabe. This form of trunking is now favoured in step-by-step equipment where straight gradings were formerly used, as it provides better performance under conditions of input traffic unbalance. Only individual twos, and fours are used in the interconnecting scheme to simplify the trunking pattern and facilitate future amendment.

Germany.

On the older 10-outlet equipment slipped multiples are used. In later equipment, skipped gradings are used, with the commoning dispersed as widely as possible. Great care is also taken to mix and balance all classes of input traffic.

Bretschneider of Siemens & Halske has studied the performance of gradings both by solving the equations of state in simple cases and also by analogue studies on artificial traffic equipment. He has established that a 20-outlet skipped grading is about 3% better in traffic capacity than an equivalent straight grading under conditions of input traffic balance. With unbalance the improvement is even greater.

Denmark.

Straight gradings are used by the Copenhagen Telephone Company on their 500 pt. selectors. The O'Dell formula is applied although they believe that for availabilities exceeding 20, the expression becomes inaccurate. In the crossbar exchanges the method of interconnecting is by link-selection.

Sweden.

Straight gradings are used, although they admit that skipped gradings perform better both in total traffic capacity and insensitivity to input traffic unbalance Therefore they propose in future to stagger to a limited extent, probably by confining this to part of common trunking. They also propose only to use individuals and pairs for commoning in future.

U.S.A.

In the Bell system, operating companies, the capacity of a grading is normally limited to 45 trunks per level. Although some economies in switches could be obtained by using larger gradings they usually prefer to adhere to this standard as it simplifies inner-rack cabling and call tracing as well as reducing the extent of equipment IDF (TDF) provision. It is also common practice to transpose at the mid-point of the grading, the first and second last full common in order to even the traffic loading on the selector outlets. Local and incoming selectors are mixed wherever a complete mixing is practicable, otherwise segregated trunking is favoured. Traffic capacity tables used for gradings in the Bell System are based on a "lost calls held" assumption and were derived originally by Molina (15). A later modification introduced as a further variable, the number of switches at the stage at which grading is being made. For more than 320 switches the effect is negligible, but for gradings from a small number of selectors there is a significant increase in the traffic capacity for the same grade of service. These corrections were made by ascertaining the percentage change in traffic capacity of a full availability group when the traffic originates from a limited number of sources —(corresponding to the number of selectors at the previous switching stage). This effect is not included in the tables for final selector provision. Great attention is paid to traffic balance, particularly at the subscriber primary stage.

The Kellog Company favours the use of homogeneous interconnecting schemes. Traffic capacity tables have been prepared based on the work of Kruitof, but modified to include the assumption "lost calls held" rather than the Erlang "lost calls cleared" which is inherent in Kruitof's work.

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ARTICLES BY P.M.G. DEPARTMENT STAFF APPEARING IN OTHER JOURNALS

By A. W. Thies, A.M.I.E.Aust.

INTERMODULATION IN IRON-WIRE PAIRS*

The ferromagnetic skin effect in a short wire conducting a single weak current is first considered. The harmonic production is found to be related to the increment of the wire impedance arising from hysteresis, so that the harmonic products may be calculated from the results of an impedance test. At sufficiently high frequencies, the relationships become independent of the geometry of the wire cross-section.

For the case of two simultaneously flowing currents, the intermodulation products of greatest interest are calculated and related to the single-tone distortion.

A knowledge of these non-linear products is required when, in the construction of open-wire routes for multichannel carrier telephony, it is proposed to use iron wires or iron-cored wires on very long spans as, for instance, across river beds. It is shown how to account for the finite time of propagation in spans exceeding a small fraction of a wave length. An approximate formula for the fraction of current conducted by the core of a composite wire is given.

*This is an abstract of an article which appeared in the November 1960 Electrical and Mechanical Engineering Transactions of the Institution of Engineers, Australia.

INSTALLING THE MELBOURNE-MORWELL COAXIAL CABLE

*C. H. HOSKING, B.Sc.**

INTRODUCTION

An article (1) in an earlier issue of this Journal dealt with the planning of the Melbourne-Morwell coaxial cable, described the cable design and briefly described the proposed method of installation. In this article, it is proposed to describe the actual installation of the cable.

The decision to proceed with this project was made late in 1958 and a special organization was set up in Victoria early in 1959 to carry out the cable installation. A division staffed by a Divisional Engineer and two Group Engineers was established to install the cable under the control of a Supervising Engineer whose duties also included the co-ordination of the Sydney-Melbourne coaxial cable project in Victoria.

SURVEY

The route between Dandenong and Warragul had already been chained and pegged and the route between Warragul and Morwell had been roughly selected at the planning stage. An immediate start was made on the detailed survey of the route, some alterations being made to the originally selected route to suit the proposed method of installation. Since the route had been originally selected, the proposed method of installation for the Sydney-Melbourne coaxial cable had been devised and it was decided to use this method for the Morwell project. The route was chained and pegged at every 1,000 feet, with pegs also at every angle and joint point. The joints were generally at 500 yard intervals and as far as practicable located so that every fourth joint coincided with a 6,000 feet loading scheme on the paper insulated layer pairs. At each pegged point, offset pegs were placed as well as centre line pegs so that when the centre line pegs were removed by the clearing and levelling operation, offset pegs still remained at the reference points.

As the survey proceeded, pre-planning of the installation work was commenced. This consisted of making a detailed study of the cable route from which job instructions for each individual party were prepared in the form of notes on 4-chain to the inch plans prepared from the survey. Unfortunately, this work was not completed before installation was commenced.

At the same time, a start was made on the selection of sites for the unattended repeater stations. These sites were selected between Dandenong and Warragul using the original chainage and, in the case of one section of the route which was substantially altered, from plans. Similarly between Warragul and Morwell the sites were selected using plans. Normally, to ensure the most satisfactory spacing of repeaters, it would be desirable to select repeater sites only after completing an initial measurement of the whole route, but in this case insufficient time was available for this initial measurement over the whole route as it was necessary to set the process of the acquisition of sites in motion immediately.

Similarly, it would normally be desirable to have the repeater locations fixed before the detailed survey is done so that the cable lengths could be ordered accurately, but due to difficulties in acquiring a few of the sites, quite a good deal of difficulty was experienced in finally arranging the cable to fit in with the sites ultimately acquired.

MATERIAL PURCHASING

It was necessary to arrange for the purchase of the material, tools and other equipment not already ordered at Headquarters. This included all the hand tools, camp equipment and some larger items such as diesel generators for camp lighting and for testing. A very formidable number of items of various types was involved, both serialised and non-standard.

TRAINING

Training of staff in the operation of the various mechanical aids and in the jointing of the cable was arranged as described in the article (1) referred to previously. For the mechanical aid operators, the aim was to train a team, in which each man would be capable of

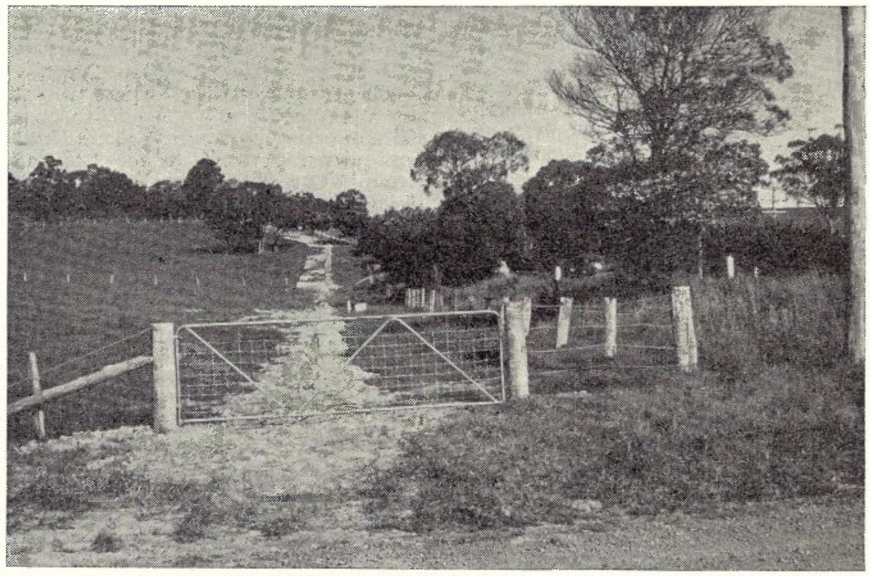

Fig. 1.—Gate installed on the cable route by the gate party.

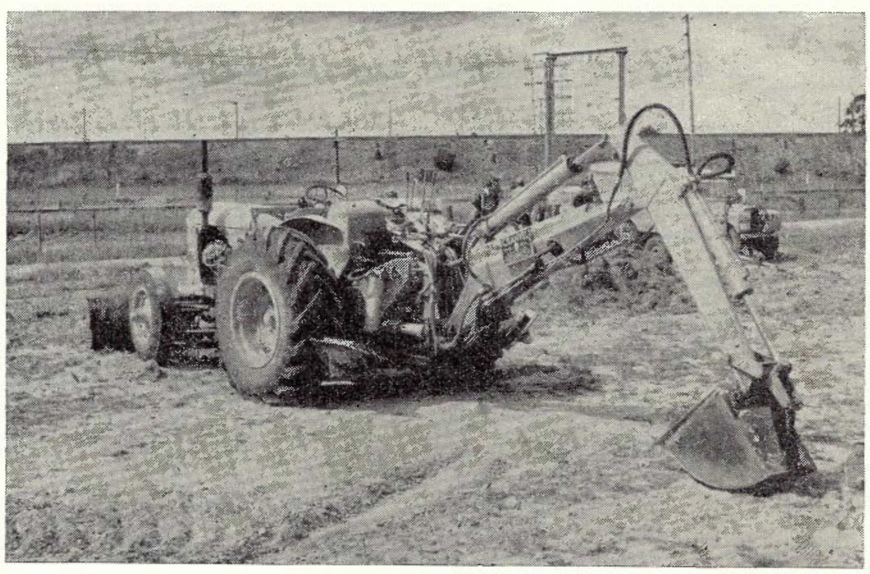

Fig. 2.—Cranvel Back Hoe.

* See page 467.

Fig. 3.—Proline Horizontal Borer showing Auger.

operating a number of machines in addition to the one it was intended he should normally operate to ensure adequate flexibility of organisation.

In the case of the Barber Greene ditchers, which were new in this country, adequate instruction was not available and this resulted, unfortunately, in a loss of efficiency in their performance which was not overcome until experience had shown up the deficiencies in operation and servicing.

CABLE INSTALLATION—BURIED CABLE SECTIONS

By July, 1959, most of the mechanical plant and material had been delivered or was in sight and it was decided to make a start on the installation of the Dandenong-Morwell section for which cable was then available and advance parties under one Line Inspector commenced work.

Installation of Gates

The first party to start was the gate installation party. This party installed gates in fences through which the cable route passed to facilitate the passage of the main installation parties and, in certain cases, to facilitate access for maintenance. Generally, on this project, permanent 13 ft. gates were installed, although in some cases, where the land owners wished it, temporary or "Mallee" gates were installed—the fences being restored after the completion of installation of the cable. The party of two men engaged on this work was equipped with a Land Rover with a post hole borer driven from the power take-off and a generator for electric hand tools for boring and cutting the fence posts The party started work in July and installed gates at an average of 2 per day.

Installation of Pipes at Road and Rail Crossings.

This same party also undertook the installation of 6″ asbestos cement pipes under highways and railways, on this job being assisted by a third man. For this operation, the post hole borer on the Land Rover was replaced with a Proline horizontal borer. A Cranvel backhoe was used to excavate the holes on either side of the highway or railway necessary to place the borer in position and to install the pipes. The pipes were installed in the bored hole with the assistance of a "Terfor" hand operated winch and a grout pump was provided to fill the cavity around the pipe with cement grouting.

The first bore undertaken was not successful. After about ten feet had been bored, the auger entered an underground cavern (which incidentally was under the paved surface of the highway) and the excavation was flooded with many gallons of water and several cubic yards of silt. After the excavation had been pumped dry and cleared of silt, the bore was continued, but due to the cavern the auger dropped and appeared on the far side of the highway about 9 feet below ground level. In view of this and the fact that it would have been otherwise virtually impossible to backfill the underground cavern, it was decided to open cut the highway to lay the pipes. Further bores were quite successful, 2 or 3 days being required per bore, depending on the length. The longest bore was approximately 57 feet.

Grouting of the majority of the bores, was not possible because, in the wet conditions, the excavation "made" too much water to enable the cement grouting to be satisfactorily placed.

Clearing and Ripping

A party comprising generally 7 men cleared the cable route, levelled where necessary and tidied up the fallen timber. This party also prepared creek and river crossings ahead of the main cable laying party. It was equipped with two HD.16 Allis Chalmers tractors with torque converter transmission, one with a hydraulically controlled 4 foot ripper tyne; a 22RB crawler mounted excavator with dragline and backacter attachments; chain and swing saws; a brush chipper for disposing of the smaller

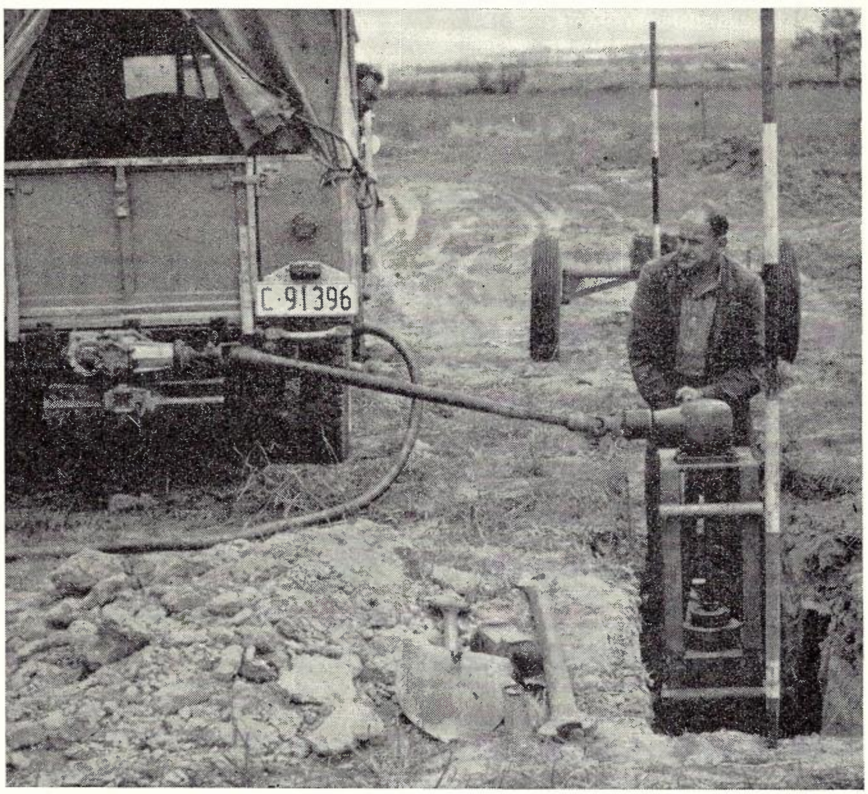

Fig. 4.—Proline Horizontal Borer showing Drive from P.T.O. of Land Rover.

branches and brush; and a tip truck and front-end loader to cart away the residue where necessary. By the time this party commenced operations in August, it was decided that it would be unwise to rip the cable route ahead of the ditchers, as it was considered that the trench produced by the ripper would in the likely event of rain cause the water to soften the soil unduly, and make the job of the ditchers more difficult rather than easier as intended. Therefore, from the start only sample ripping was done when the presence of rock was suspected and every ¼ of a mile or so to check for the presence of unsuspected rock. After a short period, the ripping operation was abandoned completely.

Altogether only three small sections of rock were encountered over the whole route and the lack of ripping did not, on this account, seriously affect the trenching and cable laying. The decision not to rip the route ahead of the ditchers proved a wise one, because in the extremely wet conditions experienced by the trenching team, trench collapse would have undoubtedly been worsened by pre-ripping which at the surface disturbs an area considerably beyond the 18" wide trench.

By the time excavating commenced, almost all of the heavy clearing required as far as Warragul had been completed and since it was then found that the excavating and laying team needed additional assistance—particularly from the crawler tractors for de-bogging other equipment—the two parties were amalgamated. Thereafter, with one exception, the clearing and levelling of the route was done just ahead of the ditchers. At a later stage, one of the HD.16 tractors was detached from the amalgamated party to carry out the only remaining heavy clearing required, through the Haunted Hills area, a 4½ mile section between Moe and Morwell.

Little use was made of the brush chipper on this project. It was found quicker to burn off the rubbish and since this was permissible at this time of the year, this method of disposing of the rubbish was resorted to. Undoubtedly, the chipper would have been of great value had it been necessary to carry out clearing during periods when burning off was prohibited. However, it would probably be more economical on any such project to arrange for the clearing to be carried out at the time of the year when burning off is permitted.

Excavating and Laying

The excavating and laying party of 10 men was under the control of one Line Inspector. This party was equipped with:

- 2 Barber Greene 774 high speed wheel type ditchers,
- 1 Barber Greene 784 vertical boom type ditcher.
- 3 crawler track mounted cable trailers
- 1 winch truck.
- 2 mobile cranes,
- 2 A.C.45 tandem graders fitted with hydraulically controlled tamping wheels.

A 25 ton low loader was also available to transport cable from the dumps to the site of laying and also for shifting the crawler track mounted mechanical plant when required. This party started work at the beginning of September at the start of the buried cable section 4 miles beyond Dandenong.

The winter of 1959 had been one of the driest on record in Gippsland, but unfortunately heavy rain fell about a fortnight before excavation commenced and a good deal of rain fell in the following 6 or 7 weeks. The point at which ditching commenced is only a few feet above sea level and the ground was completely waterlogged. The ditcher which started at this point had difficulty in maintaining traction and quickly became bogged, and, what was worse, the trench collapsed very rapidly behind the ditcher.

By contrast, the second ditcher which started near the crest of a hill only a short distance away was operating in hard clay and for a few hundred yards operated without these difficulties. Unfortunately, this ditcher also ran into poor soil conditions just over the crest of the hill and soon experienced difficulties similar to the first ditcher. It was at this stage that it became necessary to recall the HD.16 tractors from ahead to frequently debog the ditchers. To improve the traction of the ditchers, grouser plates were fitted to the tracks and by placing planks under the tracks at the worst points, the bogging of the ditchers was avoided and progress, though slow, was achieved.

In some places where the soil was very wet and soft, the 22RB backacter was used to excavate the trench and as this machine has a 3-foot wide bucket, the collapse of the trench did not cause any difficulty.

It had been intended to lay the cable by towing the cable trailers straddling the trench and laying the cable direct off the drums into the trench. This, however, was impracticable in the conditions experienced and the only method which could be used at this stage was to tow the cable trailers alongside the trench with one of the HD.16 tractors and manhandle the cable into the trench as close as possible behind the ditchers. Even then, it was frequently necessary to shovel soil which had collapsed into the trench out of the trench to get the cable down to 4 feet depth.

Fig. 6.—22RB Excavator rigged as Dragline.

Fig. 5.—22RB Excavator rigged as Backacter.

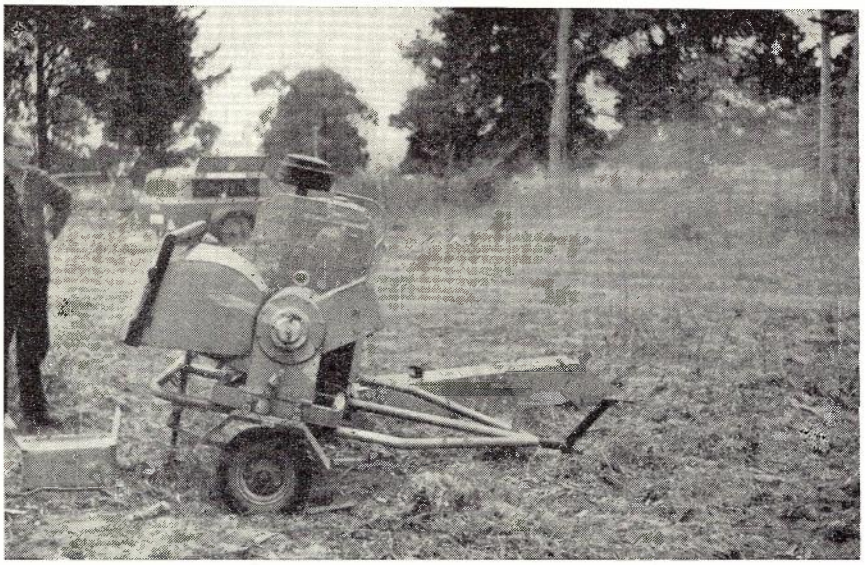

Fig. 7.—Brush Chipper.

This method of laying the cable was not satisfactory as it involved considerable manpower and was most exhausting, particularly as, in the early sections, it was necessary to excavate the trench close to the highway boundary fence and as a result the cable had to be manhandled over the spoil heap. Arrangements were therefore made to have rollers fitted on a framework over the top of one of the ditchers. The cable was then laid out on the ground ahead of this ditcher and passed over the rollers as the ditcher moved forward and dropped from the back of the ditcher into the trench immediately behind the ditcher. This considerably reduced the labour involved in cable laying and overcame the problem of trench collapse except in the very worst conditions. After the success of this trial, each of the other ditchers was similarly fitted, but with the rollers attached along the side of the ditcher so that the cable passed along the side of the ditcher and into the trench in much the same fashion.

Although this method of laying cable was developed for use in wet soil conditions, it was obvious that it had advantages for use also in good conditions and it became the standard method of laying and was used throughout the job except where special conditions made it unsuitable. For example, it cannot be used where rock excavation is encountered which necessitates bedding the cable in rock free bedding material.

Where water or other service pipes crossed the trench, the cable could not be laid directly into the trench, but had to be drawn into the trench by means of a winch, rollers being placed under the cable in the bottom of the trench. Over any great length, this was very slow and necessitated the expenditure of an excessive number of manhours. To avoid this operation where only isolated water pipe crossings were encountered, a local plumber was often engaged to cut the pipes and restore them after the cable had been laid, thus enabling the cable to be laid direct into the trench. The B.G. 784 vertical boom ditcher was used where pipe crossings were encountered, since this machine can excavate a vertical face right up to the pipe crossing thus leaving little soil to be excavated by hand.

After 7 weeks, only 8¼ miles of cable had been laid, but by the end of October, soil conditions had improved appreciably. However, the rate of ditching still did not approach the rate that had been expected. This was due to the fact that the sticky wet soil did not clear readily from the ditcher buckets and if the crowd speed (i.e. the forward motion of the ditcher) was increased beyond the optimum for the conditions, the buckets clogged up with soil and the machine had to be stopped while the buckets were cleaned out. It was apparent that the digging rate anticipated could only be achieved in dry friable soil. It is possible that the rate could have been increased to some extent by adopting one of a number of methods which it was later learned were available to improve the clearing of the buckets. These methods include the use of perforated buckets which reduce the suction which tends to hold the soil in the buckets, and loose bucket backs which tend to throw the soil from the buckets. In the following 6 weeks, 18 miles of cable were laid, an average of 3 miles per week, the best week's performance (over 6 days) being 4 miles.

Then as the ditching conditions improved still further, mechanical breakdowns of the ditchers were experienced and for the next 9 weeks there were never more than 2 of the 3 ditchers in operation at one time and the average progress during this period was only 2 miles per week.

In the final weeks of cable laying, however, although the 3 ditchers were rarely working simultaneously, the average rate of progress was 3½ miles per week, the best week's output being 4½ miles (in 5 days).

For a considerable proportion of the distance between Dandenong and Warragul the cable route passes through built up areas which appreciably slow down the rate of installation due to the restricted working width available and the frequency of sewer pipe crossings.

Beyond Warragul there are much greater distances between built up areas and this, together with the dry soil conditions, contributed to the improved rate of installation over the last 30 miles of the route.

The last length of cable in the Dandenong and Morwell section was laid on the 2nd April, 1960.

Backfilling

During the initial stages it was not possible to use the graders for backfilling. It had been intended that the spoil should be graded into the trench

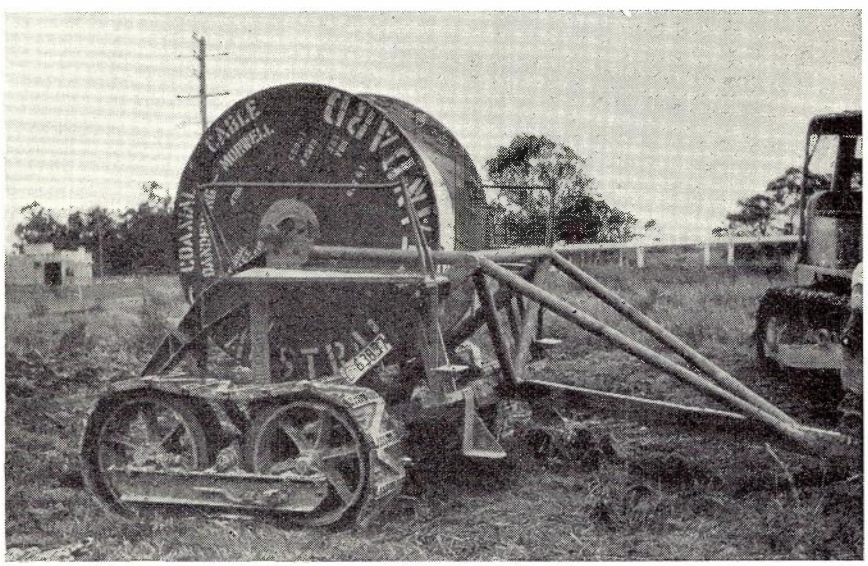

Fig. 8.—Crawler Track Mounted Cable Trailer.

in layers with the grader straddling the trench, each layer in turn being consolidated by means of the centrally mounted tamping wheel. However, in the wet conditions experienced in the first few weeks, the graders could not safely straddle the trench and could not even move alongside the trench without becoming bogged frequently. During this period, the majority of the backfilling was carried out by one of the HD.16 tractors with its dozer blade. The trench was consolidated to a certain extent by running one of the tracks of the tractor in the trench after it had been backfilled to the surface, but this was only partially effective in consolidating the soil at the bottom of the trench and subsequent subsidence of backfill over sections backfilled in this manner has been considerable.

As conditions improved slightly, it became possible to use the graders at the side of the trench to backfill. Under these conditions, the grader wheels were run in the backfilled trench to consolidate the backfill as much as possible. The use of the graders in this position enabled the backfilling to be completed at a greater rate than with the HD.16 tractors. From about December, it was possible, due to improved soil conditions, to use the graders as originally intended, although there were still many locations where only the crawler tractors could be used for backfilling.

The consolidation of backfiill in layers is most important where a 4 foot trench has to be backfilled. Where it was not possible to use the tamping wheel on the grader, there has been considerable subsidence involving repeated attempts at reinstatement. Also it has been necessary to pay compensation to a number of farmers for loss of or injury to stock which fell into the ineffectively consolidated trench.

There has, of course, been some subsidence of backfill even where the trench was consolidated in layers because perfect consolidation is dependent on correct moisture content of the soil, but the problem in these cases has been much less serious.

INSTALLATION OF CABLE IN DUCTS

Between Dandenong and Morwell the cable to be drawn into ducts through the larger towns was ordered in lengths of up to 500 yards. Epoxide resin pulling plugs were cast on the hauling end of each length of cable to ensure that the tension of the pull was distributed between all copper components of the cable. Guides made of split tube were used at intermediate manholes to lead the cable around bends and to cater for changes in duct level. In cases of slight changes in level, polythene tubing was used to guide the cable through the intermediate manholes. Care was taken to thoroughly clean the ducts and plenty of cable hauling compound was used.

Early experience of drawing the cable into the ducts near Dandenong indicated that higher tensions were required in hauling 500 yard lengths than was anticipated. Any changes in direction in the duct route or significant difference in level between the ducts on either side of a manhole, particularly if these occur near the winch end of a pull. significantly increase the tension. It was also found that getting the necessary slack into the intermediate manholes to enable the cable to be housed in these manholes was often a difficult and lengthy operation, particularly where a large number of manholes was involved. This was done by hand, slack being pulled from the ends through each manhole in turn to the centre manholes. Where manholes were built just prior to the cable installation, this operation was avoided by having the manholes built with a straight wall on one side and by installing the cable in a duct on that side of the nest of ducts.

As a result of this experience, in later duct work between Dandenong and Morwell, the longer lengths of cable were cut into two shorter lengths, except where no angles or appreciable changes in duct level were encountered. In the Melbourne-Dandenong section, the cable for which was ordered after this early experience, the lengths were limited generally to a maximum of 350 yards and these lengths laid out so that angles and large changes of duct alignment occurred near the ends of the pull at which the drum was to be placed. Between Dandenong and Morwell the team engaged on the buried cable installation also installed the cable in ducts. Between Melbourne and Dandenong a special team of 18 men was used, separate parties being engaged on cleaning and rodding of ducts, fitting up guides at intermediate manholes and on actual cable hauling. Except in the inner City area where congested manholes and heavy traffic made work more difficult, this team installed the cable at an average of 2 lengths per day.

Fig. 10.—Example of trench collapse.

JOINTING AND TESTING

Because of the slow progress made in the early stages by the excavating and laying team, the commencement of jointing was deferred, because it was anticipated that this work would proceed at approximately 4 miles per week, until sufficient cable had been laid to provide continuous work for the jointers.

The jointing team consisted initially of 12 jointers together with two men equipped with a backhoe and a front end loader for excavating and backfilling the jointing holes. The team was under the control of a third Line Inspector. Initially the testing team consisted of 2 Senior Technicians and 1 Technician.

In the buried cable sections, the joints also were buried. Immediately ahead of jointing work, a hole about 5

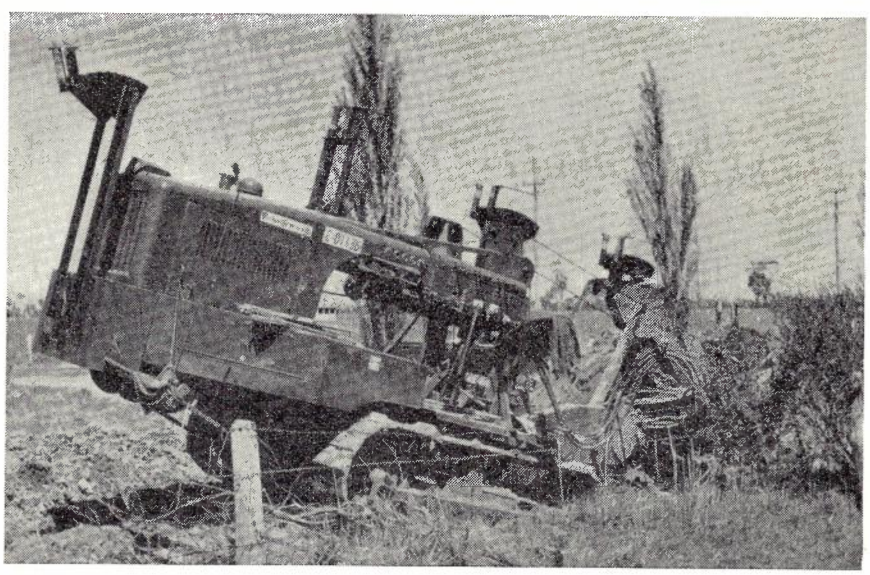

Fig. 9.—B.G.774 Ditcher Bogged.

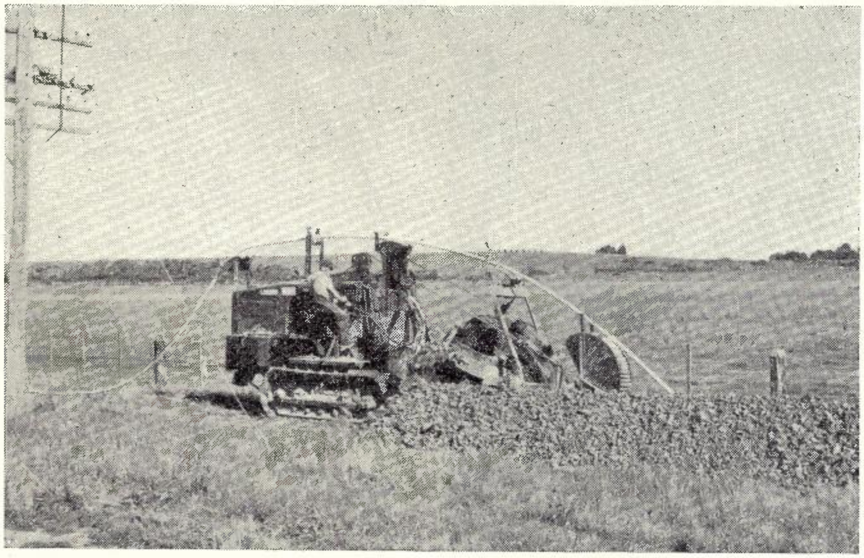

Fig. 11.—B.G.774 Ditcher fitted with rollers over the top, laying cable.

feet square and 4 feet deep was excavated at the joint point by means of the back hoe, the cable being carefully laid back out of the way during this operation. The cable ends were then placed back in the hole and a framework, consisting of 4 wall sections which interlocked together to form a temporary manhole was installed in the jointing hole. The two end sections were slotted to accommodate the cable. Integral with the appropriate walls were folding seats for the jointers and shelves for their tools and jointing material. The side walls were held in position by adjustable pipe braces which were used to support the cable during jointing. The cable was then jointed, the joint being made at a depth of about 2 feet 6 inches below ground level. Two jointers worked together in each hole, each pair of jointers being provided with a Volkswagen mobile jointers' van.

The Ericsson method as described in the earlier article (1) was used for jointing the coaxial tubes. The 20 lb. core and interstice paper insulated quads were jointed in the normal manner in their normal relative position in the joint, but the layer pairs were jointed with slack in them to allow easy access to the coaxial tubes at a later date. At loading points, the loading coil pots were set on the bottom of the trench below the joint. The cable tails emerging from either end of the loading pots were turned through 180° and jointed into either end of the cable joint. When the joint was completed, including the plumbing of the sleeve, it was made rigid with an angle iron bracket which was clamped on to the armoured cable on either side of the joint.

The jointing frames were then removed from the hole and the joint and exposed cable on either side covered with sand before backfilling the remainder of the hole with normal filling. This was aimed at preventing subsidence which would allow the joint or cable to move subsequently. A concrete slab was placed immediately over the joint before the normal soil was backfilled to afford mechanical protection to the joint if it became necessary to excavate the joint at a later date. In this latter eventuality, the sand should serve a further purpose in that the soil can be excavated down to the concrete slab with pick and shovel or mechanical equipment and then the sand more easily and carefully removed from around the joint. The front end loader was used to place the sand and generally the backfill blade on the front of the back hoe was used to push back the excavated soil.

At 1,000 yard intervals, that is, generally every second joint, a heavy gauge, small diameter bore insulated lead tube with gas alarm and test lead pairs installed in the bore of the tube was led to the surface for the cable protection staff who installed the gas pressure alarm system. At a later stage, the contactors and test terminals were installed in pre-fabricated concrete cabinets erected at ground level above these joints.

At each point at which it was necessary to lead any of the layer pairs into an exchange along the route other than at a repeater station, a 900 pair cabinet was installed. All the layer pairs in the cable on either side of the cabinet were terminated on the cabinet and the spur cable to the exchange was similarly terminated on the cabinet. Thus full flexibility in the allocation of the layer pairs is available without the need to open a joint in the main cable.

At the repeaters, the main cable was broken down into single tube coaxial cables and paper insulated tails for the core; interstice and layer pairs in a sheet steel canister type pothead joint. A gas tube was also taken out of the pothead to the gas pressure alarm equipment. Since the pothead is under gas pressure, each of the tails had to be sealed. The single tube coaxial cables are terminated on a gas tight terminating socket into which plugs the solid dielectric flexible coaxial leads to the power filter panel. The paper insulated tails are sealed at expoxide resin terminal strips which are similar to the terminal units used in the new type 900 pair cabinets, but which have "U" links for through connections or connections to jumper tags for local circuits.

Arrangements had been made for the cable manufacturers to supply full test details of each drum of cable, including the capacity unbalance measurements on all paper insulated pairs and mutual capacitance of the core and interstice pairs. It was intended that these measurements should be used to prepare jointing schedules for cross splicing of the paper insulated pairs to reduce capacity unbalances on the VF pairs in the

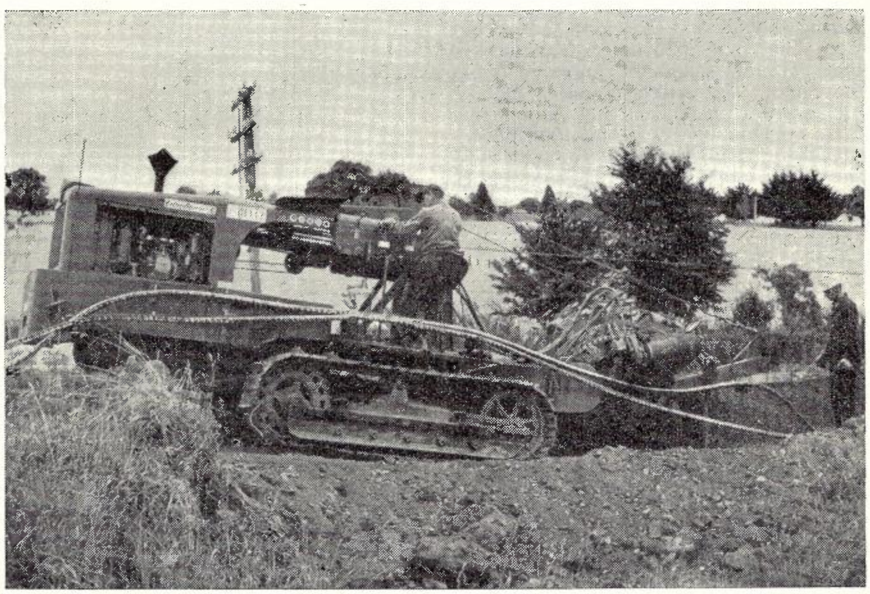

Fig. 12.—B.G.774 Ditcher with rollers fitted along the side, laying two cables.

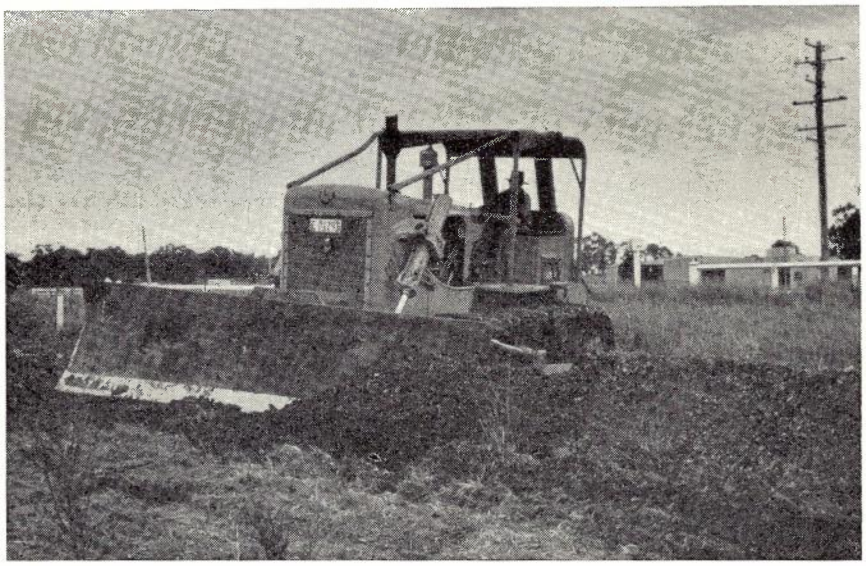

Fig. 13.—H.D.16 Tractor backfilling trench.

loading sections and to carrier balance the core and interstice pairs. In the case of the core and interstice quads in the Dandenong-Morwell section, only crosses within quad were of course possible and in the case of the layer pairs, the pairs were cross-spliced in groups of 10, to simplify selection and to facilitate future access to the coaxial tubes. It was anticipated that with the use of condensers in a very few instances it would be thus possible to achieve the desired standards. In the Melbourne-Dandenong section, within quad crosses were used for the interstice pairs and in the case of the core pairs (20) selections for cross-splicing were made between all pairs in the core.

Before jointing was commenced, however, a few lengths of cable already laid were tested to check that the capacity unbalances had not been altered during laying or that any alterations were small and in a uniform pattern so that jointing schedules prepared from the factory test sheets could in fact be used. Unfortunately, it was found that there was no consistent relationship between the factory results and the measurements obtained on the laid cable. Apparently the make-up of the cable is so loose that the characteristics are appreciably altered by the movement involved in laying the cable.

It therefore became necessary to measure the capacity unbalances, and in the case of the core and interstice pairs the mutual capacitance, on every length of cable laid and prepare jointing schedules before jointing commenced. Jointing schedules already prepared for a large number of drum lengths of cable had to be scrapped. As this involved additional work for the jointers and the testing technicians, it was necessary to obtain additional staff to enable the desired rate of jointing to be achieved. Two jointers were added to the team and the testing team was increased from 3 to 4.

ORGANISATION OF JOINTING AND TESTING

The organisation of jointing and testing was generally as follows. An advance team of Senior Technician and Technician and Cable Jointer in a test van with trunk cable test set measured the necessary capacity unbalance and mutual capacitance characteristics on the laid lengths of cable. (It is not proposed to describe in detail in this article the capacity balancing technique as this and the results obtained could well form the subject of a separate article.) An average of 4 lengths of cable were measured per day,

The main team followed approximately two days behind. The cable was first jointed into 2000 yard lengths to correspond with the loading sections for the layer pairs and at the same time the loading coil joint 2,000 yards back was made. The jointers and the testing team were disposed as shown below:

```
 LP                 LP              LP
 2J                  J   2J  2J  2J  J
— O —X—X—X—      —O—O—O—
      <—— ST + T ——>
```

J = Cable Jointer
ST = Senior Technician
T = Technician
X = Completed Joint.
O = Joint being made.
LP = Loading Point.

With this organisation it was possible to check all jointing work as it proceeded—checking residual unbalances over loading sections and testing every coaxial tube joint from no further than 2,000 yards and before the joint was wiped up. The testing team also had sufficient time to prepare the jointing schedules from the measurements obtained by the advance team. For testing they were equipped with a pulse test set (a S & H Reflectoscope), a high voltage test set (a Trimax ionization tester), capacity unbalance measuring set, I.R. tester, a meter for continuity testing and a trailer mounted 230 volt diesel alternator to provide the power supply for the Reflectoscope and the high voltage tester.

The Reflectoscope was used to check the coaxial tubes for impedance irregularities and indicates the location and magnitude of any irregularities on a cathode ray tube. The high voltage tester was used to check that the tubes would withstand the specified voltage, 3000 volts, without ionization.

The jointers first opened up the cable ends and established communication between themselves and with the testing team by loud speaking telephone. They then prepared the coaxial tube ends and connected the tubes on either side of their jointing point with temporary leads. The tubes were then tested in turn with the high voltage tester to prove the

Fig. 14.—Grader backfilling trench.

Fig. 15.—Grader consolidating back fill. Note front wheels off ground.

lengths before jointing. The coaxial tubes were then jointed. When all tubes were jointed, they were high voltage tested again, insulation resistance tested and tested with the Reflectoscope, while the jointers proceeded with the jointing of first the core and interstice pairs and then the layer pairs in accordance with the jointing schedule. As each group of pairs was jointed, the testing team was advised and when ready, they checked the identification and residual unbalances and where necessary determined the size of balancing condensers to be connected. Lastly, the insulation resistance tests were carried out on the paper insulated pairs.

The jointers in the loading coil hole worked on a similar pattern also jointing in the loading coil. The jointer at the end hole who was required to connect matching terminations on the tubes as requested, to fan out the paper insulated pairs and assist in their identification and continuity test, also placed the loading coil in position and then wiped in the loading coil tails into bases on the main cable on either side of the joint position. In this way the cable could be jointed completely at a rate of a loading section (2,000 yards) per day although this was usually a 9 or 10 hour day. The additional jointers in the team were employed in assisting the team excavating and backfilling the jointing holes, their main duty being to safeguard the cable during excavation, to assist in placing the jointing frames, and to house the cable safely during backfilling.

It was necessary at regular intervals to interrupt the procedure described above to enable other jointing work to be completed, for example, make extra straight joints where lengths less than 500 yards had been specified or where, for some reason, it had been necessary to cut 500 yard lengths of cable, install cabinets and terminate the cable in the repeaters.

Jointing in the Dandenong-Morwell section commenced during the last week in October and by the time the cable laying was completed early in April only a few joints remained to be completed. However, at this stage, a number of repeater terminations remained to be completed and due to the transfer of the majority of the staff to New South Wales for work on the Sydney-Melbourne project it was some time before all work was completed. A separate team of jointers was established to joint the Melbourne-Dandenong section, but essentially the same type of organisation was used. Since the joints in the manholes could be worked on from only one side, only one jointer worked on each joint.

A number of the faults discovered during the progress of jointing and testing are of interest. Shortly after jointing commenced, one tube was found to be breaking down at less than 2KV. From advice received at just about this stage from the United States of America, it was thought that this fault may have been due to a "sliver". Apparently during manufacture, a sliver of copper may be formed on the edge of the copper tape from which the outer conductor is formed. During testing in the factory this may "lie down" and not be detected, but due to handling of the cable during laying it may "stand-up" when the tubes are subjected to the HV test after laying and thus cause the tube to break down at comparatively low voltages. In the U.S.A. a so-called "sliver burner" is used to burn off these slivers. A "sliver burner" was made up using the high voltage tester and 2 10KV 2mf condensers. The condensers in parallel are charged to 10KV with the HV tester and then discharged through the faulty tube. A sufficiently high current thus passes through the sliver to fuse it down to a small globule of copper on the outer conductor which is insufficient to cause a HV breakdown.

This first fault and one other fault which was detected a little later, were cleared by this means, but peculiarly enough, no faults which could be attributed to slivers were encountered over the last 60 miles of the cable between Dandenong and Morwell or in the 20 miles between Melbourne and Dandenong. A direct short circuit was discovered on one tube in one length. An approximate location was given by the Reflectoscope. A bridge megger was used to make a more accurate location, but it was decided to use a Phillips cable locator to pinpoint the fault and avoid opening any more sheathing than necessary. This instrument supplies a high frequency tone and employs a transistorised detector and search coils. The cable was excavated at the location

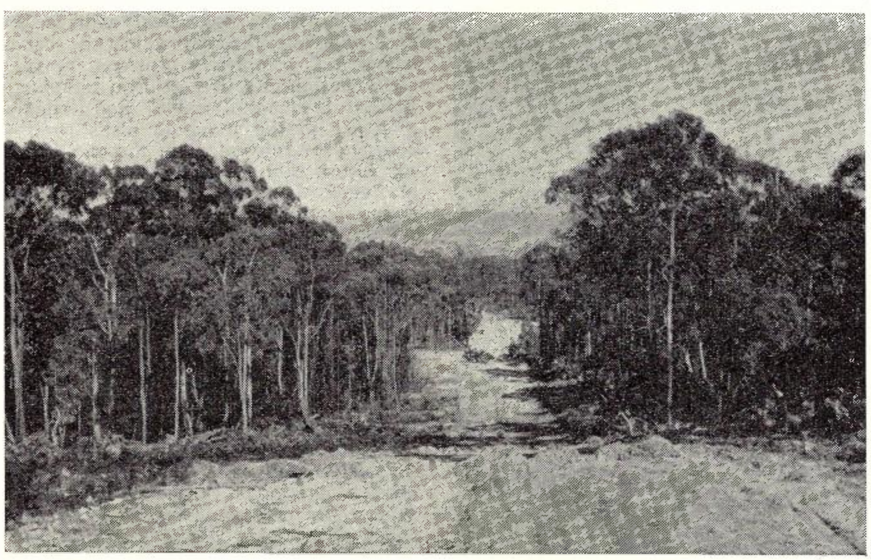

Fig. 16.—Right of way for cables through Haunted Hills between Moe and Morwell after cable laying completed.

given by the Reflectoscope and the short circuit then was located to within 1 inch with the cable locator. It was found to be due to a manufacturing defect which had not shown up in factory tests. It occurred at a point where the steel tapes around the tube were jointed. It appears that when the tapes were being jointed, the outer conductor had been kinked and this kink had worsened during laying to the extent of a short circuit. The fault was cleared by opening up the tube, straightening it out and reforming it around a split tube of ⅜" outside diameter using the crimping pliers which is one of the jointing tools, removing the forming tube, repositioning the insulating discs, closing the outer conductor with the crimping pliers and then re-wrapping the steel tapes.

This method of correcting dented tubes was used successfully on a number of occasions when, during installation, the cable was accidently knocked or kinked and one or two tubes dented, thus obviating the need for a full joint. Later the detection of faults in two tubes in the one length which were breaking down under the high voltage test at 750 volts and 1100 volts respectively, indicated a deficiency in the test instruments supplied for the installation team. These faults could not be cleared with the "sliver" burner. It became necessary to borrow a high voltage bridge instrument from the cable manufacturer to locate these faults. This instrument can be used to make a Varley loop test under high voltage conditions, thus enabling faults of this nature to be located. The faults when located were discovered as was suspected to be at the same point in the cable and were due to the cable having been kinked apparently during laying.

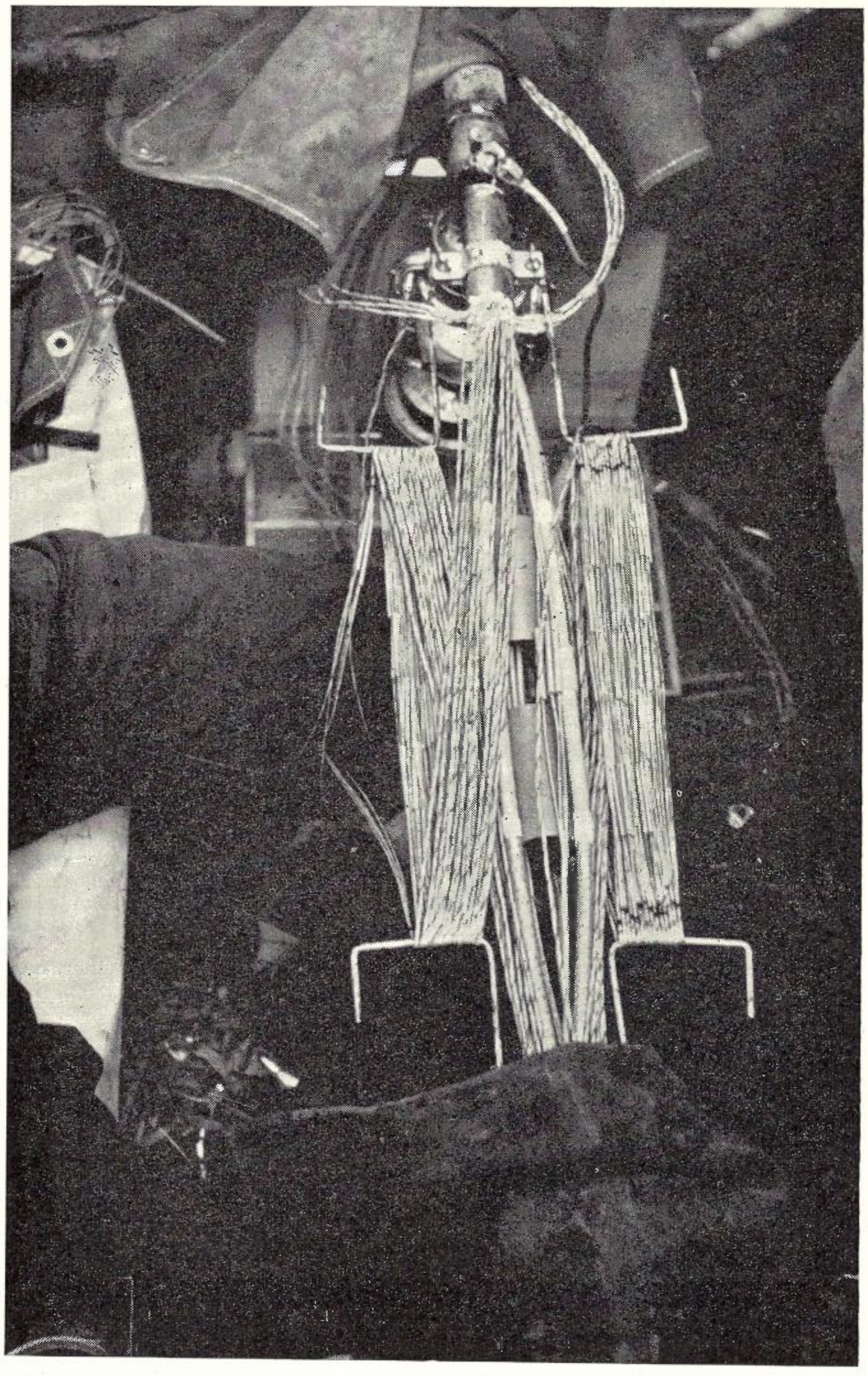

Fig. 17.—Joint showing temporary bracket used to join layer pairs to leave sufficient slack to allow access to coaxial tubes at a later date.

It was necessary, on a number of occasions, to borrow this instrument to locate high voltage breakdowns in the coaxial tubes which had been caused by denting or kinking of the cable during laying. The occurrence of these faults indicated that a high voltage bridge is a most vital test instrument for a coaxial cable installation team. It also indicated the extreme care which must be exercised when handling coaxial cable. A laying team should, however, be instructed to note and mark any point at which the cable is damaged or even suspected to have been damaged during installation, as much time may thus be saved if ultimately the high voltage test does indicate damage to the coaxial tubes.

A number of faults also occurred due to movement and consequent kinking of the cable close to joints. The sand used to backfill the jointing holes does not necessarily give adequate support to the cable and joint when heavy loads subsequently pass over the backfilled hole and it is obvious that almost continuous support is necessary for the cable and joint either on undisturbed earth or on solid supports resting on undisturbed earth.

PROTECTION OF THE CABLE

The importance of this cable demands that every precaution should be taken to protect it from mechanical damage. In each manhole through which the cable passes it is completely protected by specially designed split cast iron couplings bolted over the cable and rigidly attached to the manhole walls to discourage the movement of the cable during future cabling operations. The joints are enclosed in split sleeves of heavy gauge steel.

In the buried sections the location of the cable is indicated at all joints, angles in the route and at points of special vulnerability such as road and open drain crossings, by concrete marker posts on which are mounted plates indicating the presence of a high voltage cable. These plates are also attached to all gates through which the cable route passes.

Arrangements are being made to have caveats lodged against the titles of all private property through which the cable route passes, so that if a property changes hands in the future the new owner should be made aware of the existance of the cable and so that the Department will have prior notice of plans to subdivide a property.

The cable is protected by a gas pressure alarm system and against electrolysis, but details are not included here as these aspects could form the subject of a separate article by someone more qualified than the author of this article.

SERVICE ORGANISATION

Associated with the installation group was a team of 1 Senior Motor Mechanic and 2 Motor Mechanics equipped to carry out all minor repairs and adjustments to the mechanical plant and motor vehicles. This team proved to be a most necessary part of the organisation. The "down time" of the mechanical plant due to breakdowns was reduced to a minimum by the ready availability of skilled staff to carry out repairs. A 5-ton truck with a 500 gallon tank of diesel fuel and with greasing and oiling equipment was provided for fuelling the diesel powered plant and servicing on the job of all plant and vehicles.

The installation group was accommodated in two main camps, each with a cook, cook's assistant, and penman. A fourth Line Inspector was responsible for camp organisation, including making advance arrangements for sites and organising camp shifts and also for ensuring that all necessary material was available for the job. This relieved the other Line Inspectors of most extraneous work and allowed them to concentrate on the direction and supervision of their teams in the field. The camps comprised caravans for kitchen, dining, ablutions (showers and wash basins), toilet, office and sleeping. The men were generally accommodated in 4-berth caravans, with 2-berth caravans for each of the supervisory officers. Liquid petroleum gas was provided for cooking in gas stoves and for refrigeration and hot and cold water was supplied to the ablutions and kitchen caravans. 230 volt power was used for lighting in the camps, normally being obtained from the local mains supply, but where this was not available, from a trailer-mounted 3.5 KVA diesel alternator with automatic start. The bunks in the sleeping caravans were fitted with rubber mattresses and pillows with plastic covers, the tables in the dining caravans were laminex topped and all caravans were extremely well finished, even to fly-wire screens on all doors and windows and curtains on the windows.

This accommodation is far superior to anything provided previously by the Department for camping parties and probably by any other authority in Australia. The camps were a great success and from the point of view of staff morale were well worth the expenditure involved. At the completion of the job the caravans were in first class condition and showed very little sign of having been occupied. The staff on this project worked extremely well, at times under extremely trying conditions, and there is no doubt that this was due, in part, to the fact that they knew that after the day's work they could go "home" to hot showers, good meals in comfortable conditions and to comfortable beds.

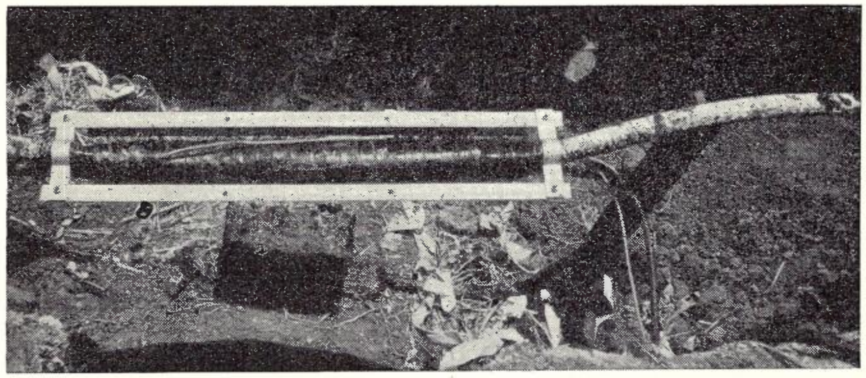

Fig. 18.—Angle-iron bracket used to make the joint rigid. The Gas Tube and Electrolyser Test Lead also can be seen.

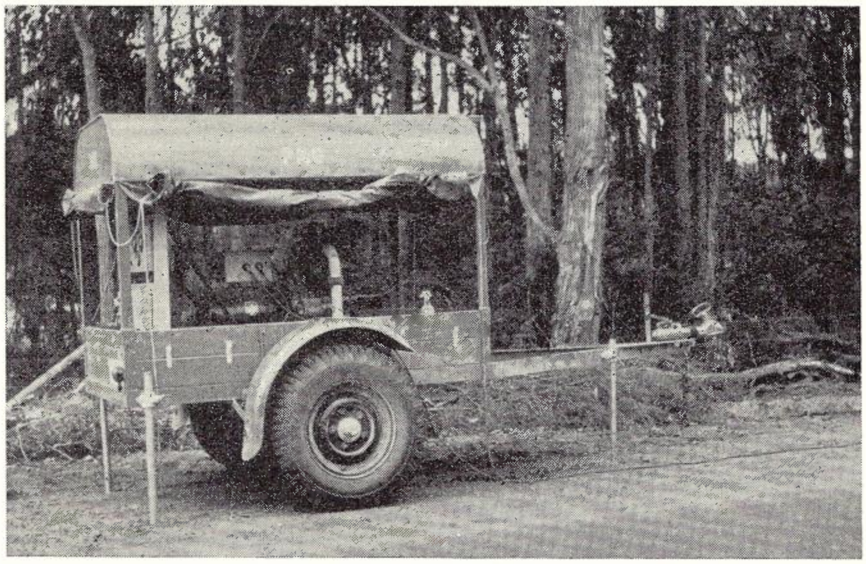

Fig. 19.—Trailer-mounted 230 volt generator used by testing team.

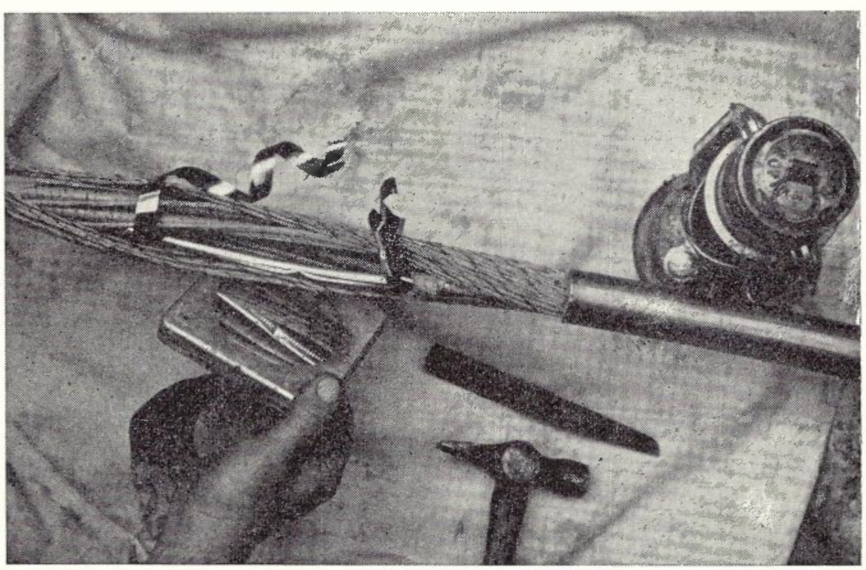

Fig. 20.—Dent in Coaxial Tube caused by manufacturing defect. This fault was cleared without making a joint in the tube by reforming the outer conductor.

Fig. 21.—Fuel tanker.

COMMUNICATION

A two-frequency mobile radio telephone system was provided for communication on the job. The office caravans at both camps, and the Line Inspectors', Group Engineers' and Senior Motor Mechanic's vehicles were fitted with mobile units. The base repeater equipment and aerial were sited on a suitably high location previously selected and checked by staff from the Radio Section to obtain the best coverage of the working area. The aerial was mounted on a 30 ft. aluminium alloy pipe mast which was made up in three sections and was easily transported, assembled, erected and dismantled. The equipment, together with the necessary 12 volt batteries, was installed in a cable jointer's trailer converted for the purpose.

The experience on this project was that a communication system such as this is most essential for such a project. Many valuable hours of travelling time on the part of supervisory officers and key personnel were saved and the mileage travelled by vehicles undoubtedly was appreciably reduced. More important, the use of the radio telephone system enabled the out of service time of mechanical plant to be reduced considerably, by enabling repair operations to be set in motion without undue delay.

IN RETROSPECT

A great deal of valuable experience has been gained during this job which must be put to use on similar projects in the future.

The pre-planning of such a project is of paramount importance. Some preplanning of this job was carried out but, because of pressure to start installation, it was not completed. It is now realised, however, that a job of this nature and magniture must be pre-planned in most fantastic detail so that each man in the team performs his allotted tasks to a job instruction set out step by step. Only by such pre-planning is it possible to achieve maximum efficiency in the use of labour and mechanical plant. On the Dandenong-Morwell project supervisory officers (Group Engineers and Line Inspectors) spent too much time, day to day, planning each day's operations and thus were left too little time for pure supervision. The ideal situation is, with all operations planned and set down in detail, the supervisory officers should be free to spend all their time supervising these operations and from time to time, as necessary, altering the plan to cater for changes in circumstances, such as, for example, different soil conditions due to wet weather.

On a number of occasions expensive items of plant such as ditchers were out of operation for lengthy periods because particular tasks had not been fully planned in detail beforehand and the staff instructed as to the correct method of tackling them. Manipulative staff are generally not capable of thinking far ahead and, as a matter of fact, should not be expected to, as they have a full time job carrying out the task immediately before them. It is necessary for Engineers and Supervisors to do this thinking and sufficient time must be allowed before a project commences, to enable the job to be planned in complete detail to ensure real efficiency during execution.

There is no doubt also that it is essential that a project should be programmed so that it can be carried out at the most favourable time of the year as far as weather is concerned. If it is necessary to work during the wet season, the appropriate mechanical plant for wet weather operations must be used. All earth moving equipment should be crawler track mounted and sufficient back hoe excavators should be available for trench excavation in all but the highest and driest locations. All motor vehicles should have 4-wheel drive.

On the testing side some valuable conclusions can be drawn. At the commencement of this project, it was believed that the pulse echo test was the most important test to be carried out on the coaxial tubes during installation. In fact, it was found that all faults detected on the tubes during installation were shown up by the high voltage test. Virtually nothing was gained during this project by pulse echo testing the coaxial tubes during installation. It is considered that if the cable lengths are properly allocated in repeater sections for matching of the end impedances of tubes at joints by the manufacturer, then with no more than reasonable care during laying, no impedance mismatch outside specification will result. The pulse echo test is necessary, of course, as part of the overall repeater section tests to confirm this.

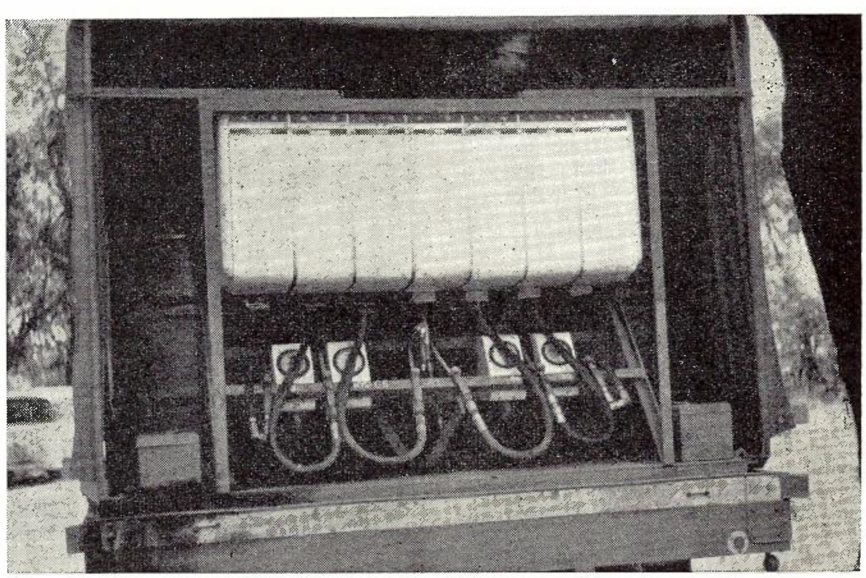

Fig. 22.—Rear view of fuel tanker showing oiling and greasing equipment.

Fig. 23.—View of camp at Tynong.

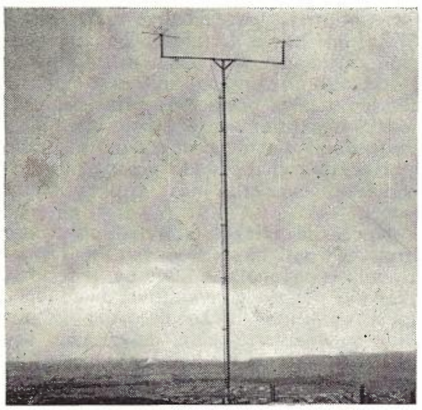

Fig. 24.—Radio Telephone System Aerial. The top of the trailer in which the repeater equipment was installed can just be seen at the bottom of picture.

The important test instrument to be used on coaxial cable installation is the high voltage tester backed up with the high voltage bridge for locating points of high voltage breakdown.

As mentioned earlier, it was also found to be most important that the joints and cables where buried should be continuously supported as far as practicable on undisturbed earth or on solid supports on undisturbed earth and, whatever method is used to house joints on future coaxial cable installations, this requirement should be satisfied.

COST OF INSTALLATION

As can be imagined from the description of the installation of the cable, the actual cost of installation considerably exceeded the estimated cost. The estimate for the buried cable section was based on an anticipated rate of cable installation of 5 miles per week, whereas the actual average was 2.3 miles per week. This lower rate of installation was due almost entirely to the unsuitable soil conditions, although inexperience with the new construction technique certainly contributed. Also it was found necessary to employ more men in the installation team than had been anticipated. One example of this was the jointers and a technician who were added to the team to make measurements on the paper insulated pairs of the laid cable after it had been discovered that the factory measurements could not be used.

The actual cost of installation of the cable between Dandenong and Morwell, not including the material costs was approximately £1,350 per mile. Between Melbourne and Dandenong the cost of installation in ducts was approximately £900 per mile.

CONCLUSION

As this was the first major coaxial cable installation in Australia many problems were encountered, the answers to which were not readily available, but all those directly and indirectly connected with the project co-operated enthusiastically to overcome these problems.

A great deal of credit is due to the members of the installation team, particularly the supervisors who effected many improvements to the planned installation technique and themselves overcame many of the difficulties encountered.

REFERENCES

(1) J. F. Sinnatt: The Melbourne-Morwell Coaxial Cable; Telecommunication Journal of Australia, Vol. 12, No. 1.

BACK COPIES

The Society has available in quantity, back copies of most issues of the Journal from Volume 5 onwards. Volume 12, Number 1 is out of print, but reprints of the two articles on co-axial cables may be obtained for a total cost of 3/-.
These Journals may now be supplied, on demand from State Secretaries* at 10/- per set of three or at 4/- per single copy.
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* For addresses see page 467.

NOTES ON THE DEVELOPMENT OF ELECTRONIC EXCHANGES

*C. I. CRUTTENDEN, A.M.I.E.Aust.**

INTRODUCTION

Electronic Switching Principles.—Electronic switching is being developed from two basically different concepts briefly known as Space Division and Time Division.

The space division system is sometimes referred to as the crosspoint system since it is the electronic counterpart of mechanical crosspoint systems such as the crossbar system. Basically, a crosspoint is a switch which can be used to connect two conductors together.

The time division system is, as its name implies, a time-sharing system as opposed to space sharing of the conventional exchange, or frequency sharing familiar in carrier telephone systems. Each subscriber's line in a time division system is scanned or sampled at very high speed, of the order of 10,000 times a second in 100 line groups, and the samples are allotted separate time-positions on a common communication channel, which is generally referred to as a common highway, or simply a highway. Each highway is divided into 100 or more time intervals or time-slots, and they can be interconnected so as to form exchanges of any size. Subscribers are switched together by arranging for their lines to occupy coincident time-slots on the same or on an interconnected highway.

Components Used for Electronic Switching.—Ordinary hot-cathode and cold-cathode valves can be used for electronic switching, and they have been the basis of many experimental electronic exchanges to date. They are not suitable for large-scale use owing to cost, current consumption, space requirements, and fundamental electrical properties such as speed of operation and noise generation.

Developments in electronic switching are now largely based on the use of solid-state devices such as the transistors, ferrite cores, and similar bi-stable (on-off) elements, but quite a number of unique devices have been suggested or used for information stores or "memories".

Some of the suggested methods rely on the fundamental properties of basic materials or elements under controlled conditions, for example, the fact that the electrical resistance of certain materials reduces to zero at the temperature of liquid helium, or approximately —450 deg. F.

The cost and the reliability of components has been, and still is, one of the major considerations in the development of electronic exchanges. At the present prices of components it is not possible to build electronic exchanges competitively with conventional exchanges. The cost of production must be reduced by improved manufacturing techniques combined with large-scale demand. The reliability of components is continually being improved but still greater improvement is required if the service reliability of an electronic exchange is to be comparable with a modern crossbar exchange. Very rapid development of new components has been made in the last few years, and there is some reason to believe that a major new development is required before electronic exchanges can become really attractive in commercial and other respects.

* See page 467.

TELEPHONE INSTRUMENTS

Electronic exchanges require a new kind of telephone instrument, chiefly for the reason that the electronic switching equipment will not pass normal ringing current due to its low frequency and high power. An amplified tone must be used instead of the usual ringer with bells.

The present dial acts as a switch to send a series of loop-disconnect impulses to line in accordance with the digit dialled, but it does not seem that this allows the potentialities of electronic exchanges to be fully exploited, and, in addition, the replacement of the dial by a device less liable to service troubles is highly desirable. A push-button device should preferably replace the dial and the digits in the called number produced by combinations of voice-frequency currents. Field trials of push-button telephones are being made in U.S.A. and Sweden, but these are associated with crossbar exchanges. Experimental telephones have been produced by the Bell Laboratories which require the called number to be keyed up before the handset is lifted. This is feasible because of the high-speed transmission of the number information, and is desirable because it substantially reduces the holding time of the exchange equipment.

At present, the telephone transmitter obtains the current for its operation from the exchange, but the minimum amount of current in the line is determined by the exchange equipment which will not operate satisfactorily on less than about 20 milliamps. These conditions would not apply to electronic exchanges and a better transmitter than the carbon granule type could be used, for instance, the electrodynamic type which operates from sound and requires no current. The sound is converted to electrical pulses which require amplification, but the transistor amplifier necessary for the calling tone could also be used for amplifying the transmitter output and for amplifying incoming speech.

The telephone is likely to be much more expensive than the present type, but it may be possible to compensate the extra cost by allowing for greater transmission loss in line plant. The present maximum allowable loop resistance of 1,000 ohms for subscribers' lines is determined by the signalling limits of the exchange equipment and the speech transmission performance of the telephone. Much higher limits would be permissible with the new type telephone, but it is not possible to estimate at this stage where the economic balance would occur. This is partly because about 80% of our lines are already under 400 ohms and there is a limit below which it is not practicable to reduce the size of copper wires in underground cables. The smallest we now use is 4 lbs. a loop mile.

OVERSEAS DEVELOPMENTS

United Kingdom: A model electronic exchange using time division has been built at the Dollis Hill Laboratories of the B.P.O.(1) under the auspices of the Joint Electronic Research Committee, on which all the major telephone system manufacturers in the U.K. are represented together with the B.P.O. This exchange uses hot and cold cathode valves and the magnetic drum as an information store. This device is electro-mechanical so that the model exchange is not strictly fully electronic.

As a result of the experience gained with the Dollis Hill model, it is planned to build a similar exchange for public service and install it alongside a new conventional type exchange at Highgate Wood in North London. The conventional exchange will act as a standby to the electronic exchange so that the public service will be protected against failures to the maximum extent possible. It is understood that at least six more public electronic exchanges are planned for installation over the next two or three years.

Since the Highgate Wood electronic exchange will have a conventional step-by-step exchange as a standby, it follows that the present conventional telephones must continue to be used. It is not known whether special telephones are planned for the additional electronic exchanges; if not, they will still comprise a mixture of electronic and conventional equipment. It is understood that each of the manufacturers is to produce what is known as the Mark II model of the Dollis Hill exchange, that the exchanges will not be identical, and that they will include the results of independent research.

The B.P.O. and the five principal telephone manufacturing companies were all working independently on electronic switching prior to 1956, and the establishment of the J.E.R.C. was an attempt to pool their efforts. The efforts towards electronic exchanges were commenced about 10 years ago.

Bell System, U.S.A.: A field trial of the world's first public electronic exchange was started at Morris, Illinois, U.S.A., on 17th November, 1960, by the Bell Telephone Laboratories and the Illinois Bell Telephone Company (2) (3). This trial exchange of 600 lines uses the space division technique with gas tube diodes at the crosspoints, but the central control serves calls one at a time and therefore operates on a time division basis. The exchange makes extensive use of transistors and other semiconductor devices, and has unique memories or stores which have resulted from intensive research over a number of years.

The basic design provides for a line scanner for each block of 1000 lines and each individual line is continuously scanned or checked for calling or called conditions 10 times a second normally, or 100 times a second during dialling so as not to miss any pulse from a 20 per second dial. The time required for scanning any line is 2.5 microseconds. The central control also operates at very high speed so that, overall, there is ample time, even in the busiest periods in a high calling-rate exchange, for the equipment to continually check its own circuitry. When a fault is found it is diagnosed and in some cases corrected, but if automatic correction is not possible the details are written out on a teletypewriter for attention by the maintenance staff.

Dialling and other temporary information is stored on a barrier-grid tube whilst permanent or semi-permanent information is recorded on photographic plates in what is known as a flying-spot store. This store contains the entire operating procedure of the exchange including special facilities, number translation, and so on.

The Bell Laboratories are now working on a production model of the exchange suitable for volume manufacture by the Western Electric Company. Many components in the production model will differ from those used at Morris, but it is nevertheless expected that the first production model will be in service by mid-1965 and that this type of exchange will thereafter be used for development and replacement purposes.

The telephone used at Morris has a transistorised tuned circuit amplifier which supplies an audio tone to replace the ringer, and the dial operates at 20 impulses a second. A low line current of about 10 milliamperes is made possible by using the amplifier for speech amplification.

The Bell Laboratories have also developed and constructed a research model of a time division exchange using solid-state devices exclusively.

International Standard Electric Corporation, New York: The French Affiliate of this organisation, the Laboratoire Central de Telecommunications, Paris, recently announced the construction of a 240 line P.A.B.X. which is undergoing service trials in the laboratories (4). This exchange operates on the space division system and employs cold-cathode gas diodes, similar to those developed by the Bell System, for the crosspoints. Line scanning is similar in principle to that described for the Morris exchange, but there are no other similarities. The common control follows space division principles and ferrite cores and transistors are used for registers, markers, and stores. The registers are simple devices consisting of a row of ferrite cores and, since they are retained for the duration of the call, may not be strictly regarded as common control equipment. It is claimed that the model P.A.B.X. has demonstrated the practicability of the technique for small exchanges and the possibility of its extension to large exchanges.

The telephone is a conventional one except that the calling signals are produced by an ordinary telephone receiver driven by a transistor amplifier. The dial operates at normal speed and make-break ratio.

The Laboratoire Central de Telecommunications constructed a laboratory model of a time division 100 line exchange in 1952, but the semiconductor components available at that time precluded further development.

General Telephone System, U.S.A.: This company resulted from the amalgamation of the Automatic Electric Co. with the General Telephone Corporation, and research work is carried out by General Telephone Laboratories Incorporated at Northlake, Illinois (5). These laboratories have been working on the development of electronic exchanges for some years and have constructed a small (10 line) electronic exchange using the time division technique.

The telephone used with this experimental exchange is a compromise. The normal ringing is replaced by a tone, but the dial has been retained although it is adjusted to operate at much higher speed than normally.

The Automatic Electric Laboratories associated with the General Telephone System have produced a model 100 line fully electronic P.A.B.X. which, like the Morris exchange, has a space division switching network and a time-division common control. The crosspoint switching elements, however, are PNPN silicon diodes instead of gas tube diodes. The behaviour of these two devices is similar in that they are switched from the "off" to the "on" state with a voltage pulse in excess of the breakdown voltage. They are then maintained in the "on" state by a fixed forward voltage which is reduced below a critical value to switch them off. The PNPN diodes have much faster switching speeds and require less power than gas diodes. The exchange has a ferrite core memory.

The telephone is fitted with a transistorised tone amplifier the output of which is connected to the receiver capsule in the handset.

L. M. Ericsson, Sweden. The North Electric Company, of Ohio, U.S.A., which is affiliated with L. M. Ericsson, has received an order for a number of small electronic exchanges from the U.S. Air Force. (6) These exchanges will be designed to operate on the time division system developed in the Ericsson Electronics Laboratory. All the circuit work will therefore be done by Ericssons in Stockholm, but the equipment will be manufactured in America by North Electric.

The cost of the electronic exchange is stated to be very much higher than for conventional equipment, but was considered warranted by the special conditions under which the equipment will operate. Some of the exchanges are for fixed installations, but some are for mobile use with transport by helicopter, so apparently they are quite small exchanges. The capacity in lines is not known.

PRACTICAL PROBLEMS

Staff training is of major importance when considering the practical problems associated with the introduction of electronic exchanges. Electronic exchanges will introduce entirely new techniques which have no present counterpart in the communications field. The basic concepts are now included in engineering studies at university level and have been appearing in technical publications of various kinds in recent years, but this is not sufficient for future needs and operating administrations must embark on long-term training schemes for Engineers and Technicians.

The requirements at technician level differ widely from those needed for conventional exchanges. Maintenance will be concerned almost exclusively with electrical phenomena whereas emphasis until now has been on the mechanical aspects of exchanges. Certainly, with crossbar systems mechanical faults are negligible, and electrical faults therefore assume greater prominence. From this viewpoint the graduation from step-by-step equipment through crossbar to electronic exchanges can have very significant advantages.

From consideration of staff training alone it is abundantly evident that no Administration can advance very rapidly into the adoption of electronic exchanges. It would be impossible, for example, for the A.P.O. to contemplate a complete change-over in supplies from step-by-step to electronic equipment in three years, as is being done for crossbar.

There are also two features of electro-mechanical exchanges which cannot be provided with electronic exchanges, and the loss of these features can assume considerable practical importance. One is the reversal of polarity on subscribers' lines which is now used for special signalling purposes, especially for public telephones. The other is the ability to make direct current resistance and insulation measurements and other tests of subscribers' lines by setting up calls from a test desk through a special group of test selectors. There can be no d.c. connection to the lines through an electronic exchange. The loss of these features can have extensive repercussions on the design of present equipment and established practices.

Electronic exchanges will employ low power levels and, consequently, all soldered joints in the wiring and cabling must be extremely good, and all jack points for jacked-in equipment must probably be plated with precious metals, or precious metal alloys.

This will raise one of the problems in the final engineering of an exchange. Ease of maintenance demands readily replaceable units on a jack-out jack-in basis, but the need for high quality jack contacts will make this costly. One alternative is the duplication of such units so that time is available for disconnection and reconnection when units become faulty.

CONCLUSIONS

It is clear that during the past ten years all large telephone manufacturers have devoted much time and effort to the development of electronic switching for telephone exchanges; some have reported their efforts only very briefly, or not at all, in technical literature. No doubt the temptation to be first in the field is tempered more or less by the strong possibility of early and rapid obsolescence.

Manufacturers are obviously faced with very great difficulties. The initial development of a telephone exchange of any kind, including the building of an experimental laboratory model, is but the first stage. The second stage is the production of a field trial exchange, which will usually incorporate some improvements found necessary from experience with the laboratory model as well as improved techniques and components; this is the case with the proposed Highgate Wood exchange in the U.K. and the Morris exchange in U.S.A. Assuming the field trial exchange is successful, the third stage is the complete engineering of the exchange for large-scale manufacture. On completion of this stage, the exchange must be suitable for use in public networks and at least be readily adaptable for many varying conditions and facilities if it is to be offered on the world market.

The third stage could take from three to five years — this naturally depends upon the effort put into it, and this would be governed to a large extent by the expected demand or other incentive. Basic developments are now so rapid that during this period there is a considerable risk that the effort will be outmoded.

No responsible Administration would commit itself to large-scale use of electronic exchanges without an extended field trial of one or more small exchanges. Where, as in America, England and West Germany, there is a close liaison or link between the manufacturing organisations and the operating authorities, it is possible to arrange for field trial in the public network of the second stage exchanges and so reduce the time period before the final design is available. Nevertheless, the change in physical design between the second and third stage exchanges is likely to be so great, even if the same basic components are used, that normal caution would tend to dictate at least a limited field trial of the final design.

With the foregoing in mind, together with the fact that electronic exchanges must prove to be convincingly superior to modern electro-mechanical systems, such as crossbar, in first costs or overall economics, in maintenance and quality of service generally, in space occupancy, and in flexibility for traffic and facilities, it is difficult to escape a conclusion that it will be at least 10 years before electronic exchanges are ready for large-scale use. Certainly, within the next five years there will be a number, perhaps many, field trial electronic exchanges in use. Almost certainly also, these will be second stage exchanges since no manufacturer would want to risk full-scale engineering effort on development from a laboratory model. This could no doubt be done, but the reaction and responsibilities of the prospective customer must be considered. Most will want the assurance of a successful field trial by themselves or others. It would appear to be over-optimistic to assume that the final period, which would include the resolution of all the problems associated with interworking with existing equipment, could be less than another five years. This does not necessarily apply to the Bell System which, following the Morris trial, expects to have the first production exchange available in 1965.

Nevertheless, it would be surprising if volume manufacture is undertaken without at least a limited field trial of the production model. Finally, it is to be remembered that Bell System exchanges are not available on the world market.

Considerations such as these influenced the A.P.O. decision in 1959 to adopt crossbar rather than wait for electronic exchanges since in ten years time the present amount of automatic exchange equipment in Australia will have at least doubled. Crossbar provides the only immediate economic solution to the urgent problems of meeting development in the Sydney and Melbourne networks, and also provides an economic and technical method of implementing the National telephone policy for many years. Nevertheless, The A.P.O. is of necessity vitally interested in the development of electronic switching and the Research Laboratories have already constructed a model 20-line time division electronic exchange with the objective of acquiring a deeper understanding of the problems and techniques, and possibly making a contribution to the art.

Although the first costs of electronic exchanges are reported to be high at present it is generally expected that they will be reduced, and in addition it is expected that substantial savings in capital costs may be made in other directions. The space requirements, especially of time division exchanges, should be relatively small, and the possibility of higher resistance limits for subscriber's lines and junctions could lead to appreciable savings in external plant. The electronic exchange appears to be ideally suited to remote concentration and this could also reduce external plant costs. There may be dramatic savings in maintenance costs through continuous automatic checking of circuits and reporting of faults, possibly to an administrative centre, from a large number of unattended exchanges. The Morris exchange points the way to this, just as the technique of having the complete operating programme for the exchange on photographic plates points the way to large savings in administrative and manipulative costs when it is desired to change the facilities available to subscribers. The output from a remotely located teletypewriter may be encoded on punched cards or magnetic tape and from these either directly or indirectly to the exchange programme whether this be photographic plates or some other form of memory.

The next decade promises to be the most interesting and exciting in the history of telecommunications, not only for the Engineer and Technician, but also to the many others who play equally vital roles in the provision of telephone service.

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INTRODUCTION TO JUNCTION TRANSISTORS

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This series of articles is abstracted from a group of transistor lectures given jointly by the author and Mr. A. C. Luther. The author wishes to acknowledge the fact that many of Mr. Luther's valuable contributions to the lectures have been retained in these articles.

PART II—THE COMMON-EMITTER AMPLIFIER AND THE COMMON-COLLECTOR AMPLIFIER

R. N. HURST

INTRODUCTION

The first article in this series introduced the transistor as an extension of a junction diode, and showed the characteristics and behaviour of a common-base amplifier, which can give large voltage gains, but always gives a current gain less than one. Operating it as a voltage amplifier is very difficult, since the driving source must have such a low impedance, and operating it as a current amplifier has no advantage, since it can offer no current gain. Although certain intermediate types of operation (for example, the delay-line circuit [56]) can make use of the CB amplifier in spite of its restrictions, it is more common to see a transistor connected in the common-emitter (CE) configuration. Therefore, this second article will deal with the common-emitter configuration. The common-collector configuration will also be discussed.

THE COMMON-EMITTER CONFIGURATION

The common-emitter configuration

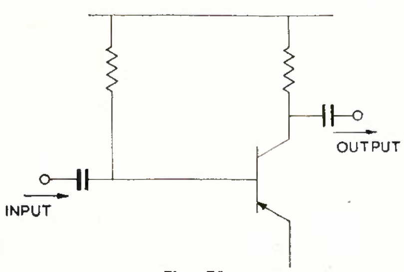


Fig. 71.

corresponds roughly to the grounded cathode configuration of a vacuum tube:

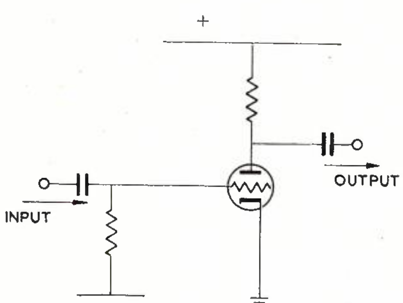


Fig. 72.

It is one of the most frequently used transistor configurations, chiefly because it offers the greatest gain capabilities of any of the three possible configurations. It also provides a higher input impedance.

The ability of the CE configuration to provide large current gains lies in the fact that the signal current is applied to the base, where it adds to or subtracts from the very tiny base current. Since the base current (bias current plus the signal current) is a fixed percentage of the collector current,

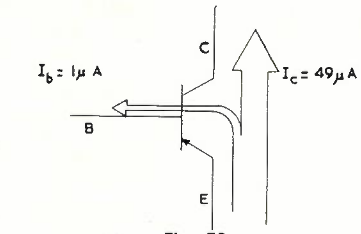


Fig. 73.

variations in the base current will cause proportional variations in the much larger collector current:

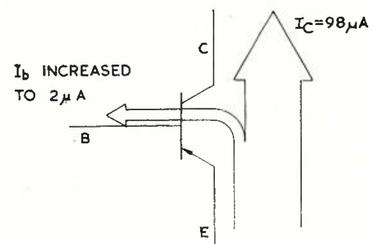


Fig. 74.

This action results in a current gain.

CHARACTERISTIC CURVES OF TRANSISTORS IN THE CE CONFIGURATION

In studying the CB configuration, a laboratory experiment was described (23, 24, 25) in which the transistor was connected to a tapped battery, in this manner;

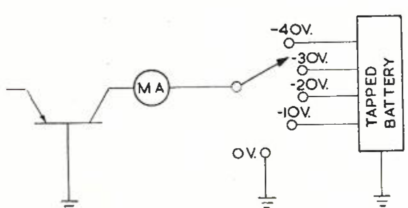
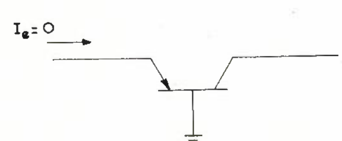


Fig. 75

and the E_c vs I_c curves were determined; first for zero emitter current:



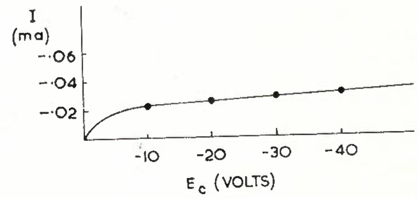


Fig. 76.

and then for several different values of emitter current:

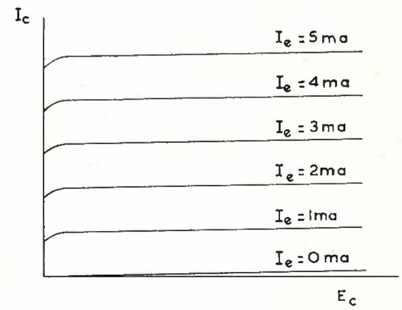


Fig. 77.

thereby generating the E_c vs I_c curves for the common-base configuration. With these curves the operation of a CB amplifier was analysed.

In a similar manner, a laboratory experiment can be set up with a transistor in the common-*emitter* configuration:

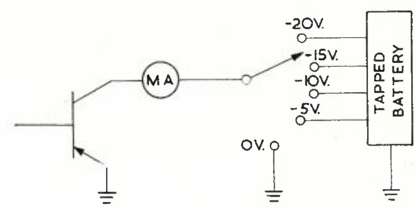


Fig. 78.

and its E_c vs I_c curves plotted; first for zero *base* current:

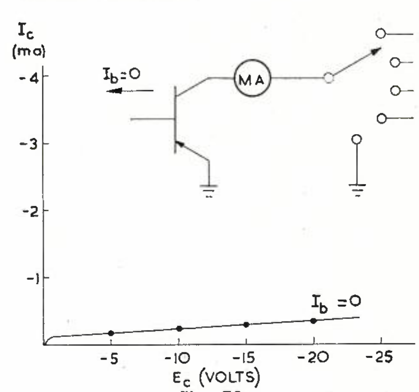


Fig. 79.

and then for several different values of base current:

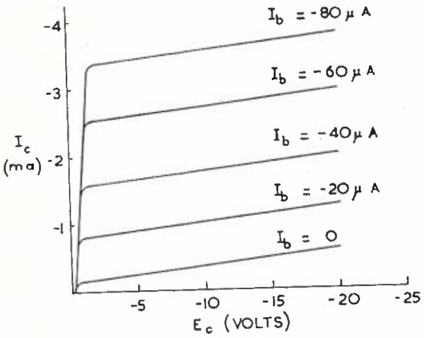


Fig. 80.

It will be observed that these curves differ from the CB curves in several respects. First, the curves have a steeper slope (1); second, the curves do not run all the way over to the left-hand axis (2); third, the running parameter, I_b, is a very small current, as compared to the collector current (3); and fourth, the collector current for zero input (base) current is much greater than the corresponding curve for the CB configuration (zero emitter current) (4). These differences are indicated in this figure:

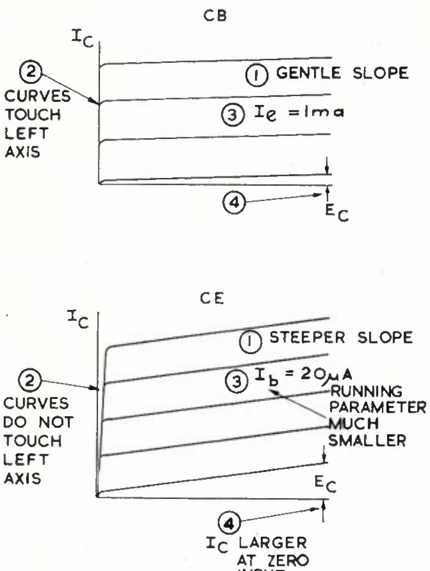


Fig. 81.

The significance of these differences will become apparent in the following discussion.

Let it be supposed that a piece of equipment contains this amplifier:

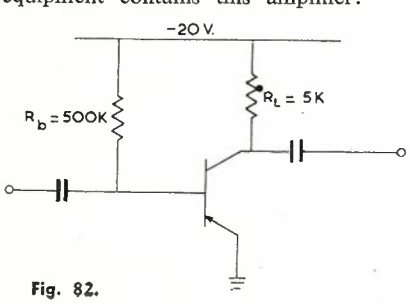


Fig. 82.

It is desired to know how this amplifier is operating—what the bias is, how much collector current flows, how much power is dissipated in the collector, and how much gain it will offer. All these facts may be ascertained by a simple construction on the common-emitter characteristics.

First, a warning: the bias method shown (82)—a resistor R_b supplying bias current to the base from the collector power supply—is an extremely poor way to bias a transistor. It would cause the amplifier to be very sensitive to both transistor replacement and change in temperature. It is used in this example because of its simplicity, which gives it value as a means of explaining the CE configuration. To make the following discussion valid, it must be assumed that the curves used are exact representations of the individual transistor in the circuit. Normally, the published curves for a particular type of transistor are for a unit whose characteristics are in the centre of the allowable manufacturing tolerances. The fact that there are rather wide tolerances on transistors is one of the factors which makes necessary the use of more elaborate biasing techniques in practical circuits.

Analysis of this common-emitter amplifier follows basically the same pattern as the analysis of the common-base amplifier (34). The analysis is begun by drawing the load line on the common-emitter characteristics:

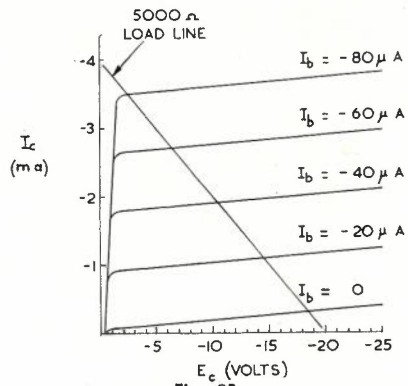


Fig. 83.

Just as for the common-base circuit, this amplifier's operating point must lie somewhere on its load line. For the common-base amplifier, it was shown (38) that the operating point lies at the intersection of the load line and the particular bias-current chosen:

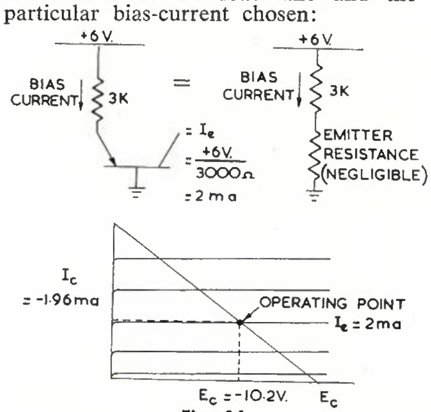


Fig. 84.

The operating point of this common-emitter amplifier may be found in a similar manner:

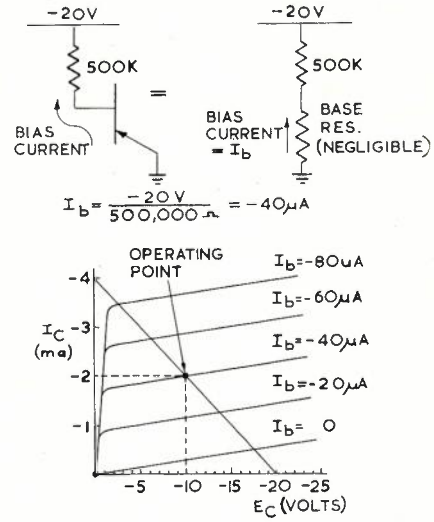


Fig. 85.

This common-emitter amplifier therefore operates with a bias current of 40 μA, a collector current of −2 ma, and a collector voltage of −10 volts:

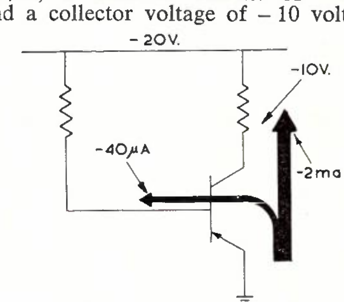


Fig. 86.

The power dissipated at the collector is:

$$P = IE = (-2 \text{ ma})\ (-10 \text{ volts}) = 20 \text{ milliwatts} \qquad (87)$$

The gain of this amplifier depends upon whether it is being used to produce voltage gain or current gain. In either case, it can produce useful gain. A simple amplifier such as this one has a current gain equal to beta—about 50 for a typical transistor—if the load is a short circuit or very low impedance:

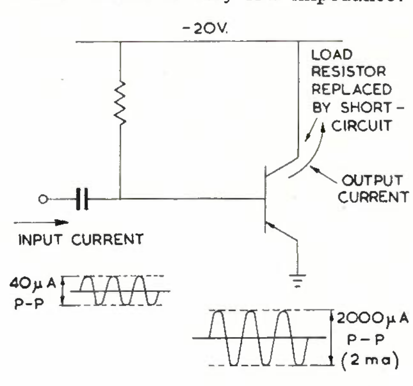


Fig. 88.

However, this particular amplifier has a load of 5,000 ohms, so its current gain will be slightly less than beta. The actual value can be determined from the characteristics in this way:—

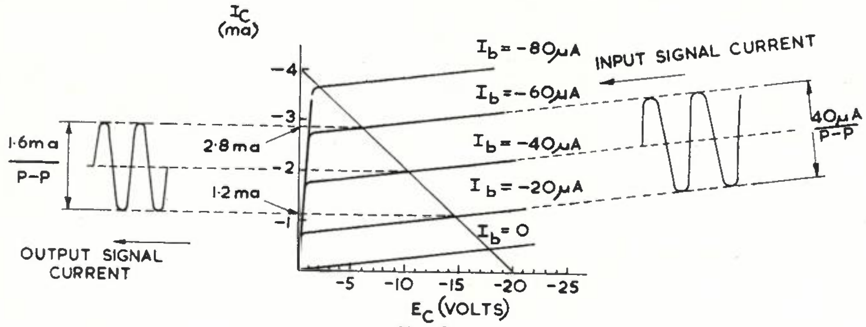


Fig. 89.

Since the output current is only 1.6 ma (instead of 2 ma, as it was for the short-circuit load) (88), the current gain of this amplifier is:

$$G_c = \frac{1.6 \text{ ma}}{40\ \mu\text{A}} = 40 \qquad (90)$$

The voltage gain of this particular CE amplifier is somewhat less than the voltage gain of the CB amplifier already analysed (46). It was shown, in that analysis, that the voltage gain is given approximately by the expression:

$$Gv_{CB} = \frac{R_L}{R_e} = \frac{5{,}000}{12.8} = 391 \qquad (91)$$

A more nearly exact value for voltage gain is:

$$Gv_{CB} = (\text{Current Gain}) \times \frac{R_L}{R_e} = \alpha \frac{R_L}{R_e} \qquad (92)$$

$$= \frac{(0.98)\ (5{,}000)}{12.8} = 382$$

but the current gain for the CB case is so near unity that it can be omitted from the expression, without introducing appreciable error. In the CE case, however, the current gain is so large that it must be included in the expression:

$$Gv_{CE} = G_C \frac{R_L}{R_b} \qquad (93)$$

Note also that in the expression for CE voltage gain the input impedance is given as R_b, the base resistance, in place of R_e, the emitter resistance. The base resistance is larger than the emitter resistance by a factor of $\beta + 1$:

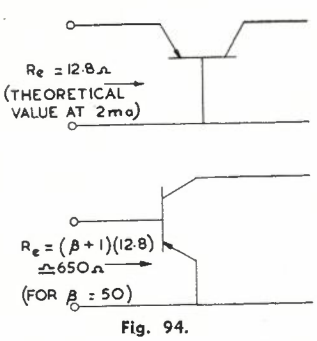


Fig. 94.

Therefore, the voltage gain is given by:

$$Gv_{CE} = \frac{G_C\, R_L}{(\beta + 1)\, R_e} = \qquad (95)$$

$$\frac{(40)\ (5{,}000)}{(51)\ (12.8)} = 306$$

An important point contained in the foregoing paragraph is the fact that the impedance seen looking into the base is $\beta + 1$ times larger than that impedance seen looking into the emitter. This base impedance can become very large—approaching that of a vacuum tube's grid—if an external resistor is included in the emitter lead:

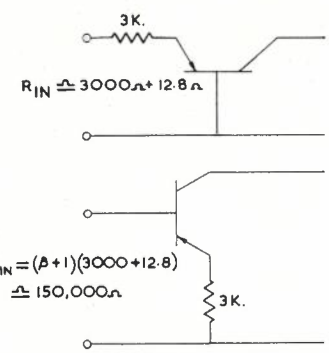


Fig. 96.

This external impedance, however, behaves like an unbypassed cathode resistor in a tube circuit—it gives higher input impedance (and greater stability as well) at the expense of gain.

The CE circuit analysed thus far is admittedly an impractical circuit. Biasing a transistor through a large base resistor (in this case 500,000 ohms) results in a circuit which may work well at room temperatures but becomes completely inoperative at higher temperatures. Or, it may work well with one transistor but work poorly or not at all with another transistor of the same type. Therefore, it is also necessary to analyse a CE amplifier using more practical biasing techniques.

PRACTICAL CE AMPLIFIER

Let us suppose that a piece of broadcast equipment contains this circuit:

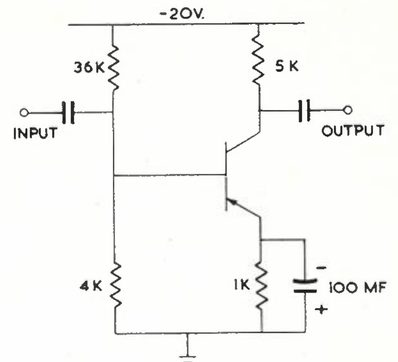


Fig. 97.

It is desired to know how this amplifier is operating; that is, what its bias is, what its dissipation is, how much collector current flows, and how much gain it provides. Although a construction of the CE characteristics could be made to yield this information, it is possible to make a fairly accurate analysis without the characteristics, since the 1,000-ohm emitter resistor stabilises the circuit and thereby makes its d-c behaviour fairly independent of the transistor's characteristics.

The analysis is begun by observing that, with the transistor out of the circuit, a potential of –2 volts appears at the junction of the 36K resistor and the 4K resistor which form the bias network. This figure shows the calculations:

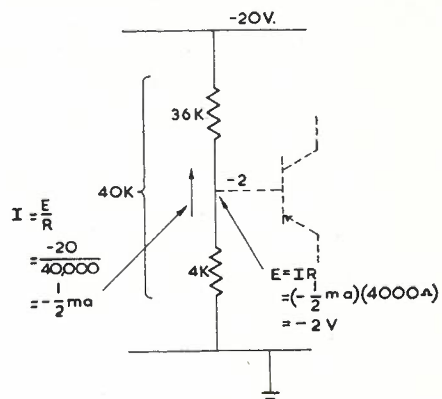


Fig. 98.

When the transistor is connected, the base current, which flows *out* of the (PNP) transistor, joins the ½-ma current in the bias network and slightly alters this –2 volt potential. However, the base current is assumed to be much smaller than the bias-network current and may therefore be safely ignored in an approximate analysis such as this one. (This assumption is usually correct in the analysis of well-designed circuits. If it should happen to be incorrect, one of the succeeding steps will reveal the error.)

Therefore, even with the transistor in the circuit, the potential at the base is –2 volts. Since the emitter and base taken together form a forward-biased diode, the voltage drop from emitter to base is very small—about 0.2 volt; a negligible amount in this analysis:

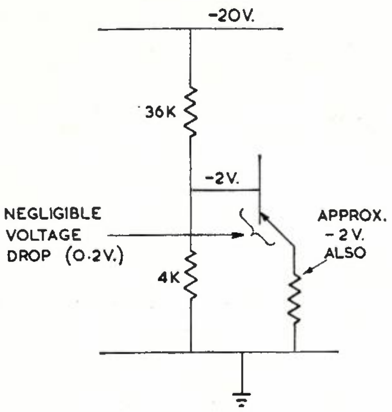


Fig. 99.

Therefore, the emitter is also at approximately –2 volts. Since the emitter resistor is 1,000 ohms, the current to cause this 2-volt drop must be –2 ma.

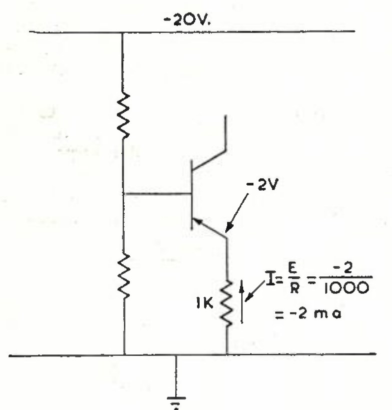


Fig. 100.

Assuming that $\alpha = 1$ (instead of 0.98) for this approximation, the current flowing from the collector is also –2 ma, and the potential at the collector is is therefore –10 volts:

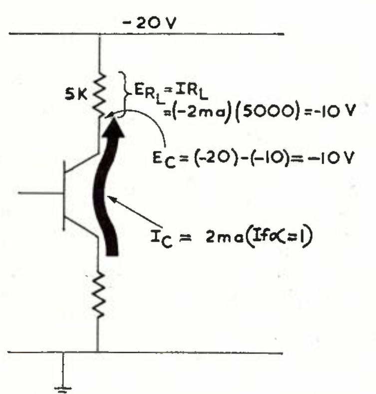


Fig. 101.

Since the emitter is at –2 volts, the voltage across the transistor is only –8 volts; therefore the power dissipation is:

$$P_c = IE = (-2\ \text{ma})\ (-8\ \text{v}) = 16\ \text{milliwatts} \quad (102)$$

Also, with the knowledge that $I_c = -2$ ma, (and assuming that $\beta_{DC} = 50$), the base current can be calculated:

$$I_b = \frac{I_C}{\beta_{DC}} = \frac{-2\ \text{ma}}{50} = -40\ \mu\text{A} \quad (103)$$

The earlier assumption that the base current was much smaller than the ½-ma bias-network current is thereby substantiated.

In computing the gain of this amplifier, the circuit may be redrawn in the following manner, which shows the circuit as it appears to the signal current:

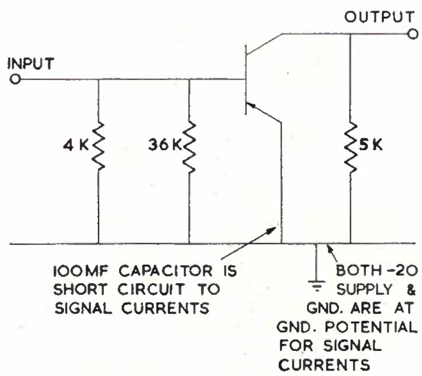


Fig. 104.

If a signal current of 10 μA is supplied to this amplifier, part of it is lost in the 4K and 36K resistors. Only a portion of it goes into the base (represented here by a 650-ohm resistor):

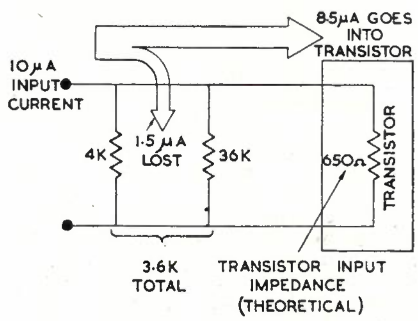


Fig. 105.

Since 15 per cent of the input signal is lost before it ever gets into the base, the overall current gain of this amplifier is 15 per cent lower than the gain of the simple amplifier already analysed (90). (That amplifier lost a negligible amount of signal current in its 500,000-ohm biasing resistor.) Since that amplifier was shown to have a current gain of 40, this amplifier will have an overall current gain of:

$$G_c = 40 - (0.15)\ (40) = 34 \quad (106)$$

The loss of gain is the price paid for the increased stability of this circuit.

The voltage gain of this amplifier may be approximated by observing that the 1.5 μA lost in the bias network causes a voltage swing of 5.4 millivolts to appear across the two resistors:

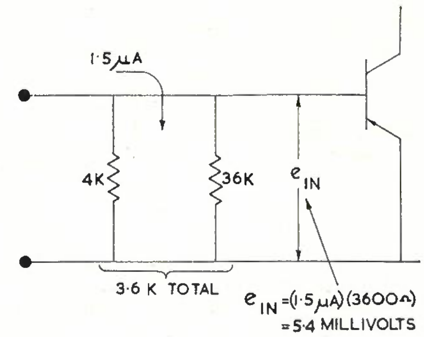


Fig. 107.

At the same time, 8.5 μA is being amplified by the transistor so that (8.5) × (40) = 340 μA appears as a current swing in the load resistor, and an output of 0.17 volts appears across the load resistor:

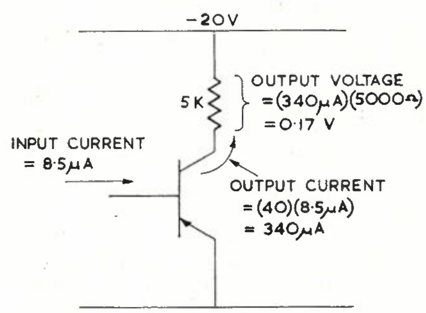


Fig. 108.

Therefore, the voltage gain of the amplifier is:

$$Gv = \frac{0.17\ \text{v}}{5.4\ \text{mv}} = 315 \quad (109)$$

THE COMMON-COLLECTOR CONFIGURATION

So far, the common-base and common-emitter amplifiers have been considered and their curves and characteristics briefly indicated. The CB amplifier is capable of large voltage gain but less-than-unity current gain. The CE amplifier can provide both voltage *and* current gain. The final configuration, the *common-collector* (CC), is the opposite of the CB configuration in that it can produce a large current gain but less-than-unity voltage gain. In that respect, it resembles its vacuum-tube counterpart, the cathode follower. Indeed, it is often called the emitter-follower configuration. Good reason for this name can be seen in the following figure:

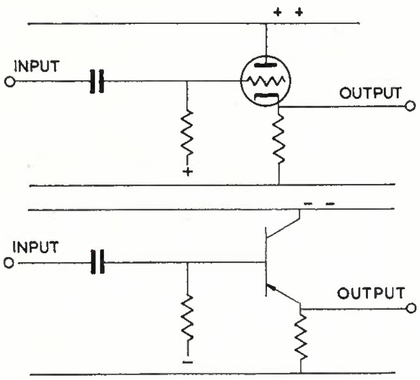


Fig. 110.

In this article, however, the name *common-collector* and the abbreviation CC will be employed, except where clarity may be served by the other name.

The discussion of common-collector amplifiers could run parallel to the discussions of the other configurations, starting with a derivation of the CC characteristic curves, and using these curves to analyse a typical amplifier. In this case, however, such an approach is not practical, because CC curves are rarely given in data sheets. Any analysis based on CC curves could not be duplicated in a practical situation, without first deriving a set of CC curves from the data sheet's CE curves. Fortunately, an approximate analysis can be performed using CE curves directly. This is demonstrated in the following analysis of this CC amplifier:

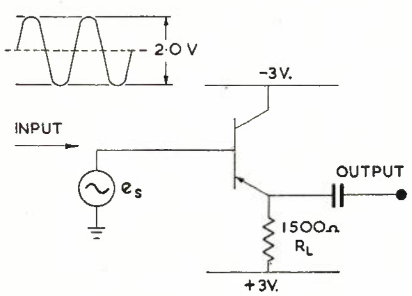


Fig. 111.

This amplifier is driven from a very-low-impedance source which approximates a true voltage source. This amplifier's voltage gain and its dc operating conditions will be determined by a construction on the common-*emitter* curves.

The biasing arrangement is practically identical to the common-base biasing-method already discussed (36). To show this similarity, the circuit can be redrawn in this manner:

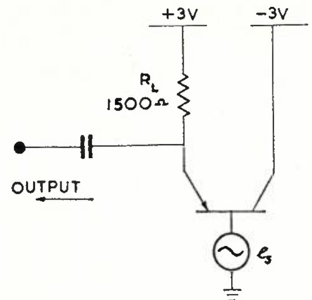


Fig. 112.

Remembering that e_s, the signal source, is practically a short circuit to the bias currents, it can be seen that the biasing arrangement bears a strong resemblance to common-base biasing.

It has been shown (36) that the input (emitter) resistance could usually be ignored in determining bias current for a CB stage. Therefore, it can be assumed that the full +3 volt supply appears across R_L, giving an approximate bias current of 2ma flowing in the emitter. With this approximate bias, we may find the operating point by drawing a load line on the CE curves. The terminal points of this load line (or any load line) are the open-circuit voltage and short-circuit current available from the external circuit at the E and C terminals of the transistor:

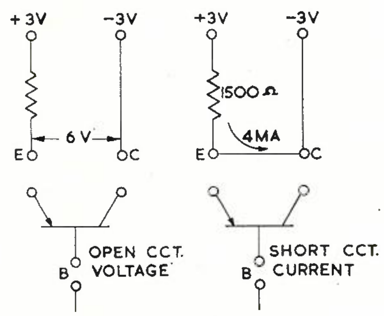


Fig. 113.

so that the load line looks like this:

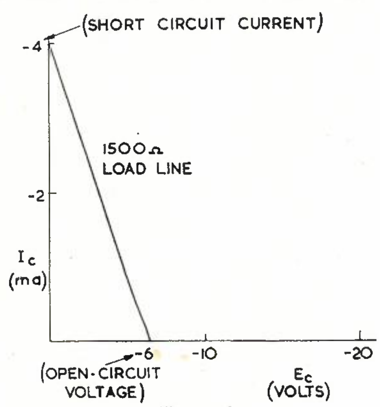


Fig. 114.

Actually, drawing a straight line between the two end points determined in the above manner is not entirely accurate because the current scale of the graph is I_c, whereas it is really I_e which flows through R_L. However, the error involved is small since I_c and I_e are nearly equal.

An approximate operating point may then be found by entering the approximate bias current on the load line of Fig. 114, as follows:

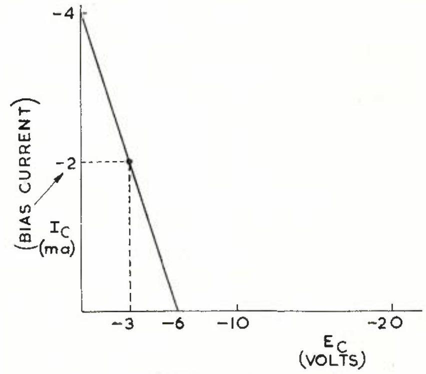


Fig. 115.

The actual CE characteristics have not been drawn on the foregoing graph purposely to show that the transistor characteristics have nothing to do with the approximate determination of the operating point. However, these characteristics must be included in order to calculate gain:

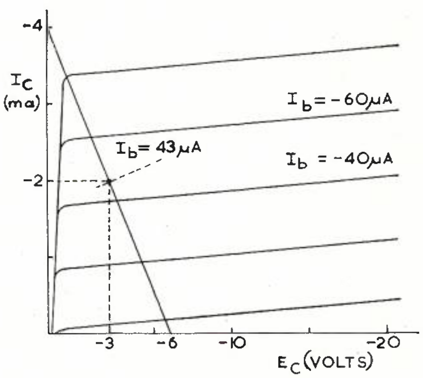


Fig. 116.

It can be seen in Figure 116 that the operating point lies between the curves for $I_b = -40\ \mu A$ and $I_b = -60\ \mu A$. Judging the relative position of the point by simple visual inspection, one can approximate the no-signal base-current to be about $-43\ \mu A$.

To simplify the analysis at this point, a rather surprising assumption is made. It is now assumed that the voltage gain is unity; that is, it is assumed that the full 2-volt input signal appears at the output. Working backwards from this assumed output voltage, one can then proceed to show that *more* than 2 volts of signal is required at the input to produce a 2-volt output. The relationship between this new input voltage and the assumed 2-volt output voltage will give the actual gain, which is slightly less than unity.

Starting with the assumed 2-volt output signal, the CE characteristics can be used to determine the base-current swing required to deliver this output.

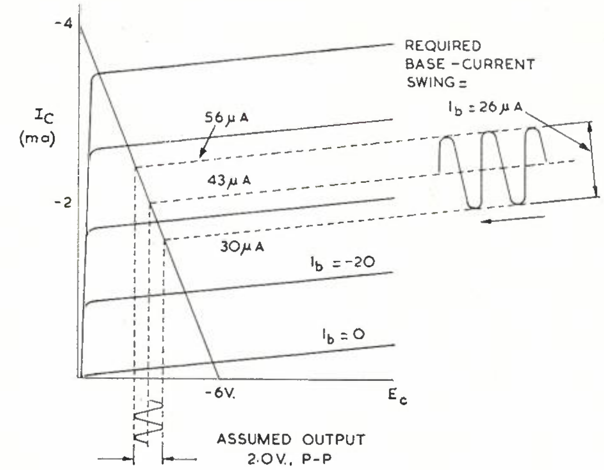


Fig. 117.

The data sheet for this transistor is then consulted to find the curve giving the relationship between base current and base-to-emitter voltage. This curve is usually given for transistors designed to handle fairly large signal swings. Using this curve:

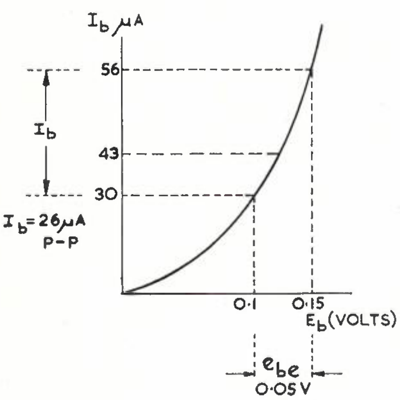


Fig. 118.

it can be seen that 0.05 volts of the input signal is lost in the base-to-emitter voltage drop. Therefore, in order to produce the assumed 2-volt output, the input voltage must swing 2.05 volts:

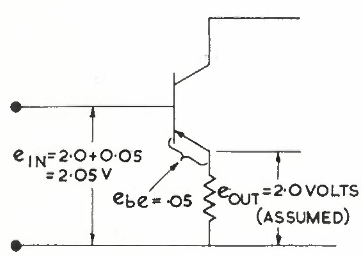


Fig. 119.

The voltage gain is therefore:

$$G_v = \frac{e_{out}}{e_{in}} = \frac{2.0}{2.05} = 0.976 \quad (120)$$

The CC configuration, driven from a *current* source, can be described in terms of *current* gain. In a simple configuration, in which negligible signal current is lost in the biasing arrangement:

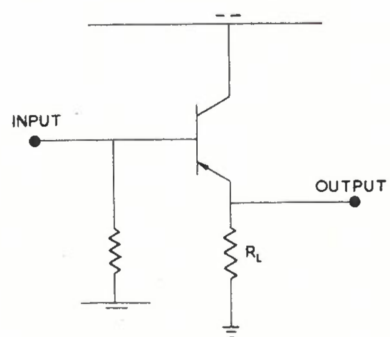


Fig. 121.

a transistor with a beta of 49 will give a current gain of 50:

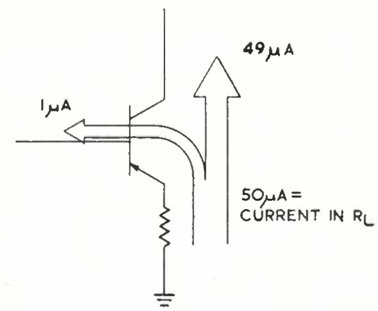


Fig. 122.

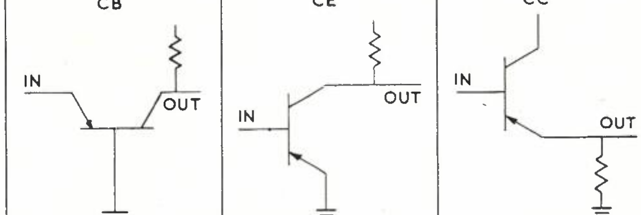
which, in general terms, is a current gain of $\beta + 1$.

The input impedance of a CC amplifier is very large. This may be seen from the fact that, in the example, a 2-volt signal causes only 26 μA to flow into the amplifier. This gives an input impedance of:

$$R_{in} = \frac{e_{in}}{i_{in}} = \frac{2.0}{26 \times 10^{-6}} = 77{,}000 \text{ ohms} \quad (123)$$

which agrees closely with the value of input impedance calculated by multiplying R_L, (1,500 ohms), by $\beta + 1$.

Thus far descriptions have been given for the characteristics of the three important transistor-amplifier configurations: the common-base, the common-emitter, and the common-collector. Their important characteristics may be summarised in this table which gives the typical values calculated for the amplifiers used as examples:



	CB	CE	CC
CURRENT GAIN	0·98	49	50
VOLTAGE GAIN	382	306	0·976
INPUT R	12·8Ω	650Ω	77,000Ω
FREQ. RESPONSE	1 MC	20KC	20KC–1MC DEPENDING ON SOURCE & LOAD

The last row of information, frequency response, indicates the price paid to obtain the improved gain capabilities of the CE configuration. Although the current gain of the CE amplifier is about 50 times greater than the current gain of the CB amplifier, the available bandwidth of the CE amplifier is about 50 times *less* than the available bandwidth of a CB amplifier using the same transistor. The values chosen for the table represent the frequency response which could be expected from typical audio transistors. Much better frequency response can be obtained by using transistors specifically designed for high-frequency operation. These matters and others will be considered in the next, and final, article in this series.

SOME THERMAL PROBLEMS IN THE DESIGN OF COAXIAL CABLE TELEPHONE SYSTEMS

N. M. MACDONALD, B.Sc., A.M.I.E.Aust.
R. W. HARNATH, A.R.M.T.C., Grad. I.E.Aust. and
*T. C. TYRER, B.Mech.E., Dip.M.E.E.**

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INTRODUCTION

The Postmaster-General's Department is embarking on an extensive programme of provision of coaxial cable telephone systems, and cable laying has commenced on the first two of these works, namely the Sydney-Melbourne (Ref. 1) and Melbourne-Morwell (Ref. 2) projects. The equipment being provided initially uses frequencies of up to 6.2 Mc/s and will enable a maximum of 1,260 telephone circuits to be derived or, alternatively, one 2-way television circuit to be obtained, from each pair of coaxial tubes. The attenuation of a coaxial tube of the type standardised internationally for long distance systems is approximately 9.5 db/mile at 6 Mc/s. and repeater stations are required at intervals of approximately 5.5 to 6 miles to enable satisfactory channel noise standards to be achieved. The attenuation of the coaxial cables varies both with frequency and with temperature, and it is also not possible to stabilize completely the characteristics of the repeaters. A complex system of equalisation and automatic gain regulation, controlled by pilot frequencies, is therefore necessary at repeater stations to ensure that the attenuation and phase characteristics of the overall systems should be maintained within predetermined limits at all times. To simplify the requirements of the automatic regulating equipment, or to correct residual variations on long routes, manual adjustments may also be necessary at fixed intervals of time.

The general economics of system design require that the majority of the repeaters in a system should be as simple as possible. These repeaters are located in small huts and are known as auxiliary or unattended repeaters. Power for their operation is fed along the coaxial tubes, and they are visited only at infrequent intervals for maintenance attention. The auxiliary repeaters compensate only for the more common changes in system characteristics and are either unregulated or controlled by a single pilot frequency. More complicated main repeaters are then located at intervals of 30 to 100 miles, the distances depending on other considerations which will not be discussed in this paper, and these repeaters compensate for all other changes. The main repeaters are generally controlled automatically by three pilot frequencies located at intervals in the transmission band of 60 kc/s to 6 Mc/s. At some of the main repeaters manual adjustments are made to take care of residual variations which are usually determined by measurements at other frequencies also within this band.

Although the coaxial cable equipment consists of units which are standardized generally among the different manufacturers, the detailed designs may differ appreciably between manufacturers, and the general design of individual systems also varies from route to route because of many local considerations. Among these are the temperature conditions along the route. Thus, for a given system design, the maximum temperature of a cable determines the maximum distance by which repeater stations may be separated, and the annual total variation of cable temperature determines whether regulation is required at every repeater station or at less frequent intervals. The temperature variations in auxiliary repeater buildings also cause changes of repeater gain which are small individually but which accumulate over the length of the route. The extent of these changes can affect the intervals at which equipment to compensate for them is located along a route, and the periods between which manual adjustments to the system may be necessary.

This paper discusses work undertaken in connection with the Sydney-Melbourne and Melbourne-Morwell projects to determine the expected cable temperatures and to establish suitable thermal designs for the auxiliary repeater buildings.

THE PROBLEMS

The two thermal problems with which this paper is concerned may be summarized as follows:—

Cable Temperatures.—The determination of a simple means of calculating the expected range of variation of temperature and the maximum temperature of cables in ducts or buried directly at different depths in various types of soil in a number of localities throughout Australia.

Auxiliary Repeater Buildings. — The design of standard buildings, which could be provided economically and practically on a number of routes throughout Australia. Short-term variations of temperature inside these buildings must be reduced within predetermined limits. The temperature must also not exceed a predetermined maximum value under all weather conditions, allowing for the heat dissipated by the repeater equipment. At a number of stations no electrical power will be available for cooling purposes or for the operation of ventilating fans, and it is, moreover, essential that the use of special cooling equipment should be avoided for maintenance and reliability reasons.

Both problems require the determination of variations of temperature at certain points in a medium due to variations in temperature at other points, and as such are heat transmission problems. The variations in temperature which are of interest can be considered broadly as a combination of daily, annual and other cycles of varying magnitudes which may be resolved into sinusoidal components. The heat transmission is therefore also alternating in character. Because of the varying temperature gradients, the accurate assessment of heat storage effects is necessary in addition to the determination of the heat transfer through materials of different thermal conductivities. In both the cable temperature and building design problems, the absorption of heat from solar radiation must be taken into account, while in the building design convection effects, for example, due to ventilation, are also relevant.

The cable temperature problem is not new in Australia, as a knowledge of soil temperatures at different distances below the surface has been necessary for agricultural purposes, and measurements of soil temperature at various places have been recorded at various depths and for various soil conditions. The information on the basic approach and some data were made available by the Commonwealth Scientific and Industrial Research Organisation. It was possible to extend this readily, using meteorological information, to enable reasonably accurate predictions to be made at a number of locations along the routes concerned. This problem will be dealt with only briefly in this paper, and has been included chiefly to illustrate the principles involved, and because it is related in some respects to the building design problem.

As far as is known, only one very general paper dealing specifically with the building design problems has been published overseas (Ref. 3). The buildings were required urgently and time did not permit the erection of experimental buildings to assist the design. The solution by the normal techniques used for heat transfer problems would have required repetitive calculations of the "trial and error" type, since the temperature is not constant at any point in the system. As a number of alternative types of building construction had to be considered also, many months of tedious calculation would have been required. An alternative approach using electric analogue methods was therefore adopted. Apart from avoiding the heat transfer calculations, it was also possible to obtain much more valuable information on the building performance by constructing an electrical model (or analogue computer) and substituting measurements on this model for calculations. Moreover, electrical network theory is comparatively highly developed, and this appeared to offer some attractions in dealing with what in effect is a complicated building "network".

* See page 466.

THERMAL-ELECTRICAL ANALOGUES

Thermal-electrical analogues are not new and have been used, for example, in the design of thermostatic ovens and air-conditioning systems (Refs. 4 and 5). The conversion from thermal systems to their electrical equivalents is relatively simple, due to the direct equivalence between the equations governing the behaviour in both systems. This is illustrated in Table I.

TABLE I.

Thermal-Electrical Equivalents

Thermal system	Electrical system
Quantity of heat—q	Charge—Q
Heat flow—h $= \frac{dq}{dt}$	Current—$I = \frac{dQ}{dt}$
Temperature difference—$\Delta\theta$	Potential difference—V
Thermal conductance—$\gamma = h/\Delta\theta$	Conductance— $G = I/V$
Thermal resistance—$\rho = 1/\gamma$	Resistance— $R = 1/G$
Thermal capacitance (mass × specific heat)—$c = q/\Delta\theta$	Capacitance— $C = Q/V$

For the purpose of relating numerical values when conversions are made between the systems, each may use any self-consistent system of units and is completely independent of the other; for example, the unit of time may be the hour or the day in the thermal system while the second could be the unit of time in the equivalent electrical system. However, when converting a "thermal" circuit to its electrical counterpart, a basic principle is that heat flow does not require a return circuit as does electricity, so that each thermal flow path requires to be replaced by two electrical wires. Examples of the process are given in the following text relating to the applications.

VARIATIONS IN ATMOSPHERIC TEMPERATURE

Temperatures below the surface of the earth and within buildings are influenced to a major extent by atmospheric temperature. A knowledge of the way in which atmospheric temperature fluctuates is therefore essential. Fortunately, considerable meteorological information is available for all main localities through which coaxial cables will be provided, and from these data it may be shown that the variations in any locality may be separated roughly into three categories.—

(i) General Annual Fluctuations: Average monthly temperatures throughout a year follow closely a sinusoidal variation as shown in Fig. 1. The hottest period is usually in January and February and the coldest in July. Long term averages show the spread of the mean monthly temperatures which is, for example, 19°F. in Melbourne and 28°F. in Wagga. This gives the amplitude of the general long term variation having a periodicity of one year. There are, of course, departures in any given year from this long term average, and at all localities these follow approximately a normal distribution with a standard deviation (σ) of approximately 13 per cent. The extreme variation likely between monthly mean temperatures in any one year would be given by the 3σ limit and, for example, would be 19°F. × 1.39 = 26°F. in Melbourne.

(ii) Fluctuations of Daily Mean Temperature: The average temperatures taken over each daily period fluctuate about the general annual cycle in an irregular manner as shown in Fig. 2, which illustrates variations at Sydney, Cootamundra and Melbourne over a typical period of three months during the summer season when the greatest variations normally occur. A complete statistical analysis of the amplitude and periodicity of these variations is not available, and a detailed analysis was not warranted for the investigations concerned. Fig. 2, however, shows that the greatest variation in the fundamental component of a single cycle is of the order of 20°F., and the longest period of variations of this order of magnitude would be unlikely to exceed 10 days.

(iii) Fluctuations Within Any Single Day: Superimposed on the combination of the general annual and daily mean variations are the normal fluctuations which occur continuously throughout any single day. These are approximately sinusoidal in nature and the maximum swing from night to day seldom exceeds 40°F., the greater values occurring in the hotter months. However, under prolonged heat-wave conditions, the maximum swing in any single day seldom exceeds 20°F. Fig. 2 shows also values of the maximum and minimum daily temperatures over the typical three-monthly period.

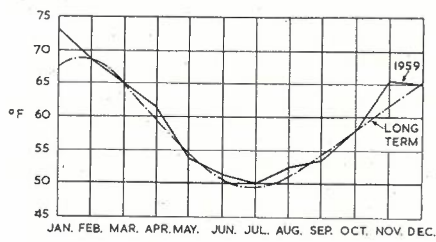


Fig. 1. Typical Variation of Monthly Mean Air Temperatures at Melbourne.

TEMPERATURE VARIATIONS OF UNDERGROUND CABLES

To a first approximation, the problem is that of determining the variation in temperature at different depths below the surface of an infinite, uniform earth due to variations in temperature at the surface, as shown in Fig. 3. Although this has been solved directly from thermal considerations, the electrical analogue consisting of an infinite R-C transmission line, also shown in Fig. 3, presents an interesting and simple approach. If the temperature at the surface varies sinusoidally, and the voltage V at the input of the line varies in the same manner, the voltage amplitude at a distance x from the end of the line is given by $V = V_0 e^{-Px}$ where $P = \sqrt{R.j\omega C} = \sqrt{R\omega C/2} + j\sqrt{R\omega C/2}$, R being the loop resistance per unit length and C being the capacitance per unit length of line. The amplitude of the voltage variation at a distance x along the line is thus attenuated by the factor $e^{-(\sqrt{R\omega C/2})x}$ compared with the amplitude at the end, and there is also a phase lag of $\sqrt{R\omega C/2}$ radians. Similar results apply directly to the temperature problem as the equations are identical. Thus the variation in temperature at a distance x below the surface is attenuated by a factor $e^{-(\sqrt{\rho\omega c/2})x}$ where ρ is the thermal resistivity and c the thermal capacitance per unit volume. For heavy clay soil, ρ is approximately 2.4 (Reciprocal B.Th.U.-ft./hr./ft.²/°F.) and c is approximately 18 B.Th.U./°F./ft.³, and the variation in temperature at typical depths compared with that at the surface would be reduced by the factors shown in Table II which have been calculated from the formula.

TABLE II.

Variation of Attenuation Factor at Different Depths in Clay (Calculated).

Depth (ft.)	Period $1/f = 2\pi/\omega$ 1 day	1 year
1	0.0925	0.88
2	0.0086	0.78
3	0.0008	0.68
4	0.0001	0.60
5	0.0000	0.53

The temperature at the surface follows largely the atmospheric temperature although there are other factors, such as cooling by evaporation of moisture and the absorption of heat from solar radiation, which are dependent on whether the land is irrigated and whether the surface is cultivated, type of vegetation, etc. For a daily temperature swing of 40°F., Table II shows that for heavy clay soil the temperature change at a depth of 3 ft. would not exceed 0.03°F. which is very small, as are also the changes due to the short term fluctuations of the daily mean temperatures. The main variations are due to the monthly mean temperature changes over the period of a year. Fig. 4 shows how the measured temperatures at Wagga follow the mean monthly atmospheric temperatures and illustrates also the phase lag involved. Although actual measurements made of soil temperatures at various depths and in different classes of soil, rock, etc., are rather limited, the available results agree closely with the theory as indicated by Fig. 5. The surface effects referred to previously are responsible for the variations in soil temperature near the surface exceeding the mean monthly air temperature swing in certain instances. At depths of about 4 ft. it has also been found that the mean soil temperature is approximately 2 to 4°F. in excess of the mean calculated in this way, due to heat transferred from the earth's interior and generated by chemical changes in the soil, and allowance must be made for this. Typical attenuation coefficients obtained by measurement for various classes of soil are given in Table III.

TABLE III.

Approximate Attenuation Coefficients for Different Types of Soil (Measured).

Type of soil	Cable depth 3 ft.	4 ft.	5 ft.
Moist sand ..	0.84	0.77	0.72
Dry sand . ..	0.88	0.76	0.66
Loam	0.81	0.73	0.66
Dry clay	0.68	0.56	0.47
Moist clay . ..	0.92	0.82	0.74

Most new trunk cables will be buried directly in the ground at depths of 4 ft. throughout the greater part of their length, and although the depth will be reduced to about 2 ft. in hard rock and sections in built-up areas located in ducts, these latter sections will have relatively little effect on the overall system design. In the buried sections, the cables will be bedded in sand and the remainder of the trench will be consolidated thoroughly with natural soil to prevent erosion. Apart from the sand layer, which will have a depth of about 6 in., the composition of the filled trench should therefore not differ to any extent from the natural soil.

From this information the maximum temperatures and probable maximum spread can be calculated as shown for the following typical section:—

Data: Location—Near Wagga.
Soil conditions—Predominantly loam (coefficient approximately = 0.75).
Cable depth—4 ft.
Highest monthly mean — 76°F. (Feb.).
Lowest monthly mean — 47°F. (July).
Annual mean—62°F.

Calculation: Long term spread of monthly means = 76°F. — 47°F. = 29°F.
Maximum spread in any individual year = 29(1 + 3 × 0.13) = 40°F.
Maximum likely cable temperature spread = 0.75 × 40°F. = 30°F.
Cable mean temperature = 62°F. + 2°F. = 64°F.
Cable maximum temperature = 64°F. + 15°F. = 79°F.

THERMAL DESIGN OF AUXILIARY REPEATER BUILDINGS.

Design Requirements.

General: The general requirement is for two types of building suitable for housing any type of auxiliary repeater equipment likely to be provided on any coaxial cable route in Australia, either initially or for addition at a later stage when expansion of a route becomes necessary. The location of the cables will be restricted for some considerable time to the south-eastern part of Queensland, central or eastern New South Wales, Victoria and Tasmania, the south-eastern part of South Australia, and the south-western part of Western Australia. The first type of building required would be of prefabricated concrete construction suitable for erection quickly in relatively large quantities on longer routes and at localities away from centres of normal building activity. The second type would be of clay brick construction suitable for routes on which only a few auxiliary repeaters would be necessary. The buildings generally would need to give complete protection of equipment against all types of weather

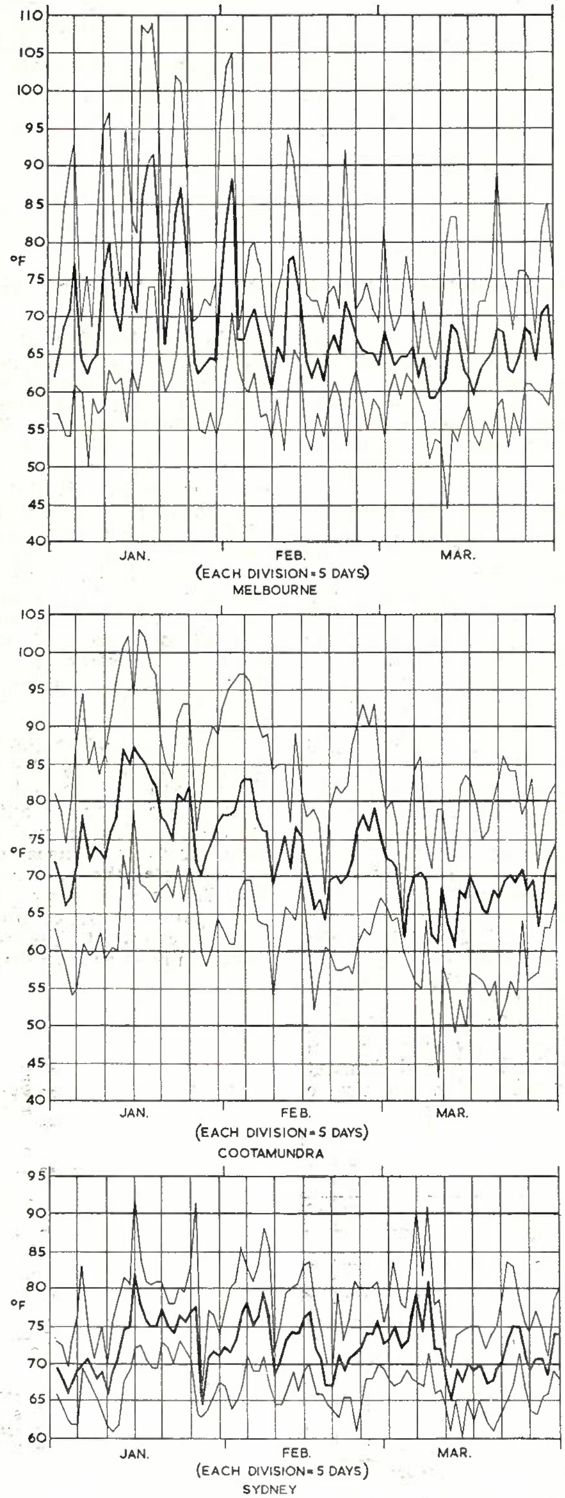


Fig. 2. Typical Variations of Daily Mean, Maximum and Minimum Air Temperatures at Sydney, Cootamundra and Melbourne.

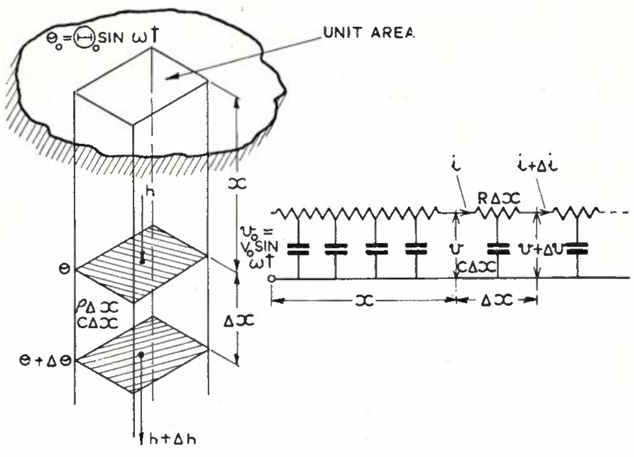


Fig. 3. Temperature Variations in Uniform Earth, and Equivalent R-C Transmission Line.

conditions and against insect entry, theft and vandalism. The internal dimensions of the buildings were selected as 10 ft. x 12 ft. x 8 ft. high to accommodate equipment of any manufacture required for a 6-tube cable, which is the largest size planned for provision in Australia at present.

Maximum and Minimum Temperatures: The maximum temperature limit for the air inside the building was set at 115°F. based on the equipment performance guarantees of some manufacturers. This limit would apply with 600 watts of heat generated continuously by repeater equipment for a fully equipped 6-tube cable, including an allowance for certain other non-coaxial equipment which would possibly be required in the future at some stations. If the internal temperatures exceed the 115°F. limit by small amounts at some stations, the equipment would not necessarily be damaged, although the overall system performance would be degraded. Higher temperatures also reduce the life of equipment components. The minimum limit of ambient temperature for the equipment is not critical and is of the order of 30°F. With the heat generated by the equipment, the other design requirements resulted in expected minimum temperatures of the order of 50°F. and it was not necessary to set a firm lower limit for the building design. At the same time, condensation of moisture within the building at lower outside temperatures was also not a problem, due to the stabilisation of temperatures discussed in the next paragraph.

Periodic Temperature Variations: The determination of exact limits for the variations in internal air temperature over various periods of time is difficult. The changes in gain with temperature of the individual repeaters are generally very small and are mainly due to the networks associated with the repeaters and not to changes in the amplifiers themselves. In some designs the changes are claimed to be so small that no special action is necessary to compensate for them. In others, for example the systems described in Ref. 6, the design has been arranged so that the gain-frequency characteristics with different temperatures follow closely the loss-frequency characteristics of the cable, and the main changes are corrected automatically by the same equipment which corrects for the basic cable changes. Other systems, for example, the systems described in Ref. 7, use a separate pilot frequency and separate networks to correct for the main changes at intervals along the route. In most systems there are residual variations which are not corrected by the automatic regulating equipment and, on many of the longer distance systems at least, these must be corrected by manual adjustments at periodic intervals. The characteristics of every type of system likely to be required in Australia in the future were not or could not be known completely, some of the systems are likely to be of considerable length, and it has been stated in some references that equalisation effects may be experienced which cannot be predicted and are therefore not taken into account in the equipment design. For these reasons it was decided that the standard repeater buildings should be designed to permit, if required by the system design or if found to be necessary as a result of experience with the systems, periodic manual adjustments to compensate among other things for repeater temperature changes. To be effective in compensating for the range of temperatures over an annual cycle, the adjustments would need to be carried out at approximately one-monthly intervals. The temperature variations between the times of adjustment would also need to be as small as practicable in relation to the range of temperature for which the manual adjustments were designed to compensate. In addition, it would be necessary to ensure that, at the time manual adjustments are made, the ambient temperatures in the buildings over a long route should be near the monthly mean temperatures.

Stable temperature conditions would also reduce, by an appreciable amount, the total variations for which the automatic equipment would have to compensate. Outside air temperatures in most parts of Australia have an extreme overall variation of about 80°F., for example, from about 30°F. to about 110°F. The monthly means vary over an annual period only by about 20 to 25°F., and if the variations inside the buildings were controlled to, say, within 10°F. over any month the total range would be reduced to less than half the outside range.

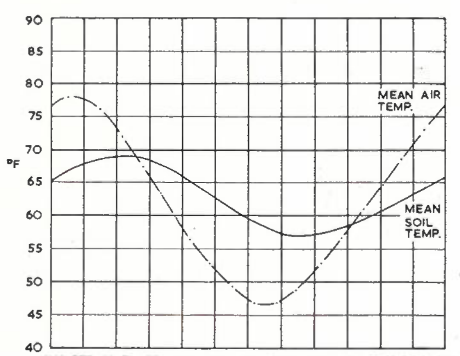
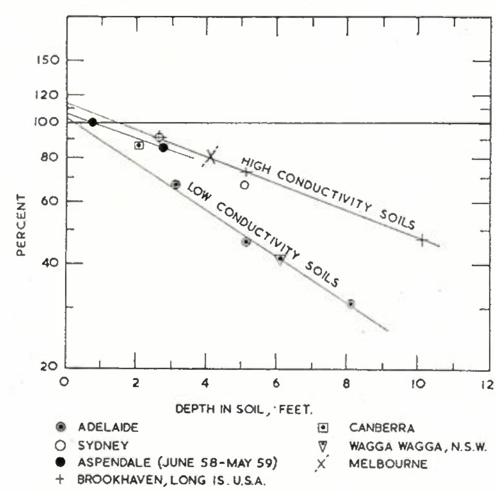


Fig. 4. Variations in Mean Monthly Air Temperature and Earth Temperature 6 ft. Underground at Wagga.



(DERIVED FROM C.S.I.R.O. DWG. NO. P.1399, DIVISION OF METEROLOGICAL PHYSICS.)

Fig. 5. Results of Earth Temperature Measurements at Various Locations.
Range of long-term earth temperature variations as a percentage of long-term air temperature variations.

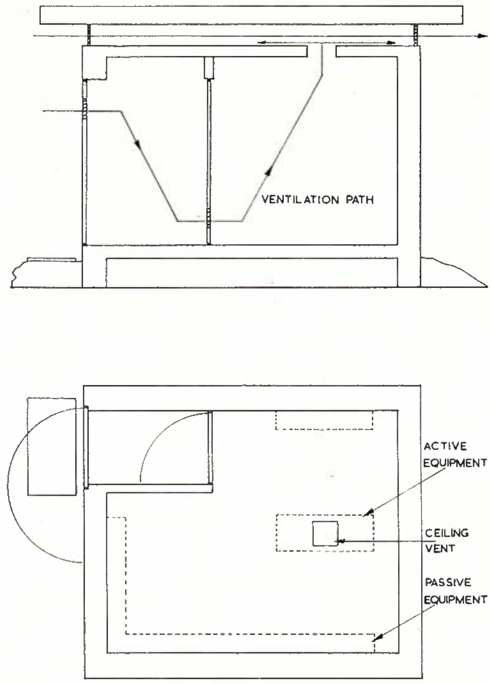


Fig. 6. Basic Form of Repeater Building.

In addition to the general objective of controlling the temperature variation over, say, a monthly period, there are two other reasons why it is desirable to reduce the temperature variations within a building. These may be summarised as follows:—

(i) Sudden changes of temperature of the order of 1°F. per minute should be avoided under all conditions as they could give rise to transient disturbances in the long chain of relatively slow-acting feed-back type regulators. On the Sydney-Melbourne route about 120 of these regulators will be connected in tandem and the design problems involved in achieving complete stability of such a chain are formidable.

(ii) Daily variations in temperature result in ageing of components and wiring, and the normal method of determining the life of many components is by means of accelerated temperature cycling. It is therefore most desirable that daily variations should be restricted to a minimum.

Individual equipment manufacturers are often not in a position to set down exact limits for the permissible temperature variations for their systems until they have been in operation in the field for a considerable period and under different climatic conditions. Some, however, are prepared to recommend types of building designs which experience has shown to be satisfactory under climatic conditions similar to those in Australia. These building designs vary between manufacturers and most of the designs are of substantial construction which do not lend themselves to prefabrication. A typical example is the building used by the American Telephone & Telegraph Co. which is described in Ref. 3 and which has 16-in. double block concrete walls, while in other instances the repeaters have been located in underground chambers.

For well designed buildings in which adequate measures have been taken to minimise the effects of solar radiation, the main changes in the internal air temperatures will be due to external temperature variations, but these will be attenuated by the building structure. It was determined from measurements that, for a typical building, the attenuation factor of a 10-day cycle is approximately 20 per cent. of that for a daily cycle, and for swings due to external temperature changes alone, the internal temperature variation for a given external variation would be about 5 times as great for a 10-day cycle as for a one-day cycle. It was indicated earlier in this paper that a fairly extreme variation in average daily temperature within a monthly period could be taken as a 10-day cycle with a maximum swing of 20°F., while the maximum swing over a daily period was approximately 40°F. Thus a building which would produce a 1°F. temperature swing over a daily period with an outside swing of 40°F., would produce a 2.5°F. swing over a 10-day period with an outside swing of 20°F.

After consideration of the performance expected from buildings of overseas design, the practical and economic requirements of the buildings and the uncertainties involved, it was decided to adopt as the design objective for the building a maximum variation of about 7°F. over an extreme 10-day cycle, which corresponds roughly to a maximum variation of 3°F. over an extreme daily cycle. The maximum likely swing over a monthly period would then be about 10°F., having regard to the fact that the effects of the 1- and 10-day cycles are additive. With the limited daily swing of 3°F., the likelihood of any sudden changes occurring would also be negligible provided that suitable precautions were taken when opening doors, and

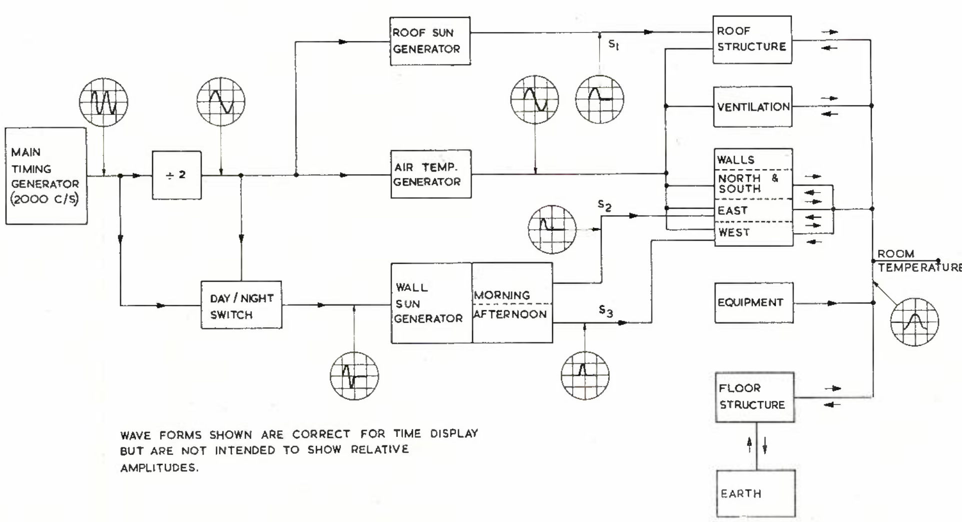


Fig. 7. Block Diagram of Computer.

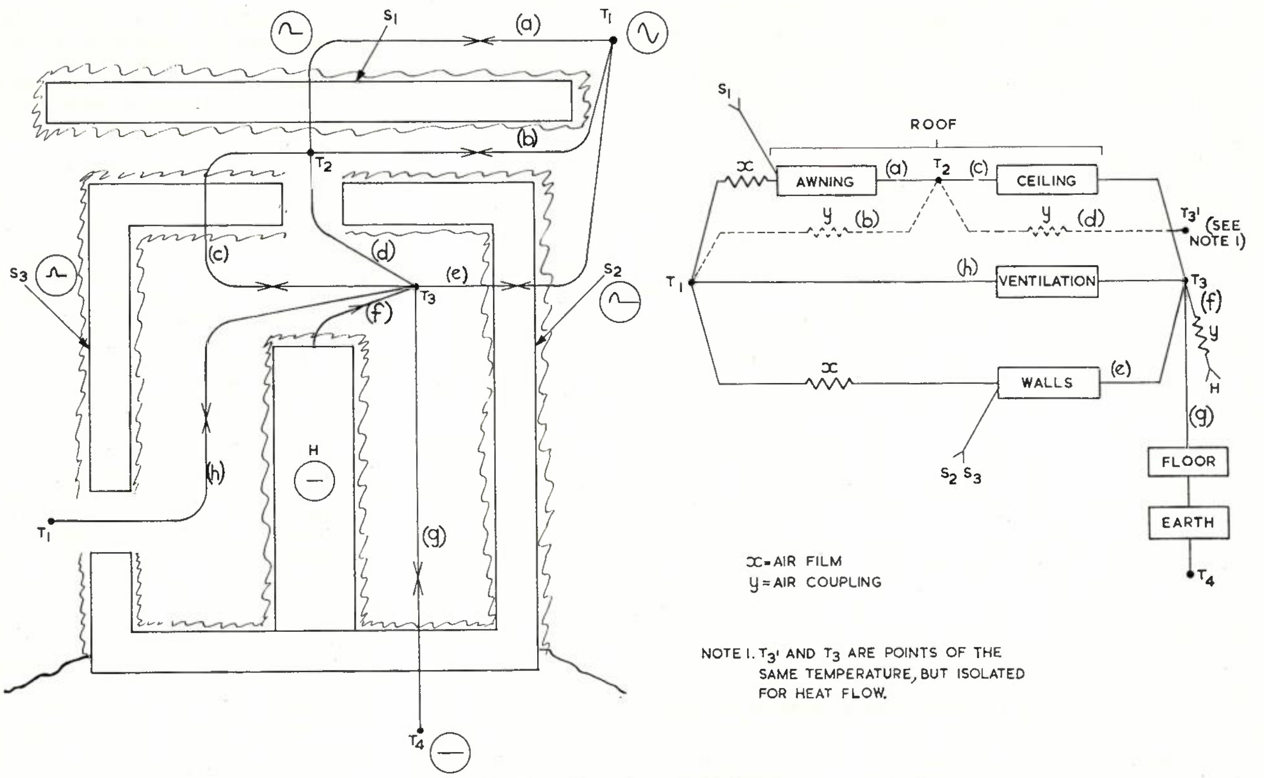


Fig. 8. Heat Flow Paths in Building.

direct sunlight were not permitted to enter the building.

General Building Design

The general form adopted for the building is shown in Fig. 6 and is very similar to the plans recommended by the equipment manufacturer for the Melbourne-Morwell project, Siemens & Halske, A.G., West Germany. This form was considered as tentative only in the initial stages of the design, and modification or deletion of certain features might have been found desirable as the detailed design proceeded. This, however, was not necessary. The entry arrangement, consisting of two doors and a small lobby, was designed to minimise the change of air inside the building during staff entry, to act as a dust trap for air entering the building for ventilating purposes, and to minimise the entry of direct sunlight into the building. The buildings were to be orientated with the doors facing generally in a southerly to easterly direction, so that the sun's rays could never fall directly on the equipment if both doors were left open unintentionally by visiting maintenance staff. Provision was made for ventilation if required as a means of reducing the maximum temperature within the building, although no ventilation is used, for example, in the American Telephone & Telegraph Company's buildings (Ref. 3). This aspect will be discussed further later in this paper. A roof cavity with free access to the outside air was added to reduce the effect of solar radiation on the roof, and the ventilation outlet was taken to this cavity to minimise dust entry and the effect of the wind on the ventilation system. The provision of the cavity would involve no extra cost as it was evident that double slab construction would be required in any case to minimise solar heat gain through the roof, and a greater than normal separation between the slabs only was necessary.

After the general design was established, it was necessary to confirm the various features and to determine the types and thickness of material to be used in the construction, including walls, floors, doors, ceiling and roof, having regard to practical construction and to the thermal requirements. The thermal design was generally a matter of compromise as, for example, insulating materials in the walls and roof of the building would minimise internal variations but would not allow the heat generated within the building to be dissipated, so that an excessive maximum temperature would result. Similarly, excessive ventilation would enable the dissipation of the heat produced internally but would nullify the insulating and heat storage properties of the building. Ideally the best result would be given by materials which have large thermal storage and low insulation, but, unfortunately, economical materials of this type do not exist.

The design approach was to make up the electrical model of the building, taking into account all known factors, and then measure the temperatures and variations with different wall, floor and roof structures, so proceeding until the optimum design was established. The computer was relatively simple to construct and all necessary components and electrical testing instruments were available in the Postmaster-General's Department, Long-Line Equipment Laboratory. The work was commenced in July, 1959, and the main design was completed within four weeks.

Analogue Computer

Basic Form: A general block diagram of the computer is shown in Fig. 7, and a general schematic diagram showing the corresponding heat flow paths is shown in Fig. 8. It was assumed that the building was orientated in the north-south direction. As maximum temperatures within the building were of interest mainly in the summer season when there would be little solar radiation effect on the north wall due to the roof overhang, the effects of the sun's rays on the roof, east and west walls only were simulated. The equipment for simulating the outside air temperature and the sunshine is shown in block form on the left hand side of Fig. 7 and consists of an oscillator, an electronic pulse frequency-dividing network with a suitable output shaping circuit, gating circuits, various rectifying devices, and amplifiers with the necessary phase, output voltage, and impedance characteristics. Voltage, current and waveform measurements were made using an accurately calibrated D.C. coupled cathode ray oscilloscope. Each block on the right hand side of Fig. 7 represents a separate electrical network. Details of the directly analogous electrical networks calculated as a first step for the final building used on the Sydney-Melbourne route are shown in Fig. 9 and the corresponding building components are shown in Fig. 10. These networks were calculated directly from the thermal resistances and capacitances of the various building components using B.Th.U./°F./hour units, which were taken to be equivalent to electrical units of ampere-volt-second. The coefficients used for the building materials were taken in general from the American standards used for air-conditioning system design (Ref. 8) with slight modifications where these were normally necessary to meet local conditions. The main values used are summarised in Table IV. The values shown in Fig. 9 and the frequencies involved are impractical electrical values, and the networks were transformed into practical values by the normal electrical network transformation devices of adjusting ω and C values while keeping the ωC products constant as a first step, then transforming impedances, currents and voltages by factors K, $1/K$, and 1 respectively, and finally adjusting the voltages by a further common factor. By this means the final practical network shown in Fig. 11 was evolved.

Conduction through Walls and Roof: Although building materials have distributed thermal characteristics and should be represented exactly by sections of electrical transmission lines, the equivalent T-circuits were used in the analogue as a reasonable approximation since the sections of line were relatively short.

It was also necessary to take into account the air films that surround the building on all walls and above the roof. These air films have very low mass and may be considered in the analogue form purely as resistances to the passage of thermal current. The outside air film coefficient was taken as the value given in Table IV for a wind velocity of 15 m.p.h. The air space between the walls contains relatively still air, the only air movement being due to convection caused by heating. This layer was also represented by a resistance having a higher value than that of the outside air lamina. On the inside of the wall is a

TABLE IV.

Values of Conductivity and Specific Heat Used for Calculations.

Material or film	Conductivity (B.Th.U./hr./ft.²/°F./in.)	R (= 1/Conductivity)	Weight (lb./ft.³)	Specific heat
Outside air film (15 m.p.h. wind) vertical or horizontal	6*	0.167		
Wall air space	1.1*	0.909		
Interior air film (walls)	1.65*	0.607		
Roof air space up	1.32*	0.757		
down	0.863*	1.158		
Ceiling air film up	1.95*	0.513		
down	1.21*	0.826		
Floor air film up	1.95*	0.513		
down	1.21*	0.826		
Earth air space up	1.95*	0.513		
down	1.21*	0.826		
Brickwork	5	0.2	120	0.25
Concrete dense	12	0.0834	150	0.2
Concrete lightweight	2.83	0.366	90	0.2
Steel	420	0.000238	490	0.12
Glass wool	0.27	3.7	—	—
Clay (dry dense)	5	0.2	100	0.18
Air	varies	—	0.075	0.24

Note: * These figures are conductances (B.Th.U./hr./ft.²/°F.) since the resistance to heat transfer of air film or air space is independent of thickness to a first approximation.

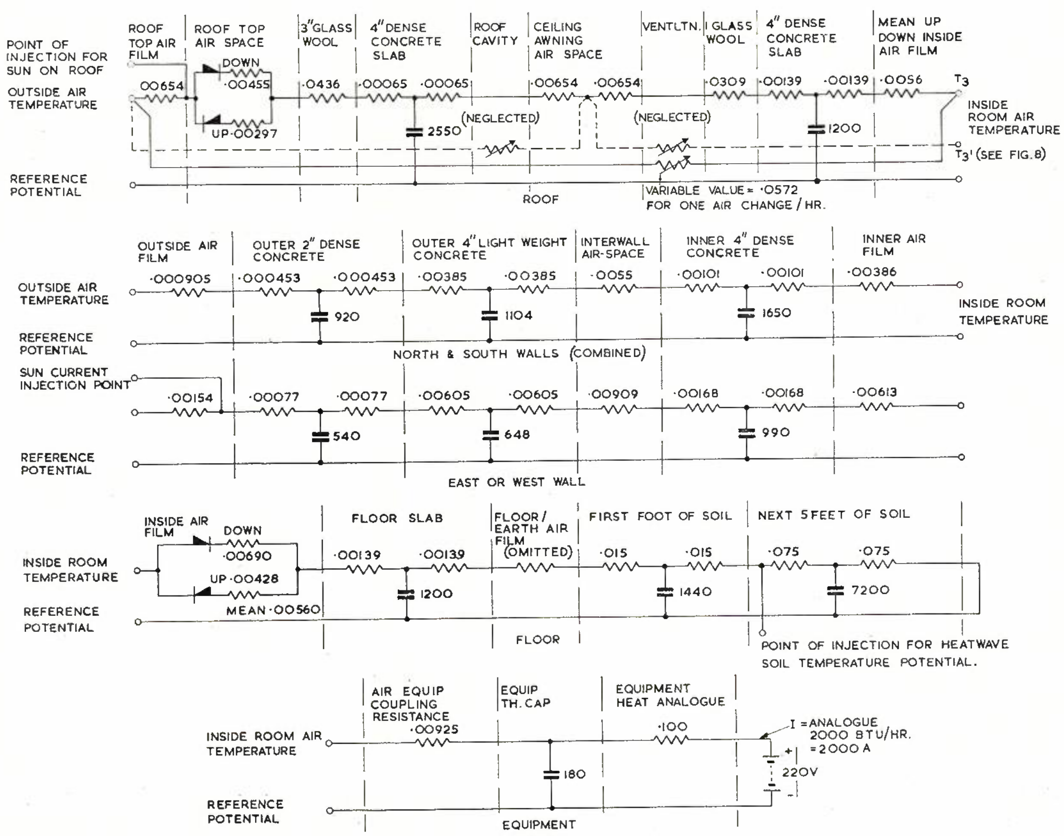


Fig. 9. Basic Electrical Networks Representing Components of Final Sydney-Melbourne Building.

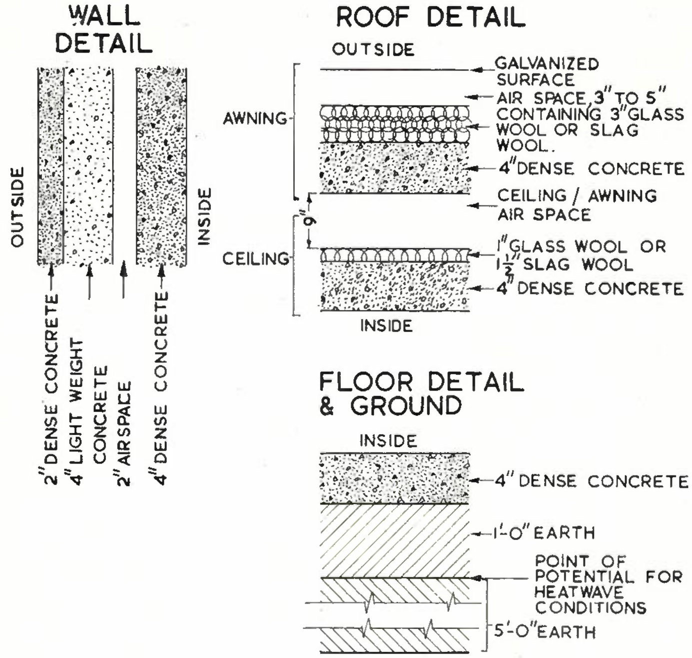


Fig. 10. Building Component Details.

third air film in which the air movement is also small and which again may be represented by a resistance of similar value. Because the air surfaces on the walls are vertical, the heat flow current is horizontal and the resistance to heat flow from outside to inside is identical with the resistance to flow from inside to outside for a given temperature difference. This state does not apply to air films which are horizontal such as those in the roof cavities, in the laminar films immediately below the ceiling and above and below the floor slab. In these cases the heat flow upwards will be considerably greater than that in the downward direction, because the upward heat flow is assisted by convection, whereas the downward heat flow is chiefly by conduction, and air is quite a good insulator. In order to provide an electrical analogue of this behaviour, resistances having the appropriate directional resistance to heat flow were connected in series with diodes which allow the current to flow through each resistance only in the appropriate direction. If this directional flow characteristic is a controlling factor in the thermal behaviour of the associated structure it is important that the rectifiers used in the equivalent circuit should have very low forward resistance and high backward resistance. If, however, there are other resistances due to the insulation of the building materials, the difference in results caused by the use of separate resistors and perfect diodes compared with a single average value resistor may be unimportant, and the single resistor only may be used.

The two sections of the roof are coupled together by the air in the roof cavity. There is also an auxiliary coupling due to radiation between the surfaces of the cavity, but the temperature difference between these surfaces would be small with most practical designs, and this effect was neglected. The air in the roof cavity may be divided into three parts, the upper and lower air films and the larger body of air between these films. The air from the equipment room is exhausted directly into the roof cavity and causes the main body of air in the cavity to change at a fairly high rate as the cavity is much smaller than the room. The cavity has also free access to the outer air and the external wind may increase the rate of change of the air appreciably. The main body of the air in the cavity is therefore turbulent and has a thermal resistance much lower than that of the air films. The effective thermal resistance between this body and the outside air is also relatively low. The effects of ventilation of the main equipment room and the cavity are discussed further in a later paragraph.

The circuitry of the computer was designed to take into account as closely as practicable, the physical behaviour in the roof cavity. The top part of the roof structure, or awning, was designed separately by measurements on the analogue so that the heat flow into the cavity due to solar radiation on the roof was negligible. The ceiling section was then designed as a part of a complete building so that its thermal properties were similar to those of the wall structure.

Outside Air Temperature Generator: As air outside the outer wall air film can be assumed to be circulating freely and has an effectively large thermal capacity, it was important that the output impedance of the generator simulating outside air temperatures should be very low compared with the network into which it was working.

Sun Generators: The solar gains due to the sun on the roof and walls are set out in Table V. These figures have been calculated for 35° south latitude which approximates to the mean latitude on the Sydney-Melbourne route. Since the roof has an overhang sufficient to stop the sun falling on the north wall during the summer months, and it has been assumed that no sun falls on the south wall, the figures for the north and south walls shown in Table V are due to diffusion effects in the atmosphere, but include diffused and reflected radiation from the ground and other surfaces. It will be seen that they are approximately one order of magnitude below the gains due to the direct sunlight, and thus may be neglected. The solar gains on the roof and east and west walls may be represented fairly accurately by half sine waves derived also from Table V. These assume that the sun shines on the roof from 6 a.m. to 6 p.m., on the

TABLE V.
Solar Gains on Roof and Walls.
(Values are in B.Th.U./hr./ft.^{2}, for black body.)

Time	Roof gain Calc.	Roof gain Used	N. wall gain Calc.	N. wall gain Used	S. wall gain Calc.	S. wall gain Used	E. wall gain Calc.	E. wall gain Used	W. wall gain Calc.	W. wall gain Used
5 a.m.	6	0	2	—	3	—	43	0	2	—
6	59	0	10	—	14	—	171	150	10	—
7	122	88	15	—	16	—	229	260	13	—
8	187	175	20	—	18	—	224	300	17	—
9	246	247	25	—	19	—	252	260	19	—
10	291	303	28	—	21	—	147	150	22	—
11	298	338	14	—	10	—	57	0	10	—
12 N.	288	350	—	—	—	—	—	—	—	—
Morning totals							1,123	1,120		
1 p.m.	306	338	20	—	16	—	17	—	95	0
2	283	303	27	—	21	—	21	—	167	137
3	238	247	25	—	19	—	19	—	213	238
4	172	175	19	—	17	—	16	—	177	275
5	107	88	14	—	15	—	13	—	221	238
6	43	0	8	—	11	—	7	—	141	137
Aftn. totals									1,014	1,025
Day totals	2,646	2,652								

Note: The "Calculated" figures are derived from Ref. 8 and standard Sun Charts; the "Used" figures are the sine wave shape giving the same total B.Th.U./ft.^{2} over the slightly different period.

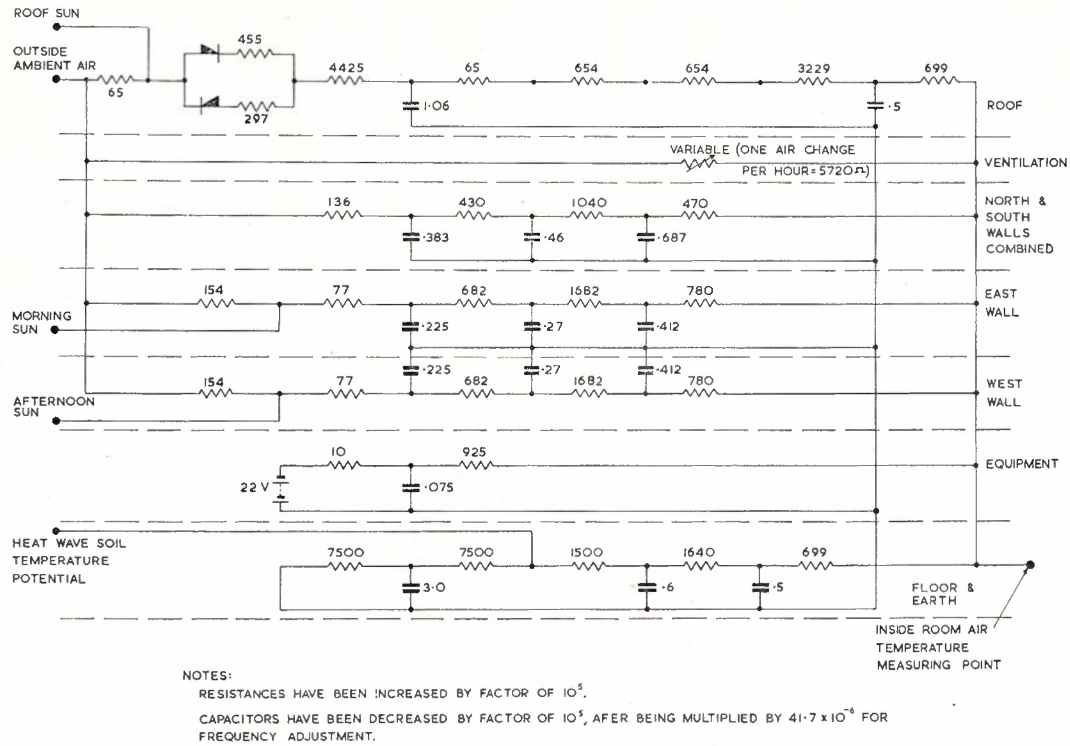


Fig. 11. Electrical Networks after Transformation to Practical Values for Use in Computer.

east wall from 6 a.m. to 12 noon, and on the west wall from 12 noon to 6 pm. The electrical equivalent is the introduction of currents of the required waveform and amplitude directly on to the outer roof and wall surfaces from high impedance (constant current) "sun" generators. The generation of these currents presented some difficulties as high voltages were necessary in order to give the correct high impedance source characteristics. The solar gains have direct-current components and effectively raise the mean temperature inside the building as well as causing cyclic variations.

Internal Air and Equipment: A calculation of the "stack effect" of the duct-like enclosures of the heat-producing equipment in the building showed that there would be sufficient recirculation of internal air to ensure intimate mixing. The air within the building would therefore be at an approximately uniform temperature. The equipment will be coupled to the internal air by the air stream from the equipment, and its equivalent electrical circuit includes a constant current generator to supply the equivalent of 600 watts or 2,000 B.Th.U./hr.

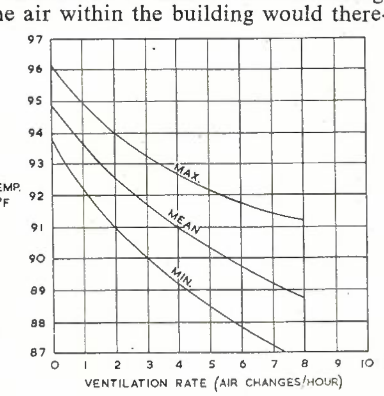


Fig. 12. Effects of Ventilation Rates on Building Temperatures over a Daily Cycle. The external temperature swing was 60° to 100°F. with solar radiation equivalent to summer conditions and 85°F. earth temperature.

Floor Structure: The floor of the building is similar in most respects to the walls but is connected to the earth beneath it rather than to the external air. Earlier in this paper it was shown that the earth temperatures are free from short term variations, and the earth represents a valuable potential means of absorbing the heat generated by the equipment without producing short term temperature variations within the building. It is therefore most desirable that the thermal resistance between the earth and the interior of the building should be as low as possible. The earth has also a relatively large thermal capacity and with good transmission between it and the inside of the building, use could be made of this capacity in minimising temperature variations. For the purpose of the analogue computer, the earth was taken as consisting of a 6ft. slab of dense dry clay divided into two sections of 1 ft. nearest to the surface and 5 ft. below that. For practical reasons each section was represented by an equivalent T-network, instead of a transmission line, and the division was made in the way indicated to give satisfactory impedance matching. Dry clay was chosen as it has relatively poor conductivity and is similar thermally to the soils encountered over much of the central part of the Sydney-Melbourne route. Moreover, it is the most unfavourable type of soil from the viewpoint of assisting the thermal requirements of the building.

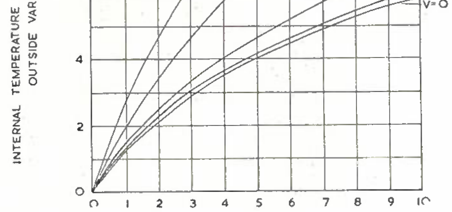


Fig. 13. Effect of Frequency of Cycle on Temperature Swing in Building. The external swing was 20°F. without solar radiation.

Ventilation: With still outside conditions, the air flow through a room would be that due to the pressure difference between two columns of air having heights equal to the vertical distance between the inlet and outlet ventilators, and each having different temperatures corresponding to the temperatures of the air passing through each of these ventilators. The pressure difference is proportional to the temperature difference and to the height of the columns, and this in turn causes a rate of flow proportional to the square root of the pressure. However, in practice the rate of flow is influenced by many other factors such as the outside wind velocity, the resistance of ventilator openings, and the air velocity inside the room near the ventilators due to other causes such as the escape of air from cooling ducts included in the equipment. It has been found that the rate of flow in buildings of the type proposed is determined largely by the other factors and not by the temperature difference, and is approximately constant and of the order of 1 to 2 air changes per hour. At a constant rate of flow the amount of heat exhausted from a room in a given time is the product of the thermal capacity of the air exhausted in that time and the temperature difference between the points of entry and exit. A given ventilation rate can thus be represented by a simple resistor. The specific heat of air is 0.24 B.Th.U./lb. and if the ventilation results in the transfer of, say, 10 lb. of air/hour, approximately 2.4 B.Th.U./°F. flows as an effective thermal current.

Air would normally enter the repeater building equipment room through the door ventilators and leave through the ceiling vent. Although the direction of flow could be reversed at times, this would occur only under very exceptional circumstances and the effect was neglected. Referring again to Fig. 8, if the thermal capacity of the air exhausted from the room in a unit time were, say, A_1, and the air entered at a temperature T_1, and left at a temperature T_3, the heat removed from the room in unit time would be $A_1(T_3—T_1)$. The room ventilation would therefore be represented completely by a thermal conductance of value A_1, connected directly between points of temperature T_3 and T_1. The air exhausted from the room would enter the roof cavity at temperature T_3 and leave it at temperature T_2, so that the heat removed from the cavity in unit time by this air current would be $A_1(T_2 — T_3)$. In addition, a further volume of air would enter the cavity due to outside air movement, and would leave after mixing with the other air in the cavity. If the thermal capacity of outside air entering in unit time were A_2, then the additional amount of heat removed in unit time by this air current would be $A_2(T_2—T_1)$. The effects on the cavity can be represented by the supplementary thermal conductances shown in Fig. 8, one of value A_2 connected between points of temperature T_2 and T_1, and the other of value A_1 connected between points of temperature T_2 and T_3. The latter point of temperature, however, must be isolated completely from the equipment room as the heat current concerned would not flow into the room, and in any case the effect of the ventilation on the room has already been covered completely by the conductance connected between points of temperature T_3 and T_1.

In the electrical analogue, an isolated point having an electrical potential equivalent to T_3 but connected to the outside air through a very low impedance could have been obtained using a

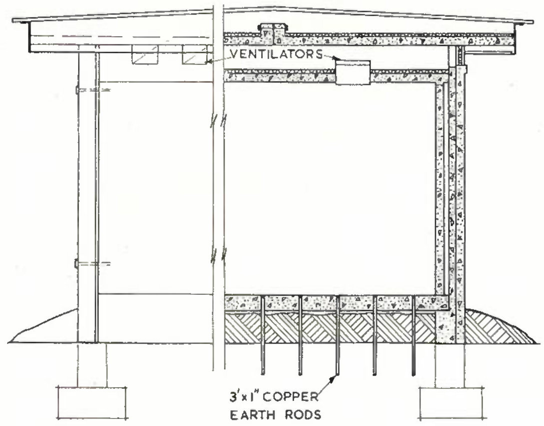


Fig. 14. Final Building Design for Sydney-Melbourne Route.
For details of materials see Fig. 10.

cathode follower circuit, or, alternatively, having regard to the small variation of T_3, using a variable D.C. bias circuit. However, it was found that in buildings with substantial awnings, the difference between T_3 and T_2 was very small, and it was possible to neglect completely the heat flow in this particular path. The heat loss from the cavity due to the external wind would also normally be low, and the greatest values of temperatures within the building would be experienced under still outside conditions. This loss was also neglected in the analogue, although the design of the ceiling slab was arranged so that the required limits of temperature variation within the equipment room would be obtained when temperatures in the cavity approached those of the external air.

In an auxiliary repeater building it is practicable to control the ventilation rate if necessary by means of adjustable baffles and/or suitable shaping and location of the exhaust ducting from the equipment local cooling system. To avoid uncertainties the analogue computer was arranged to include a variable resistor which could be adjusted to represent a range of air flow rates and the general effect of ventilation was determined in this way. The intention was that if ventilation were found from the analogue to be beneficial in reducing the maximum temperature in the building under extremely hot conditions without adversely effecting the temperature variations, then provision for it would be made in the final building design and the rates of flow required would be determined on an experimental basis after temperature observations had been made in several buildings.

Measurements Made: Measurements were made with a number of different building structures to determine the expected variations for the most adverse daily and ten-daily cycles, the maximum temperatures likely under heat wave conditions, the effect of ventilation and other factors on these, and the minimum temperatures possible under fairly severe winter conditions. Results for the final Sydney-Melbourne building are set out in Table VI. Typical effects of ventilation on the maximum temperature and of the frequency of the cycle on the building attenuation are shown in Figs. 12 and 13. It is of interest to

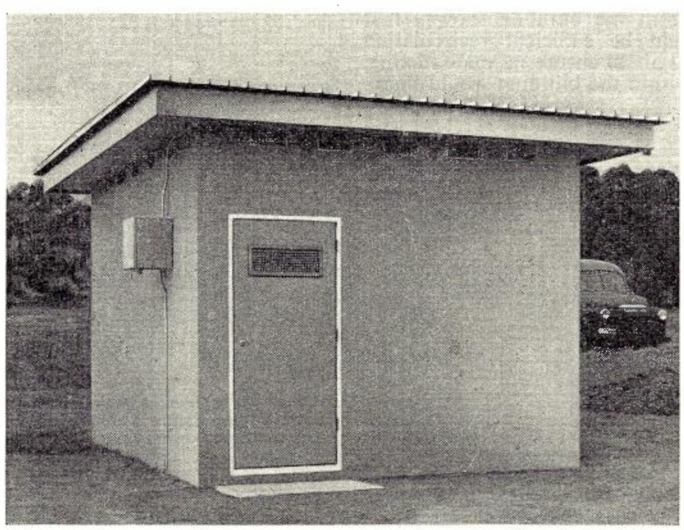


Fig. 15. Typical Completed Building on Sydney-Melbourne Route.

TABLE VI.
Test Results for Daily Cycles on Analogue for Final Sydney-Melbourne Building.

Test conditions					
Condition simulated	External air temperature swing	Sun generators	Earth temperature	Ventilation rate (air change/hour)	Internal air temperature
Extreme outside temperature variations in summer	60-100°F.	Used	82°F. at 6 ft.	0	94-96.5°F.
	,,	,,	,,	1	92.5-95°F.
	,,	,,	,,	2	91-94°F.
	,,	,,	,,	4	89-93°F.
	,,	,,	,,	8	86-91.5°F.
	,,	Not used	,,	1	88.5-91°F.
Heat wave	95-110°F.	Used	87°F. at 1 ft.	0	111.5-112.5°F.
	,,	,,	,,	1	110.5-112°F.
	,,	,,	,,	2	109.5-111.5°F.
	,,	,,	,,	4	108-110.5°F.
	,,	,,	,,	8	106.5-109.5°F.
	,,	,,	Disconnected	1	116-118°F.
Winter	30-60°F.	50% of summer	47°F. at 6 ft.	1	56-58°F.
	,,	Not used	,,	1	54-56°F.

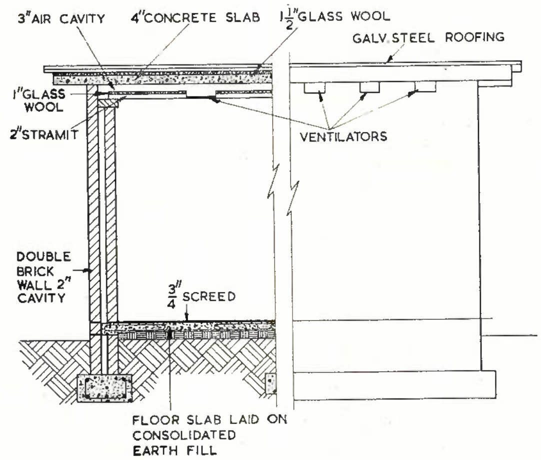


Fig. 16. Final Building Design for Melbourne-Morwell and other Short Routes.

note that solar radiation was responsible for a mean temperature increase inside the building of about 4°F. under summer conditions. Under heat wave conditions a ventilation rate of two air changes/hour reduced the mean temperature by 1.5°F. without increasing the daily variation significantly, and the transfer of heat through the floor reduced the maximum temperature by approximately 6°F.

Final Building Designs

The building design finally adopted for the Sydney-Melbourne route is shown in Fig. 14. One hundred buildings are required on this route and a design using prefabricated concrete sections involving only a small amount of on-site work was adopted. Contracts have been placed for the 68 buildings required in New South Wales where the cable laying has commenced. The erection of these buildings is well advanced and a rate of provision of seven buildings per month is being achieved.* Fig. 15 shows a typical completed building of this type. The constructional details of the Sydney-Melbourne buildings were determined by the Commonwealth Works Department Headquarters and New South Wales Offices in conjunction with the Postmaster-General's Department. The Works Department is responsible for the provision of the buildings through the contractor, Concrete Industries Pty. Ltd., Sydney. As only 15 buildings are involved on the Melbourne-Morwell route, a double brick construction was adopted and the design is shown in Fig. 16. The constructional details of these buildings were determined by the Commonwealth Works Department Victorian Office. All buildings on this route have now been erected.

Both types of buildings include ventilation despite the small advantage likely to be obtained in reducing the maximum temperatures. The provision was made because the maximum temperatures within the buildings are likely to approach the limit on occasions and even a small reduction will be beneficial under these circumstances. Internal and external temperatures are being recorded and ventilation rates measured at three buildings to enable the final ventilation rates and other details to be determined. It is probable that the ventilators will be closed except during the summer months. In the Sydney-Melbourne building, where the floor is a pre-cast section and it was not economical to consolidate the ground sufficiently to ensure an intimate thermal contact with the floor over a long period, a system of forty 1-in. copper earth stakes is being used to assist in reducing the maximum temperature.

** Since this article was written all buildings in New South Wales and approximately 90% of the buildings in Victoria have been completed.*

ACKNOWLEDGMENTS.

This paper is published with the kind permission of the Assistant Director-General, Engineering, and the Director, Buildings, Postmaster-General's Department. Considerable assistance with the work described in the paper was given by many individuals. In the text reference has already been made to the valuable information obtained from the Meteorological Physics Section of the Commonwealth Scientific and Industrial Research Organization, and the Central and State Offices of the Bureau of Meteorology. Mr. S. Dossing, Divisional Engineer, Postmaster-General's Department Long-Line Equipment Laboratory, contributed considerably to the design of the electronic circuitry of the analogue computer, and in discussion on the project in general. It should also be recorded again that the provision of the buildings concerned was the responsibility of the Commonwealth Works Department, and various aspects were discussed from time to time with officers of that Department. The authors wish to thank all those concerned with the project for their ready assistance and advice.

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THE EXPIRED AIR TECHNIQUES OF ARTIFICIAL RESPIRATION

*S. C. HILTON**

INTRODUCTION

During the past few months a great deal of publicity has been given to a form of artificial respiration known variously as Expired Air Respiration, Exhaled Air Respiration, Oral Resuscitation, Rescue Breathing, Positive Pressure Respiration or Mouth-to-Mouth and Mouth-to-Nose Resuscitation.

Expired Air Respiration (the term most commonly used by the medical profession) is not a new type of artificial respiration; reference is made to mouth-to-mouth resuscitation in the Bible and it is also known to have been practised for centuries in China and other parts of the Old World. The method has long been in dis-use but recent studies by medical authorities in Australia and Overseas have clearly demonstrated its superiority to the other types of resuscitation at present practised. The mouth-to-mouth and mouth-to-nose versions of the method have already been adopted by many organisations throughout the World. These techniques have recently been adopted by the Australian Post Office as the standard method of artificial respiration to be applied by Departmental workmen in reviving victims of electric shock, drowning, gas or smoke asphyxiation, etc., whose breathing has stopped.

Briefly the technique consists of blowing what can be literally the breath of life from the rescuer direct into the lungs of the victim through his mouth or nose. The process is rather like inflating a balloon (the lungs of the victim) by a single breath. When the rescuer stops blowing and withdraws his mouth the air is automatically exhaled from the victim's lungs. Inflation of the lungs is repeated every three to four seconds until the victim commences to breathe naturally of his own accord.

It is proposed to outline the investigations carried out in Australia and Overseas to determine the relative merits of the various methods of artificial respiration which have led to the adoption of the expired air technique and to deal particularly with the application of this method to cases of electrocution.

NATIONAL CONVENTION OF LIFE SAVING TECHNIQUES — SYDNEY, MARCH, 1960

This convention was organised by medical, scientific and humanitarian organisations to study recent advances in life saving techniques, particularly in regard to artificial respiration.

The medical and scientific sections of the convention were organised by the Post Graduate Committee in Medicine (University of Sydney) under the auspices of the Post Graduate Medical Foundation and was attended by a number of leading Australian and Overseas doctors in the fields of anaesthesiology and artificial respiration. Overseas notables present included Dr. P. Safar, Chief of the Department of Anaesthesia, Baltimore City Hospital, Baltimore, U.S.A., who has been prominent in investigating and developing the expired air respiration technique.

The convention was also attended by representatives of the Surf Life Saving Association, Royal Life Saving Society, Ambulance Services, Red Cross Society, Police Department, Fire Brigades, Electricity Authorities, the P.M.G's. Department and many other similar organisations, who discussed the practical application of life saving techniques.

The most important findings of the convention regarding the methods of artificial respiration were.

(i) That direct insufflation of the lungs by air or oxygen under positive pressure was much more effective in providing adequate ventilation of the lungs and re-oxygenation of the blood than the manual methods of artificial respiration (Schafer, Eve Rocker, Holger, Nielsen and Silvester-Brosch) at present practised.

(ii) That the best universal applicable type of artificial respiration for field use is expired air respiration by either mouth-to-mouth or mouth-to-nose methods.

Full details of the conclusions and recommendations of the medical committee of the convention are given in Appendix "A".

EXPERIMENTAL STUDIES

To determine the most effective method of resuscitation on an unconscious non-breathing person, experimental studies have been carried out by medical authorities on several thousand volunteers in Australia and overseas. The general procedure in these experiments was to simulate asphyxia by first anaesthetising the subject and then giving an injection of the drug curare, which causes paralysis of the muscles and stops breathing. Various methods of artificial respiration were then performed and the patient's air exchange (tidal volume per breath) recorded by means of a Spirometer. The subject's head was placed in a variety of positions to determine which position gave a clear passage way for the flow of air to the lungs.

The experiments demonstrated that in many cases none of the manual methods of resuscitation moved sufficient air into the lungs to sustain life. Mouth-to-mouth and mouth-to-nose resuscitation on the other hand supplied up to several times the volume of air averaged by experts using the older methods and in all cases provided adequate ventilation of the lungs.

Typical of the results obtained from these experiments are those given in Table 1 below for tests carried out recently at the Royal Prince Alfred Hospital, Sydney.

In these tests cyanosis (deficiency of oxygen in the blood) was evident in all cases where manual methods were employed. With both mouth-to-mouth and mouth-to-nose methods arterial oxygen saturation remained between 95 and 98 per cent. for the entire test period of 30 minutes.

All studies proved that the correct positioning of the head to obtain a clear airway is vital. No ventilation at all was obtained when some patients were placed in the prone position with the head turned to one side for performance of the Holger-Nielsen or Schafer resuscitation. Flexion of the neck (chin on chest) was found to completely block the throat with the patient lying in the prone position (face down) as well as

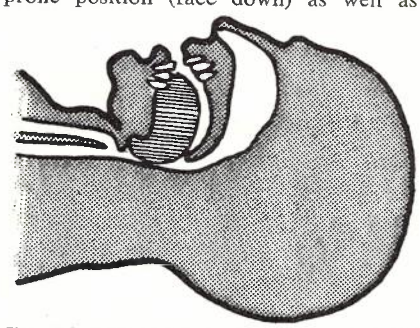

Fig. 1A.—Air passage obstructed by the tongue falling back.

TABLE 1: HIGHEST TIDAL VOLUMES RECORDED FOR EACH MANUAL METHOD (in cubic centimetres)

Patient	Holger Nielsen Head Down	Holger Nielsen Head Up	Back Pressure Hip Lift Head Down	Back Pressure Hip Lift Head Up	Silvester
1	330	800	500	750	1,000
2	150	810	—	630	480
3	—	360	—	—	450
4	150	960	630	1,170	720
5	—	1,020	600	990	840
6	800	960	800	960	1,000
7	600	660	360	360	360
8	450	600	—	—	—
9	300	450	—	—	—
Total:	2,780	6,620	2,890	4,860	4,850
Mean Tidal Volume	348	736	578	810	693

Mouth-to-Mouth and Mouth-to-Nose Methods: Tidal volume: 1,000-2,000 c.c.

*See page 465.

the supine position (face up). X-Ray studies demonstrated that this obstruction of the air passageway was due to the disappearance of throat reflexes in an unconscious person, allowing the tongue to sag against the back of the throat blocking the air passageway, the closer the chin was to the chest the greater the obstruction to the airway. (See Fig. 1A.) In some patients the air passage could be opened simply by pulling the chin up so that the head was extended to the sniffing position, while in others forward displacement of the lower jaw in addition to head extension was necessary. It was found that a clear, continuous airway (greater than the air passage of a normal conscious person) could be obtained in all cases by a full backward tilt of the head, as shown in Fig. 1B.

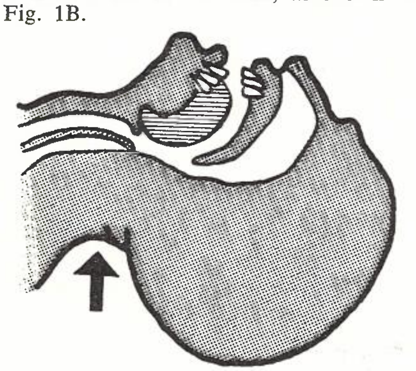

Fig. 1B.—Air passage clear with head tilted backwards and lower jaw pulled forward.

Adequate oxygen remains in the exhaled breath of the rescuer to quickly restore the normal oxygen content in the victim's lungs. The average content of free and exhaled air is given in Table 2:

TABLE 2. AVERAGE CONTENT OF FREE AND EXHALED AIR

	Free Air	Exhaled Air
Oxygen	20%	14-15%
Carbon Dioxide	Negligible	5-6%
Nitrogen	80%	80%
Other gases	Traces	Traces

It is evident from these figures that the utilisation of oxygen in the lungs is only one-quarter of that available and the rescuer's exhaled air still contains roughly twice as much oxygen as can be utilised by the victim.

In tests conducted by Dr. P. Safar, artificial respiration was stopped deliberately and it was noted that the oxygen saturation of the victim's blood started to drop rapidly after 45 to 90 seconds. However, reoxygenation was accomplished by as few as five deep mouth-to-mouth inflations within 10 to 20 seconds. The ability to reoxygenate a victim as rapidly as this is of extreme importance in resuscitation.

The controlled tests and experimental studies showed the expired air techniques to have the following advantages over manual methods of resuscitation:—

(i) It is the only non-mechanical technique which provides optimal ventilation of the lungs in all cases for both infants and adults. Manual methods may provide only partial, and sometimes no ventilation, unless a second rescuer can devote himself to assuring that the air passageway remains open.

(ii) When the rescuer breathes into the victim's airway he can immediately detect obstruction by feeling resistance to insufflation and by noting when the chest fails to rise and fall rhythmically with each breath. With the manual methods the operator is not able to detect any airway obstruction.

(iii) If partial obstruction occurs and cannot be relieved by the rescuer's fingers he can increase his insufflation pressure in order to ventilate the lungs. He can also slow his rate of insufflation to bypass a partial obstruction. This is not possible with manual methods.

(iv) Expired air respiration can be applied in many situations where the manual methods are seriously restricted such as where the victim is suffering from fractures or severe injuries to the limbs or thorax, or burns and for cases where the victim is in an unusual position or parts of his body are trapped.

APPLYING EXPIRED AIR ARTIFICIAL RESPIRATION

Expired air respiration consists of direct insufflation of the lungs by the rescuer blowing into the victim's nose (mouth-to-nose method) or his mouth (mouth-to-mouth method). Though these methods are equally effective, the mouth to-nose technique is generally preferred as much less air is blown into the victim's stomach and consequently the tendency to vomit due to inflation of the stomach is avoided. External circumstances such as blockage of the victim's nasal passage, tightly clenched jaw or injury to either his mouth or nose may determine which of the two methods should be used. In the event of failure to obtain insufflation of the lungs by one method the other should always be attempted.

Preparing for Resuscitation. Place the victim on his back, face up. Where a pad of clothing or similar material is **immediately** available, place it under his shoulders (clear of the neck) to raise them two to three inches above ground level. If any foreign matter is visible in his mouth, turn his head to one side, force his mouth open and quickly wipe the mouth and throat clean with your fingers or a piece of cloth (see Fig. 2.)

Lift the neck and tilt the head as far back as possible by holding the crown of the head with one hand, pulling the chin upward with the other (Figs. 3 and 4).

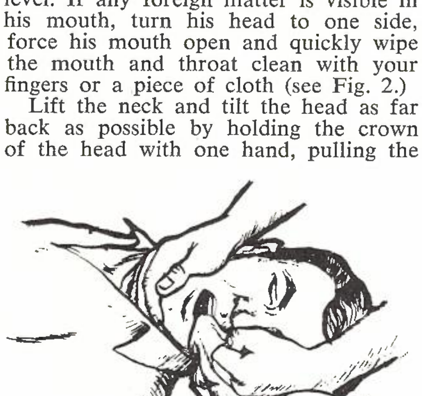

Fig. 2.—Clearing the throat of foreign matter.

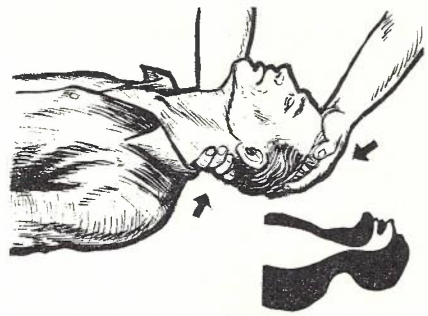

Fig. 3.—How to lift the neck (inset shows effect on airway)

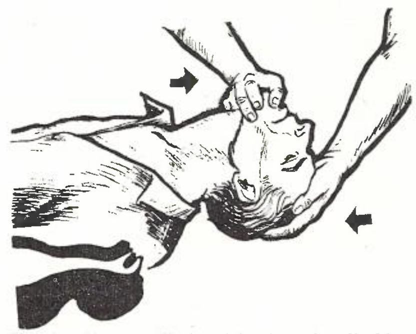

Fig. 4.—How to tilt head back and pull chin forward (inset shows effect on airway).

These operations must be carried out with the utmost speed to avoid delay in getting air into the victim's lungs.

Mouth-to-Nose Method. Lie or kneel to one side of the victim's head so that you are looking down into the nostrils. With your hands continuously maintain maximum extension and backward tilt of the victim's head and hold the victim's mouth closed. Lower your head vertically downwards, opening your mouth widely in an "O" and covering the patient's mouth with your cheek (see Fig. 5A). Place your mouth right around both nostrils and well on to the nose, reaching the bony part of the nose, taking care not to press more on one side of the nose than the other (or that side of his nose may become blocked, while the other side is possibly blocked already). (See Fig. 5B). See that you make a good "seal" with your mouth. Keep your cheek over the patient's mouth, but make sure that the full head-tilt is not impaired by pressure against his mouth.

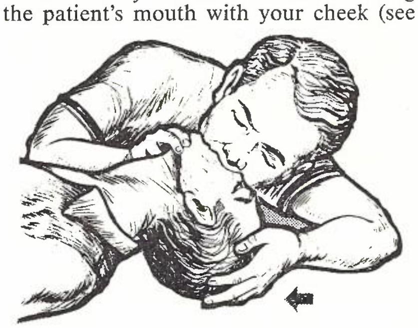

Fig. 5A.—Position of rescuer's head for mouth-to-nose method.

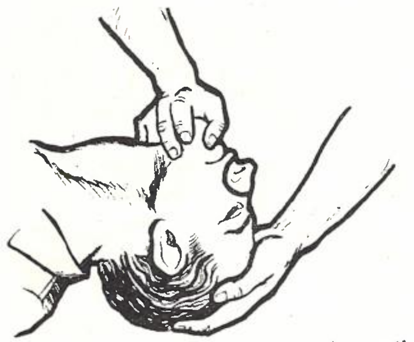

Fig. 5B.—Area covered by rescuer's mouth in mouth-to-nose method.

Inflate the patient's lungs by blowing steadily, but firmly, down into the nose while maintaining the backward head-tilt. If the patient's chest is not readily visible shift your hand from below the jaw momentarily across the patient's chest to gauge rising of the chest. Do not blow with a jerk to start with, but steadily as in inflating a football. Continue to blow until the chest expands noticeably or, if the patient roughly equals your own size, until your own lungs are emptied.

Remove your mouth to a comfortable distance and allow the patient to breathe out automatically (see Fig. 6). In some patients it may be necessary to open the mouth to assist exhalation. Listen to the air being exhaled. When flow of air stops blow in the next breath. Make the first ten breaths deep and at a rapid rate (but without jerking your breath into the patient) to give a good quick supply of life-giving oxygen. Thereafter, determine the rate of breathing by the time taken to inflate and deflate the lungs. This varies from 10 breaths per minute for an adult to 20 breaths for a child. Continue until the victim breathes naturally.

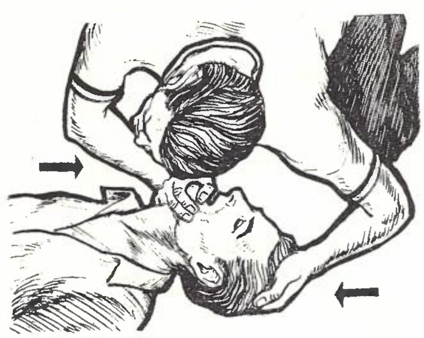

Fig. 6.—Position of rescuer's head during exhalation of patient.

Mouth-to-Mouth Method. This method is similar to mouth-to-nose resuscitation except that the victim's lungs are inflated via his mouth instead of his nose. While maintaining maximum backward head tilt with your hands separate the victim's lips with your thumb. Open your mouth widely and place it tightly over his mouth, press your cheek against the nostrils to prevent air leakage, and blow steadily to inflate the lungs (see Fig. 7). Take care not to lose head tilt by pressure against his mouth.

Watch the victim's chest. When it rises take your mouth away and let him breathe out naturally. Listen to the air being exhaled. When exhalation is finished blow in again. Repeat as for mouth-to-nose resuscitation. If insufflation of the lungs cannot be obtained it may be necessary to draw the tongue further forward to clear the air passageway. This may be done by inserting your thumb between the victim's teeth and holding the lower jaw upward so that the lower teeth are in front of the upper teeth. The nostrils may be closed between fingers and thumb of the other hand if difficulty is experienced in sealing with the cheek (Fig. 8).

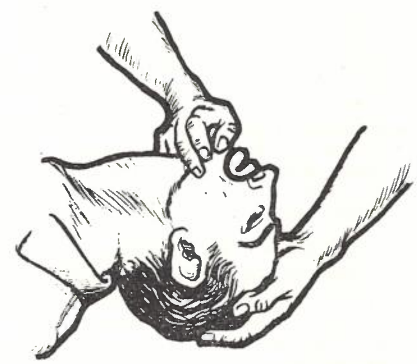

Fig. 7.—Area covered by rescuer's mouth in mouth-to-mouth method.

Fig. 8.—How to improve air flow and seal nose in special cases of difficulty.

Technique for Infants or Small Children. Lay the child on its back with its head tilted well backward. Open your mouth widely and cover the child's mouth and nose (see Fig. 9). For babies, at first use a "cheek puff", feel for chest expansion and watch for deflation. If no movement occurs use a "mouth puff"—that is, blow in only the air content of cheeks and mouth.

If the chest still does not rise check that full backward head tilt is being obtained and hold the lower jaw forward. This may be done by hooking a finger inside the jaw and pulling the lower gum well forward of the upper gum or grasping the angles of the jaw at the ear lobes on each side and pulling it forward. Gradually increase force of blowing until chest rises. The larger the child the more force required, but full force should never be used. Repeat inflations every 2 to 3 seconds.

Where a foreign body is lodged in a child's throat the obstructing material may be dislodged by inverting the victim and administering a sharp blow between the shoulder blades. If this is unsuccessful use a finger pushed well down past the larynx to hook it up or push it down as far as possible.

Fig. 9.—Position of patient's head and area covered by rescuer's mouth in case of infants or small children.

POINTS TO NOTE WHEN APPLYING EITHER METHOD

1. **Gauging Amount of Breath Required.** Blow steadily until the patient's chest expands noticeably; forcefully for an adult, gently for a child and puffs only for an infant. When the chest rises the breath has reached the patient's alveoli and lung ventilation is assured. Forcing more air into the patient than is required to fully inflate the lungs serves no useful purpose and can be harmful in the case of children.

2. **If the Victim's Chest Does Not Rise.** Increase the backward head tilt, hold the jaw forward, improve the mouth seal and blow again. If still not successful look for foreign body in the patient's throat. If foreign body cannot be seen or dislodged with the fingers place the victim over your forearm or knee in a face down position, then slap him firmly between the shoulder blades to dislodge any foreign body.

3. **If the Victim's Stomach Bulges.** This may be due to a blockage of the air passageway as a result of improper support of the head or too forceful blowing. Slight distention of the stomach will not stop the air entering the lung and no action is required to remove it. If the distension is gross and the abdomen is really tight and tense, stop blowing for a moment and press your hand between his navel and breast bone. This will cause the air in the stomach to be burped. If it causes the victim to vomit, turn his head well to one side, press his abdomen again, quickly clean his mouth and throat and resume rescue breathing.

4. **Removal of Water from Drowning Victims.** Commence artificial respiration immediately. Water may have entered the victim's lungs and stomach but generally this can be disregarded as water cannot be satisfactorily removed from the lungs without special equipment. Do not waste valuable seconds turning the victim to try to drain the lungs or empty the stomach. Only when the stomach is

obviously bulging or when the throat continues to fill up with regurgitated material should it be emptied (by hand pressure between the navel and breast bone). The mouth and throat must then be quickly cleaned and resuscitation recommenced.

5. **To Help Shallow Natural Breathing.** If the victim is breathing only faintly, blow in at the moment he inhales and take your mouth off quickly when he exhales.

USE OF ACCESSORY APPARATUS AND APPLIANCES

Resuscitation aids fall generally into two classes, artificial airways (intrapharyngeal tubes) to be used as adjuncts for mouth-to-mouth resuscitation and mechanical resuscitators fitted with face masks through which air or oxygen is pumped under pressure into the lungs of the victim. Such appliances are of value in certain circumstances, but they are not recommended for field use by lay personnel because of the skill required for their effective operation and the impracticability of ensuring that they are immediately available in the event of an emergency.

Artificial Airways. Artificial airways are plastic or rubber tubes which are inserted into the victim's mouth and throat to provide a mouthpiece for the rescuer and a breathing tube for the victim. Manufacturers of these appliances claim that they make resuscitation easier, assist in providing a clear air passageway and overcome the greatest objection to the mouth-to-mouth method, viz. the reluctance of rescuers to come into direct mouth-to-mouth contact with the patient.

The insertion of the airway tube requires a deal of skill. The necessary practice to acquire this skill is difficult to obtain as insertion of the tube in a normally conscious subject causes him to gag or retch and effective training can only be given on anaesthetised subjects under operating theatre conditions. This, of course, is impracticable.

Incorrect insertion of the airway could cause laceration of the throat membranes by the end of the tube with resultant bleeding or could push the tongue back to further block the air passage. In the cast of a patient who is not completely unconscious and retains certain reflex response, manipulation of the airway tube in the pharynx will cause him to vomit or regurgitate passively with the resulting danger of stomach contents entering the lungs. With some patients the throat structure makes the tube difficult to insert even by a trained operator and an unskilled person could waste much valuable time in this operation. Opening the mouth of a victim of asphyxia whose jaws are tightly clenched is extremely difficult and at times impossible.

Since it is possible to abtain a clear air passageway simply by maintaining the the victim's head in the proper tilted position and employing either mouth-to-nose or mouth-to-mouth resuscitation, commercial claims that artificial airway appliances work better than the direct oral or nasal methods are not substantiated by fact. Comparisons of efficiency and speed of resuscitation with and without adjuncts have repeatedly demonstrated the superiority of direct mouth-to-nose and mouth-to-mouth breathing by both professional and lay personnel. Non-professional rescuers cannot be expected to carry appliances with them at all times and should not be encouraged to spend the time required to find them in an emergency. Even when the appliance is readily available, some delay is caused in inserting it which could be avoided by immediate commencement of the direct nasal or oral methods.

The several hundred successful resuscitations performed by laymen without auxiliary appliances which have been reported during the last two years indicate that laymen will perform nasal or oral resuscitation without adjuncts and the natural reluctance to come into direct mouth contact with the victim is neglected in an emergency.

Mechanical Resuscitators. Pure oxygen supplied through a mechanical resuscitator provides better resuscitation than either normal or expired air. However, these machines are expensive, comparatively large in size and require considerable skill for efficient operation. Most breathing machines will function correctly only in the presence of a leak-proof mask fit. It takes considerable practice to learn how to hold a mask tightly on a victim's face. Unless the rescuer knows how to hold the chin up, how to maintain an air tight mask fit, how to recognise vomitus under the mask and how to determine whether or not the machine actually inflates the victim's chest he will be unable to breathe for the victim effectively with the mechanical equipment often without recognising this failure. For these reasons, mechanical resuscitators are impracticable for field use by lay personnel, though of considerable value to professional rescue services such as ambulance, mine rescue teams, etc.

Several simple resuscitators consisting of a balloon type bag and appropriate valve combination and a face mask are available commercially. When the balloon is compressed, air is forced through the face mask into the lungs of the patient. The valves permit natural exhalation by the victim. While this equipment does not require the amount of training necessary for the more elaborate breathing machines, it suffers from the disadvantages of all adjuncts when considered for field use—it cannot be made immediately available at the scene of the accident and can only be effectively operated by trained personnel.

TRAINING METHODS

The simplicity and ease of application of the mouth-to-nose and mouth-to-mouth methods of artificial respiration make them particularly suitable for field use. There are no complicated procedures to be learnt, no mechanical apparatus or appliances to be carried and anyone can be taught how to perform resuscitation by these methods in a few minutes. It is easy to remember the simple steps of tilting the head back and inflating the lungs through the mouth or nose.

It is not practicable to practise mouth-to-nose or mouth-to-mouth resuscitation on human subjects owing to the danger of spreading infection. However, demonstrations of the techniques and the showing of training films are normally adequate to enable a person to apply artificial respiration in an emergency. Instructors can demonstrate the methods fully without actually breathing into the lungs of the victim. A piece of plastic sheet placed over the nose or mouth of the victim will enable the mouth positions to be indicated.

Training manikins have recently been developed which permit trainees to actually perform both methods of resuscitation and several types are now available commercially. The manikins are normally in the form of a human head and chest with airways from the mouth and nose to an inflatable bag in the chest. They can mimic obstruction and opening of the airways in the manner the rescuer will encounter in a human patient and unless the manikin head is given maximum backward tilt and the jaw extended, valves in the airway prevent inflation of the "lungs". This equipment is a valuable training aid particularly where instruction is being given to a large number of men.

TREATMENT OF ELECTRIC SHOCK

Effects on Body. The effects of an electric shock on a human being are governed by the following electrical and physiological factors:—

Electrical

- Magnitude of current.
- Duration of current.
- Frequency of current.
- Wave shape of current.
- Voltage applied initially.

Physiological

- General physical condition of victim, e.g., condition of heart.
- Type and condition of skin at point of contact.
- Path of current flow.
- Phase of heart cycle subject to shock.

Injury to the body may include one or more of the following:—

- Paralytic injury to the brain.
- Injury to the heart and hence circulatory failure.
- Respiratory failure.
- Damage to tissue and organs by severe burns.
- Muscular convulsions.

Currents which pass through the torso in the neighbourhood of the heart and those that include the brain or parts of the central nervous system, are likely to produce fatal shock. The heart is vulnerable because currents, whether from hand to hand or hand to foot, travel principally in the blood vessels and so reach and traverse the heart. Current flowing between two points on the same limb will not cause death though severe burns may result.

The severity of the shock depends mainly on the current flow which, of course, is determined by the applied voltage and the resistance of the circuit through the body. The electrical resistance of the body is concentrated chiefly in the skin tissues at the points of contact. The resistance of the skin varies greatly, e.g., the calloused hands of a manual worker would have much higher resistance than those of an office worker. Skin that is wet with perspiration or water may have a resistance as low as 500 ohms while intact, dry, healthy skin may record up to 500,000 ohms. Once the skin is punctured, body resistance decreases greatly and consequently the prolonged application of a current by causing sweating and blistering and finally destruction of the skin is more dangerous than a brushing contact. Increased contact area with the conductor and increased contact pressure also reduces body resistance.

Alternating current and direct current are distinctly different in their shock effect. Alternating voltage of 50 c.p.s. (standard mains frequency) reaches maximum value at intervals of .01 seconds and when such a voltage is applied to the human body the nerve-muscle system is still in the refractory period caused by one peak, at the time of the next impulse and consequently with A.C. of sufficient magnitude, muscles remain in spasm and the victim is unable to free himself from the contact.

As the frequency is raised, the body is able to tolerate more current. The shock effect is detectable up to about 50 kc/s, but above this frequency only heat is experienced and this effect is used in diathermy where 1mc/s or more is used.

Muscular contraction is negligible in direct current cantact, except when the current value changes rapidly as in making or breaking the contact. When a person is subjected to alternating current the "Let Go" voltage at which he can release himself from contact varies in individuals from 15-90 volts and the "Let go" current is in the range of 8-14 m. amps.

Alternating currents from "Let-go" up to about 25 m. amps cause muscular cramps and may lead to exhaustion, loss of consciousness and inability to to breathe. Muscular contractions will cease when the current is removed but the inability to breathe may persist, requiring artificial respiration. From 25 m. amps to 80 m. amps the situation is intensified and death is possible.

Currents from 80 m. amps to approximately 8 amps can cause instantaneous death due to ventricular fibrillation, a condition where the heart loses its rhythm and muscles quiver in an unco-ordinated manner even after cessation of the current. Most authorities place the range of extreme danger between 100 and 200 m. amps. Tests have shown that the heart is vulnerable only at the end of the contraction period but a current of very short duration could be fatal if it coincided with this period. Artificial respiration in itself does nothing to restore heart rhythm when fibrillation occurs. Above the fibrillation range the heart locks in spasm but generally resumes its normal beat when the current is interrupted. Resuscitation if immediately applied is often successful.

Higher voltages, causing greater currents are therefore not necessarily more dangerous than lower ones, although currents over 10 amps produce burning of the tissues and death is probable (perhaps not immediately) from poisoning by combustion products.

Resuscitation Principles. In cases of electric shock where asphyxiation is caused by muscular contraction or paralysis of the respiratory system there is an excellent chance that the victim can be revived if artificial respiration is promptly applied.

When ventricular fibrillation has occurred artificial respiration does little to restore the heart action and the chance of successful treatment is small. A new method of treatment for circulatory arrest resulting from fibrillation or heart "standstill" consists of sharply compressing the chest three or four times during the exhalation period of resuscitation. This method has proved successful in stimulating the heart into voluntary action.

It is impossible for the layman to determine which shock condition has been established in the body and artificial respiration should be applied as the only means of possible recovery. If the supply of oxygen is cut off for more than 3-5 minutes irreparable damage is caused to the brain and if the victim is then revived by artificial respiration his mental capacity could be impaired. An indication of the chances of revival by means of artificial respiration after breathing has ceased (providing ventricular fibrillation has not occurred) is given in Fig. 10. It will be noted that

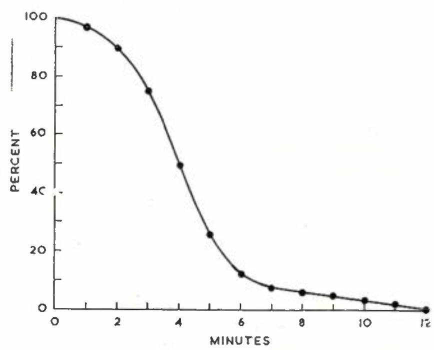

Fig. 10.—Chances of recovery after cessation of breathing provided competent artificial respiration is given.

every moment of delay in the commencement of resuscitation greatly reduces the victim's chances of recovery.

If damage to the respiratory nervous system is not too severe, paralysis will gradually disappear and the body will resume natural breathing providing artificial respiration has been applied continuously to maintain the life-giving oxygen supply.

Rescuers should not be discouraged if the victim takes a long time to revive as cases have occurred where shock victims have recovered after eight hours' resuscitation. Death must not be assumed, therefore, and artificial respiration must be continued until breathing is restored or a doctor pronounces life extinct, or if medical attention is not available, until unmistakable signs of death appear, e.g., rigor mortis (stiffening) or skin becomes blue in colour.

Rescue and Treatment. Prompt action by a rescuer is essential if a victim is to be given maximum survival chances. A quick appraisal of the situation should be made while approaching the victim. If he is still in contact with a conductor, the electricity supply should be switched off where possible, or other expedient means taken to interrupt the supply, such as pulling a flexible cord from a socket outlet.

Where supply cannot be interrupted quickly, the victim should be removed from the conductor by using some insulator such as dry wood, dry clothing, rope, rubber mats, rubber gloves, etc. If such aids are not readily to hand, the feet should be used to move the victim rather than the hands. In the case of a lineman being "caught" on aerial conductors, a sharp blow on the front or back of the wrist with the rescuer's closed hand (preferably wrapped in dry cloth) will generally break the victim's grip of the conductor.

Immediately the victim is cleared from the cause of the accident and there is no danger to the rescuer, artificial respiration should be commenced. At this stage, seconds are precious. Where it is necessary to rescue a workman from a pole top he should if practicable be given ten quick breaths (mouth-to-nose, or mouth-to-mouth) as soon as he is cleared from the live wires. This will restore the oxygen content of the blood to 95% of normal and another period of 3 to 5 minutes may then elapse before oxygen lack again becomes crucial. During this period it will generally be possible to lower him to the ground where continuous artificial respiration can be applied.

Medical assistance should be summoned as soon as possible, but commencement of artificial respiration should not be delayed for this purpose. Soon after artificial respiration is commenced, the carotid artery (on either side of the throat) should be checked for pulse. If pulse cannot be felt stimulation of the heart to promote circulation should be commenced in conjunction with artificial respiration by placing the heel of the hand on the lower half of the victim's breastbone and compressing the chest sharply three or four times during the exhalation period. If the current has been above the fibrillation range, the heart may be at "standstill," and this heart massage action would tend to stimulate the heart into voluntary action.

If assistance is available, the inside of the patient's limbs should be briskly rubbed, towards the heart, tending to create movement of blood in the veins. There is some evidence that occasional heart beats or half-beats occur, which may just enable life to be supported with well oxygenated blood, pending resumption of a normal heart rhythm.

The commencement of voluntary breathing does not mean that the victim is out of danger and will continue breathing; shallow breathing should be assisted and even if the victim regains consciousness, he should not be left alone, because it is possible that he will lose consciousness again and his respiratory action cease.

Moving a Victim. If an unconscious person has to be moved before artificial respiration is commenced, he may be carried, rolled, or dragged. The risk of damage from this source is of secondary importance, although it is unlikely that any damage will result from moderate handling. The uppermost thought in a rescuer's mind should be to commence resuscitation with minimum delay.

Where a victim has been rescued from a pole, he can be lowered onto the rescuer and carried by the fireman's carry or back carry. Where the victim is lying on the ground, the easiest method of shifting him is by the wrist grip-back drag method.

First Aid on Restoration of Normal Breathing. When the victim's normal breathing has been restored, the following first aid may be given pending the arrival of a doctor.

(i) If the victim is breathing normally but still unconscious hold his head backward and his jaw forward to keep the air passageway clear until he is fully conscious.

(ii) Keep him warm and quiet.

(iii) Do not give any liquids by mouth unless he is fully conscious. A stimulant in the form of hot tea or coffee, aromatic spirits of ammonia in water or a little spirits and water may be given after he has recovered consciousness.

(iv) Control bleeding from any wounds and attend to serious burns in the usual manner.

(v) Immediate rest for any victim of electric shock is essential, especially where there has been unconsciousness. Keep him under constant observation and do not allow him to sit up or walk until placed in the care of a doctor.

CONCLUSION

The expired air techniques have proved to be not only more effective than conventional methods, but also simpler to learn and apply by untrained people. It is confidently expected that their use will help save many lives in the future.

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APPENDIX "A"

INTERNATIONAL CONVENTION ON LIFE SAVING TECHNIQUES

New South Wales : Australia
March 11-20, 1960

Conclusions and Recommendations of the Medical Committee regarding Methods of Artificial Respiration.

1. The most efficient type of artificial ventilation of the lungs is intermittent positive pressure breathing. Manual artificial respiration is less effective.
2. Expired air artificial respiration is recommended as the best universally applicable field type of artificial respiration.
3. The best methods of expired air artificial respiration provide an adequate airway, are free from air leaks and provide adequate inflation pressures.
4. The most important single factor in providing airway patency is maximal backward tilting of the head. In some persons in addition to the backward tilt of the head, forward displacement of the mandible and/or separation of the lips may be necessary.
5. The recommended methods of expired air respiration are mouth-to-mouth and mouth-to-nose according to circumstances.
6. Accessory apparatus and appliances, such as masks and artificial airways, are of some value in certain circumstances as adjuncts to expired air respiration (but no recommendations are made regarding their use).
7. The Silvester-Brosch and the Holger-Nielsen are the recommended methods of manual artificial respiration. The Silvester-Brosch provides better lung ventilation but the Holger-Nielsen may be the preferable method in some circumstances.
8. 100% oxygen given through a suitable machine provides better resuscitation than expired air respiration or manual respiration. This should only be given by fully trained professional rescue personnel.
9. Closed chest manual systole may be a significant advance in the rescue of persons about to die of circulatory arrest from ventricular fibrillation or standstill.

BOOK REVIEW

MATHEMATICS FOR TELECOMMUNICATIONS AND ELECTRICAL ENGINEERING, VOL. 2.

D. F. Spooner and W. H. Grinstead, 1960. English Universities Press. P.p. 509. Australian Price, 28/-.

Chapter Headings: Fundamental processes in Algebra—The Treatment of Surds: Further solution of Equations—Graphs of Mathematical Functions—Harder variation and the progressions—The Trigonometry of any Triangle—General Formulae in Trigonometry applications—Introduction to the Calculus —Introduction to the Integral Calculus—Further algebra mainly about Series—Further differentiation—Further Integration-Complex Numbers — Answers to Exercises — Logarithmic and Trigonometric Tables—Index.

This book has been written to cover the syllabus for the final two years Mathematics (3rd and 4th Years) of the City and Guilds examination and the National Certificate Course in London. Some of the work is aimed at covering part of the syllabus for the British I.R.E. examinations which are of Engineering Degree standard.

In one volume this book covers from fundamental algebra to quite complex integration, and in doing so it tends to become vague.

However, considering the size of the Book, the coverage of the work is as thorough and as simple as can be expected.

The Index covers every small section of the book, making it very good as a reference book.

The paper and binding of this book are good, the paper being quite thick and smooth, while the hard cover is of good quality.

Answers to exercises are given at the back of the book.

The scope of this book is far too much to be of use to study for Technicians or Senior Technicians exams., but for the Senior Technician who wants to do more mathematics in the Telecommunications field, it should prove a very good text or for the first year University student it should make a handy reference book.

ERRATA

P. 245
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D. J. DORAHY, B.E.

METHODS OF NUMERICAL FILTER DESIGN – PART VI

*E. RUMPELT, Dr. Ing.**

11. THE INFLUENCE OF DISSIPATION IN CIRCUIT ELEMENTS ON THE INSERTION LOSS OF FILTERS.

The inevitable dissipation in the circuit elements of filters, which for the purpose of simplifying the design process have been assumed to be dissipationless, always has an unfavourable influence on the filter performance. This influence is particularly noticeable near cut-off frequencies, in pass-bands as well as in stop-bands. Owing to dissipation the insertion loss is increased in pass-bands, to a rising extent as a cut-off frequency is approached, and it is reduced in stop-bands, especially at attenuation peaks. For this reason the dissipation in filter components should always be kept as small as feasible under the circumstances, depending on the range of frequency and the values of the components.

11.1. THE EFFECT OF DISSIPATION ON THE PASS-BAND INSERTION LOSS.

In the pass-band of a filter the voltages across and the currents through its individual components rise steadily as a cut-off frequency is approached and they reach maximum values in the vicinity of the cut-off frequency. These maximum voltages and currents may be several times the voltages and currents at the filter input and output if there is a sharp rise of insertion loss in the transition band. As the filter components are dissipative they cause power losses which are proportional with the squares of their voltages and currents, and the transmission loss in the filter is accordingly increased.

The variable dissipative insertion loss in the pass-bands of filters causes linear distortions of the transmitted signals and, in the case of image parameter filters, the only way of keeping these distortions within tolerable limits is to use filter components with small dissipation and, if necessary, to equalise the pass-band insertion loss to an approximately constant value. This value must be slightly higher than the largest insertion loss value of the filter in its practical pass band. If this loss exceeds 0.5 . . . 1 db the reduction in discrimination against the stop-band insertion loss must be taken into account in the filter design by a corresponding increase of the specified minimum insertion loss in the stop-band. This makes it desirable to be able to calculate the insertion loss rise in the pass-band for given dissipation in the filter components with reasonable accuracy at an early stage of the design.

11.2. CALCULATION OF THE PASS-BAND LOSS DUE TO DISSIPATION.

11.2.1. The Dissipation Coefficients of the Filter Components. The dissipation of an inductor may be represented by a resistance connected in series with its inductance, and the dissipation in a capacitor by a conductance connected in parallel with its capacity. The impedance of the dissipative inductor is then:

$$Z_l = j\omega L + R = j(\omega - j\varepsilon_l)L \quad \ldots\ldots (11.1)$$

where $\varepsilon_l = \dfrac{R}{L}$

and the admittance of the dissipative capacitor is:

$$Y_c = j\omega C + G = j(\omega - j\varepsilon_c)C \quad \ldots\ldots (11.2)$$

where $\varepsilon_c = \dfrac{G}{C}$

ε_l and ε_c are the dissipation coefficients of the inductor and capacitor, respectively. Their relationship with the Q-factor, Q_l of the inductor and the dissipation factor, δ_c, of the capacitor is as follows:

$$Q_l = \frac{\omega L}{R} = \frac{\omega}{\varepsilon_l} \quad \ldots\ldots (11.3)$$

$$\delta_c = \frac{G}{\omega C} = \frac{\varepsilon_c}{\omega} \quad \ldots\ldots (11.4)$$

It shall now be assumed that all inductors and capacitors in a filter have the same dissipation coefficients:

$$\varepsilon_l = \varepsilon_c = \varepsilon \quad \ldots\ldots (11.5)$$

which means that, according to Eqs. (11.1) and (11.2), the impedances of all inductors and the admittances of all capacitors can be obtained from the impedances and admittances of the corresponding dissipationless components by substituting $(\omega - j\varepsilon)$ for ω.

11.2.2. The Insertion Transfer Constant of a Dissipative Filter. The insertion transfer constant of a dissipationless filter is some complex function of the impedances $j\omega L$ of all its inductances and of the admittances $j\omega C$ of all its capacities:

$$P_L(\omega) = \phi\,(j\omega L,\ j\omega C)$$

If uniform dissipation in accordance with Eq. (11.5) is introduced into the filter components and the impedances of the inductors become $j(\omega - j\varepsilon)L$, and the admittances of the capacitors become $j(\omega - j\varepsilon)C$, then the same substitution also transforms the insertion transfer constant of the dissipationless filter into that of the dissipative one, i.e.

$$P^*_L(\omega) = A^*_L + jB^*_L = P_L(\omega - j\varepsilon) \quad (11.6)$$

where A^*_L is the insertion loss and B^*_L the insertion phase-shift of the dissipative filter.

Developing the function $P(\omega - j\varepsilon)$ in a Taylor series at the point ω yields:

$$P^*_L(\omega) = P_L(\omega) - j\varepsilon \frac{dP_L(\omega)}{d\omega} - \tfrac{1}{2}\varepsilon^2 \frac{d^2P_L(\omega)}{d\omega^2} + j\frac{\varepsilon^3}{6}\frac{d^3P_L(\omega)}{d\omega^3} + \ldots\ldots (11.7)$$

with $P_L(\omega) = A_L + jB_L$ (dissipationless filter)

11.2.3. The Pass-Band Insertion Loss of Dissipative Filters. The insertion loss of the dissipative filter is the real part of Eq. (11.7). In the practical pass-bands of filters the various derivatives of the insertion transfer constant have no excessively large values, and if the filter components have a reasonably small dissipation only the first two terms in Eq. (11.7) need be taken into account. This gives for the pass-band insertion loss the approximate relation:

$$A^*_L \doteqdot A_L + \varepsilon \frac{dB_L}{d\omega} \text{ in nepers} \quad (11.8)$$

It has been pointed out previously that in the practical pass-band of a filter, where the mismatch between image impedances and terminating resistances is small, the difference between the insertion phase-shift, B_L, and the image phase-shift, β, is negligible. It is therefore permissible to replace in Eq. (11.8) the insertion phase-shift by the image phase-shift, and the increase of the insertion loss due to dissipation is:

$$A_d \doteqdot \varepsilon \frac{d\beta}{d\omega} \text{ in nepers}$$

$$\doteqdot 8.69\,\varepsilon \frac{d\beta}{d\omega} \text{ in db} \quad \ldots\ldots (11.9)$$

11.2.4. Average Value of Dissipation Coefficient. In the derivation of the above formulae it has been assumed that the dissipation coefficients of all components of a filter are equal. In practice the dissipation coefficients ε_l of the inductors in a filter do not differ very much among themselves, and neither do the dissipation coefficients ε_c of the capacitors. But ε_l and ε_c frequently differ by about one order of size, the dissipation being much larger in inductors than in capacitors, and Eq. (11.5) is not applicable. In such cases this relation must be replaced by:

$$\varepsilon = \tfrac{1}{2}(\varepsilon_l + \varepsilon_c) \quad \ldots\ldots (11.10)$$

which means that the average dissipation coefficient of a filter is the arithmetic mean of the dissipation coefficients of its inductors and capacitors.

A rather crude physical explanation of Eq. (11.10) can be obtained by the following consideration: During signal transmission through a filter pulsating electro-magnetic energy is stored half the time in the electric fields of the capacitors and half the time in the magnetic fields of the inductors. The energy losses due to dissipation are connected with the process of electric and magnetic energy storage. If now e.g., only the inductors were dissipative the energy

* See page 298, Vol. 12, No. 4.

losses would obviously be halved as compared with the case where inductors and capacitors have equal dissipation.

11.2.5. Final Formula for the Pass-Band Insertion Loss Due to Dissipation. The dimension of the dissipation coefficient, ε, is somewhat unwieldy and it is preferable to use instead the Q-factor, Q_l of the inductors and the dissipation factor δ_c, of the capacitors, which are generally accepted as a measure of the dissipation in these components. With the help of Eqs. (11.3), (11.4) and (11.10), Eq. (11.9) is transformed into its final form:

$$A_d \doteqdot 4.34 \left(\frac{1}{Q_l} + \delta_c\right) \omega \frac{d\beta}{d\omega} \text{ in db} \quad \ldots\ldots (11.11)$$

Herein is Q_l the average Q-factor (in the order of 50 to 500) of the inductors and δ_c the average dissipation factor (in the order of 0.0005 to 0.01) of the capacitors in the filter at the considered frequency. $d\beta/d\omega$ is the differential delay of the filter at this frequency and when the previously derived formulae of the differential delay for the various filter types are applied, it will be seen that the factor ω in Eq. (11.11) either cancels altogether or can be combined with a cut-off or centre angular velocity in the denominator of the expression for the differential delay to give a normalised frequency of the order of 1.

11.3. THE EFFECT OF DISSIPATION ON THE STOP-BAND INSERTION LOSS OF FILTERS.

The most conspicuous effect of dissipation in filter components on the stop-band insertion loss is the reduction of the theoretically infinite insertion loss at attenuation peaks to finite values. This effect may be so pronounced that peaks nearest to a cut-off frequency completely disappear from the insertion loss characteristic of a filter. However, unless a particularly large insertion loss is required at discrete frequencies in the stop-band, the loss at attenuation peaks is of practical interest only indirectly because it gives an indication of the insertion loss reduction due to dissipation at the minima between peaks. Here the insertion loss may be critical as filters are usually so designed that there is little margin between the minima and the specified loss characteristic. As a rough rule it may be said that no marked reduction of the insertion loss at a minimum is to be expected as a result of dissipation if the insertion loss at the two nearest attenuation peaks is still at least 6 db above the design value of this minimum. If the margin between the minima and the specified insertion loss has been made at least a few db, which always is a good policy in design, even less protruding peaks are still adequate.

If, on the other hand, a calculation of the insertion loss at an attenuation peak reveals that its value is below the specified insertion loss limit special methods must be applied to lift the peak loss sufficiently to meet the requirements. Such methods will be discussed later on. As they necessitate resistances to be included in the filter circuit they should be used only if it can really not be avoided because the resistances introduce additional energy losses in the pass-bands.

11.4. CALCULATION OF THE PEAK LOSS IN DISSIPATIVE LADDER FILTERS.

In calculating the insertion loss of a dissipative ladder filter at an attenuation peak frequency it will be assumed that only the series or shunt branch, respectively, which produces the peak is dissipative and the rest of the filter is dissipationless. This is in general permissible as the calculation is only supposed to give an approximate value, considering that the dissipation of the components is usually not well enough known in advance to justify a precise calculation.

An attenuation peak is produced either by a parallel resonant circuit in a series branch or by a series resonant circuit in a shunt branch. In both cases the inductance and capacity of the circuit resonate at the peak frequency:

$$LC = 1/\omega_\infty^2$$

Let it be assumed that at this frequency the inductor has the Q-factor Q_l and the capacitor the dissipation factor δ_c, then the effective Q-factor of the resonant circuit is:

$$Q_{lc} = \frac{Q_l}{1 + \delta_c Q_l} \quad \ldots\ldots\ldots (11.12)$$

At the peak frequency the impedances of both the parallel resonant circuit and the series resonant circuit are resistive and the equivalent resistance values are:

(i) Parallel resonant circuit:

$$R_d = X_o Q_{lc} \ldots\ldots (11.13)$$

(ii) Series reconant circuit:

$$r_d = X_o/Q_{lc} \ldots\ldots (11.14)$$

where X_o is the characteristic reactance of each resonant circuit:

$$X_o = \omega_\infty L = 1/\omega_\infty C = \sqrt{\frac{L}{C}} \quad (11.15)$$

Two cases must be distinguished:

(a) The peak producing resonant circuit is inside a regular filter section.

(b) The peak producing resonant circuit is at the outside end of a matching section facing a terminating resistance of the filter.

11.4.1. Peak Producing Resonant Circuit Inside the Filter. If the peak producing resonant circuit is in a regular filter section (with constant-k image impedances) the image impedance of this section at the peak frequency is practically the same as if there were no dissipation provided that the effective Q-factor of the resonant circuit is reasonably large. This means that there is no marked disturbance due to dissipation of the reflectionless transmission conditions inside the filter.

The image attenuation of the section at the peak frequency can easily be calculated. It is:

$$\alpha_d = 20 \log \left|\frac{2R_d}{Z_I}\right| \quad \ldots\ldots (11.16)$$

if the peak is produced by a parallel resonant circuit in a series branch, and it is:

$$\alpha_d = 20 \log \left|\frac{2Z_I}{r_d}\right| \quad \ldots\ldots (11.17)$$

if the peak is produced by a series resonant circuit in a shunt branch of the filter. R_d and r_d are given by Eqs. (11.13) and (11.14), respectively, and Z_I is the image impedance of the relevant filter section at the peak frequency.

The total insertion loss of the filter at this frequency is then, according to Eq. (4.15):

$$A_L = \alpha' + \alpha_d - 6 + 10 \log \frac{1 + p_1^2}{2p_1} + 10 \log \frac{1 + p_2^2}{2p_2} \quad \ldots\ldots\ldots (11.18)$$

Herein is α' the image attenuation at the peak frequency of the filter without the peak producing section. (The basic loss A_t has been neglected.)

The formulae of Eqs. (11.16) and (11.17) hold for every filter type. The values of R_d and r_d are given by the effective Q-factor and the L– and C–values of the resonant circuit, which themselves are given for each filter type by cut-off frequency, attenuation peak frequency and nominal image impedance. The image impedance, Z_I, in Eqs. (11.16) and (11.17) is also given by these parameters, and if the latter are introduced in these equations they yield the same expression for a given filter type. The result is:

Low-pass and high-pass filters:

$$\alpha_d = 20 \log \left[4Q_{lc}(\Omega_\infty^2 - 1)\right] \quad (11.19)$$

Frequency-symmetrical band-pass and band-stop filters:

$$\alpha_d = 20 \log \left[4Q_{lc}(\Omega_\infty^2 - 1)\frac{y_\infty^2 - 1}{y_\infty^2 + 1}\right] \quad \ldots\ldots\ldots (11.20)$$

Herein is Ω_∞ the peak frequency of the normalised low-pass filter from which the above filters are derived. y_∞ is the upper peak frequency of the band-pass or band-stop filter, corresponding to Ω_∞ and referred to the centre frequency of the bass-band or stop-band, respectively (see Eq. (8.3)).

The formula of Eq. (11.20) may with adequate accuracy also be applied to frequency-unsymmetrical band-pass filters if the corresponding section produces two peaks which are approximately symmetrical with respect to the centre frequency of the pass-band. Otherwise Eq. (11.16) or (11.17) must be used.

It must be mentioned here that none of the above formulae may be applied to determine the insertion loss at the centre frequency of the stop-band of a band-stop filter. The assumption that the influence of the dissipation on the image impedance may be neglected can here no longer be maintained. The easiest way of calculating the insertion loss in this case is to replace all resonant circuits tuned to the centre frequency by their equivalent resistances and determine the insertion loss directly from the resulting circuit diagram.

11.4.2. Peak Producing Resonant Circuit Facing a Terminating Resistance. If the peak producing resonant circuit belongs to a matching section and faces therefore the terminating resistance at one filter end, the image attenuation of this matching section as well as the reflection loss at this filter end are reduced at the peak frequency as a result of the dissipation in the peak producing resonant circuit. If the latter is a parallel resonant circuit in series connection this image attenuation and reflection loss combined are:

$$\alpha'_d = 20 \log \left| \frac{R_d}{\sqrt{Z_I R}} \right| \quad \ldots (11.21)$$

R_d is again the anti-resonant impedance of the parallel resonant circuit and is given by Eq. (11.13). Z_I is the image impedance of the filter following the matching section at the peak frequency, and R is the terminating resistance of the filter at the considered end. It is assumed that $R_d \gg R$, otherwise R_d in Eq. (11.21) must be replaced by $(R_d + R)$.

If the peak is produced in the matching section by a series resonant circuit in shunt connection, the image attenuation of the matching section combined with the reflection loss against the terminating resistance is at the peak frequency:

$$\alpha'_d = 20 \log \left| \frac{\sqrt{Z_I R}}{r_d} \right| \quad \ldots (11.22)$$

where r_d is the resonant impedance of the series resonant circuit and is given by Eq. (11.14). Z_I and R are defined as above. It is assumed that $r_d \ll R$, otherwise r_d in Eq. (11.22) must be replaced by $r_d/(1 + r_d/R)$.

The total insertion loss of the filter at the peak frequency is:

(i) If the matching section is only at one filter end:

$$A_L = \alpha' + \alpha'_d - 3 + 10 \log \frac{1 + p_1^2}{2p_1} \quad \ldots \ldots \ldots (11.23)$$

where α' is the image attenuation at the peak frequency of the filter without the matching section and p_1 is the matching factor at the other filter end.

(ii) If both filter ends are fitted with equal matching sections:

$$A_L = \alpha'' + 2\alpha'_d \quad \ldots \ldots \ldots (11.24)$$

where α'' is the image attenuation at the peak frequency of the filter without the two matching sections.

By introducing the design parameters of the matching sections for the various filter types into Eqs. (11.21) and (11.22) in a similar way as it has been done before in Eqs. (11.16) and (11.17) for regular filter sections, the following formulae are obtained which are equal for both types of matching sections (i.e. halved T– and π–sections).

Low-pass and high-pass filters:

$$\alpha'_d = 20 \log \left[Q_{lc} (\Omega_\infty^2 - 1)^{3/4} \right] \quad (11.25)$$

Frequency-symmetrical band-pass and band-stop filters:

$$\alpha'_d = 20 \log \left[Q_{lc} (\Omega_\infty^2 - 1)^{3/4} \frac{y_\infty^2 - 1}{y_\infty^2 + 1} \right] \quad \ldots (11.26)$$

Ω_∞ and y_∞ are defined as in Eqs. (11.19) and (11.20).

11.5. METHODS OF INCREASING THE INSERTION LOSS AT ATTENUATION PEAKS OF DISSIPATIVE FILTERS.

In dissipative lattice filters the limitation of the insertion loss at attenuation peaks is due to the fact that at the peak frequencies where the reactive components of series and lattice arm impedances are equal, their resistive components (caused by dissipation) are usually different. It is, however, a simple matter to enforce equality of the resistive components at least at one peak frequency by adding a small series resistance or a large shunt resistance to each one of the two filter arms with the smaller dissipation. At this peak frequency the dissipative lattice filter is then again equivalent to a balanced bridge, as it would be without dissipation.

On a similar basis the insertion loss at an attenuation peak of a dissipative ladder filter may be increased by transforming an appropriate part of the filter, containing the peak producing resonant circuit, into the equivalent of a balanced bridge. As in the case of lattice filters the balancing effect is achieved by inserting a resistance in the filter circuit.

11.5.1. Increasing the Peak Loss of a Dissipative T-section. A T-section will be considered consisting of two series branches with the reactive impedances jX_1 and jX_2 (dissipationless) and of a dissipative resonant circuit as shunt branch with the inductance L, the capacity C, and the resistance r_d as the equivalent of the resistive resonant impedance of the shunt branch. r_d may be expressed in terms of the effective Q-factor, Q_{lc}, of the resonant circuit and its characteristic reactance, X_o, as in Eq. (11.14).

By adding to this T-section a bridging branch consisting of the resistance R_b (see Fig. 13) the section becomes the equivalent of a balanced bridge at a frequency close to the resonant frequency f_∞, of the shunt branch provided that the following conditions are met:

$$\text{(i)}\ R_b = Q_{lc} \frac{X_1 X_2}{X_o (1 + x^2)} \quad (11.27)$$

with $X_o = \sqrt{\frac{L}{C}}$

$$\text{(ii)}\ Q_{lc} \geqslant 2X_o \left| \frac{X_1 + X_2}{X_1 X_2} \right| \quad (11.28)$$

The frequency of balance, f_b, where Eq. (11.27) is fulfilled is the actual insertion loss peak frequency of the bridged T-section. The parameter x in this equation is a measure of the deviation of the peak frequency from the resonant frequency, f_∞, and of the quality of the resonant circuit:

$$x = Q_{lc} (\eta - 1/\eta) \quad \ldots \ldots \ldots (11.29)$$

where $\eta = f_b/f_\infty$

x can be calculated from the relation:

$$x + 1/x = \frac{Q_{lc}}{X_o} \frac{X_1 X_2}{X_1 + X_2} \quad (11.30)$$

From the two values of x (reciprocal to one another) resulting from Eq. (11.30) the one with the smaller magnitude should be taken in order to get a large value of the bridging resistance, R_b, and consequently small energy losses in it. Also the deviation of the peak frequency from f_∞ will then be small.

If the magnitude of the expression in Eq. (11.30) is large, the square of the smaller one of the two values of x may be neglected in Eq. (11.27) and the bridging resistance is approximately:

$$R_b \doteqdot Q_{lc} \frac{X_1 X_2}{X_o} \quad \ldots \ldots \ldots (11.31)$$

The condition of Eq. (11.28) indicates that there is a lower limit of the effective Q-factor of the resonant circuit below which no complete balance can be achieved. It also shows that this limit is low for a small ratio of the characteristic reactance X_o to a parallel combination of the series arm reactances, X_1 and X_2. These reactances should therefore be large. At the peak frequency they must be of the same type, i.e., either both inductive or both capacitive, because otherwise the bridging resistance would have to be negative for balance.

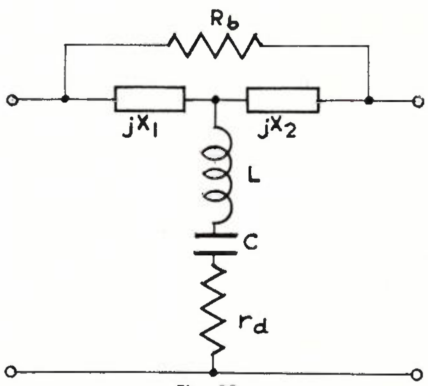

Fig. 13.

When this method of raising the insertion loss at an attenuation peak is applied to a composite ladder filter, the bridging resistance is circuited across the combined series branches of the m-derived T-section with the attenuation peak concerned and of the two neighbouring T-sections (if any) in the filter circuit.

The method can also be used if the shunt branch consists of two series resonant circuits in parallel producing two attenuation peaks at two different frequencies, such as in certain band-pass and band-stop filter sections. In general, perfect balance can be obtained only for one of the two peaks unless the two resonant circuits are adjusted for equivalent dissipation. It may, however, without such an adjustment be quite satisfactory to give the bridging resistance a value which raises the two peaks to equal level.

The method cannot be applied if the shunt branch (with one or two series resonant circuits) is right at the end of a filter circuit and therefore one of the required series branches is missing.

11.5.2. Increasing the Peak Loss of a Dissipative π-Section. The basic principle used for raising the insertion loss at attenuation peaks of dissipative, m-derived T-sections can also be applied in an analogous way to dissipative, m-derived π-sections.

The transformation into the equivalent of a balanced bridge may here be accomplished by adding a common resistance, r_c, to the shunt branches of the π-section where they normally are connected to the base lead (see Fig. 14).

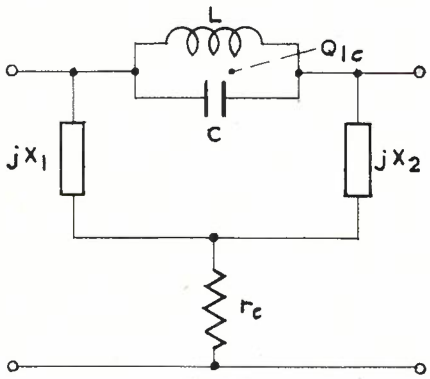

Fig. 14.

With jX_1 and jX_2 being the reactive impedances of the two shunt branches, and L, C, and Q_{1c} being the inductance, capacity and effective Q-factor of the peak producing parallel resonant circuit in the series branch of the π-section, the conditions for perfect balance are:

$$\text{(i)}\quad r_c = \frac{X_1 X_2}{Q_{1c} X_o}(1 + x^2) \quad \ldots\ldots \quad (11.32)$$

$$\text{with } X_o = \sqrt{\frac{L}{C}}$$

$$\text{(ii)}\quad Q_{1c} \geqslant 2\frac{|X_1 + X_2|}{X_o} \quad \ldots\ldots \quad (11.33)$$

The parameter x again gives a measure for the deviation of the peak frequency (i.e. the frequency of balance) from the resonant frequency of the parallel resonant circuit and is defined as in Eq. (11.29). It may be calculated by solving the following equation:

$$x + 1/x = Q_{1c}\frac{X_o}{X_1 + X_2} \quad \ldots\ldots \quad (11.34)$$

The same principal considerations apply as previously mentioned for the dissipative T-section. The value of x with the smaller magnitude should be chosen when Eq. (11.34) is solved and, if it is small enough, it may be neglected in Eq. (11.32). A lower limit of the Q-factor for perfect balance is given by Eq. (11.33) which shows that this limit is low if the ratio of the sum of the shunt arm reactances to the characteristic reactance of the resonant circuit is small. The shunt arm reactances should therefore be small for safe attainment of balance. They must have the same sign so that Eq. (11.32) yields a positive value for the common resistance r_c.

The method cannot be used if the parallel resonant circuit is right at the end of a filter circuit. There is, however, another method which is always applicable to a parallel resonant circuit in the series branch of a filter and which is not limited by the magnitude of the Q-factor. In this method the inductor of the parallel resonant circuit is (approximately) centre-tapped and a resistance, R_s, is connected between the centre tap and the base lead of the filter as shown in Fig. 15. (Though this is a special case of the method, it is the only one with practical importance.) By means of Bartlett's bisection theorem it can be shown that very close to the resonant frequency this circuit is the equivalent of a balanced bridge if the following condition is fulfilled.

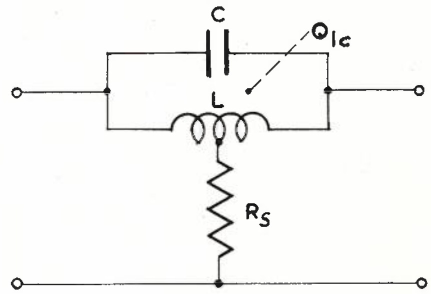

Fig. 15.

$$R_s = \tfrac{1}{4}\, Q_{1c} X_o \quad \ldots\ldots\ldots\ldots \quad (11.35)$$

where Q_{1c} is the effective Q-factor of the resonant circuit and X_o is its characteristic reactance as defined by Eq. (11.15).

In all these methods of increasing the insertion loss at attenuation peaks of dissipative ladder filters the peak loss can theoretically be lifted to infinite value if a complete balance is at all possible. In practice the value is limited by the accuracy with which the condition of balance can be maintained over a length of time. As it is in most cases only necessary to raise the peaks at least 6 db above the level of the specified minimum insertion loss in the vicinity of the peaks, the required accuracy of balance is not very great and can be maintained without difficulty.

BOOK REVIEW

WORKSHOP ENGINEERING PRACTICE, VOLUME 1, FITTING.

H. G. Rider, 1959, Iliffe and Sons Ltd., London, pp. 150, Australian price 15/9.

Our copy from: Technical Book and Magazine Co. Pty. Ltd., 295-299 Swanston Street, Melbourne.

Chapter Headings: Introduction to Fitting—Saws and Shears—Files and Filing—Scrapers and Scraping—Cutting Screw Thread and Reaming Holes—Measuring Instruments — Marking Out — Drilling Machine—Practical Exercise in Fitting—Safety in the Workshop.

This is the first of a series of books on aspects of workshop engineering intended for those taking this subject at Secondary, Modern and Junior Technical Schools in the U.K. and at examinations of the City and Guilds of London Institute. The author is Chief Instructor in Workshop Engineering at the Borough Polytechnic, London.

The book deals essentially with the care and use of the various tools and measuring instruments used in fitting but one chapter is devoted to a practical exercise, namely, the making of a simple gauge from ¼" thick black mild steel plate. The book is written in simple, direct English and contains more than 400 drawings. The drawings are clear but are crowded together in some instances.

The quality of paper, printing and linen cover is adequate for a book of this type. The four page index is very clear and easy to use.

The book uses standard terminology and would be a good reference book for instructors in metal work in Australian technical and trade schools.—A. N. BIRRELL, B.E., A.M.I.E.Aust.

CONTROLLED FIELD TESTING OF DRIP POINT CORROSION

*V. J. WHITE, B.A.(Hons.), B.Sc., A.M.I.E.Aust., M.Br.Ps.S.**

INTRODUCTION

In the post-war period there has been rapid technological development leading to the introduction of many new materials and methods. The large number of new items being introduced and the need for accurate observation of their behaviour in the field severely strained the existing system whereby small trial purchases of new items were made and sent to all States for installation and report. Defects in the system were:

(i) The formal lines of communication between the Central Office Engineer and the Field Engineer who installed the new item were so long and allowed so much filtering and interpretation of field observations that accurate and detailed data on plant performance was difficult to obtain in Central Office.

(ii) The Central Office Engineer had very little control over the selection of areas in which the new items were installed and instructions about points to watch whilst installing the new items often failed to get through to the installing staff.

(iii) No specific action was taken in most cases to clearly label test installations and often maintenance staff unwittingly interfered with test installations.

(iv) The large number of new items coming forward increased the amount of paper work involved in field testing and placed an unnecessarily large administrative burden on Field Engineers generally.

In 1957, in order to overcome these problems and permit of more accurate and better controlled field testing of external plant materials and methods, a System of Controlled Field Tests was introduced. This paper describes this system and gives a detailed report on one project which is of interest in itself as well as being a good example of how the Controlled Field Test System works.

THE CONTROLLED FIELD TEST SYSTEM

The controlled Field Test System provides for a suitable selection and variety of test areas, accurate recording and reporting of observations on test items and direct communication between the Headquarters Design Engineer and Field Engineers in Test Divisions.

Selection of Test Areas

Eleven Lines Divisions scattered through the Eastern States were selected as Field Test Divisions. In selecting these Divisions the following criteria were used:—

Climate. The Field Test Divisions have to be representative of the various types of climate which prevail in Australia. Monthly rainfall averages, mean maximum and minimum temperatures and mean relative humidities of various centres were examined before selecting Test Divisions. Graphs showing these figures for some of Field Test Divisions are shown in Figs. 1, 2, 3 and 4.

Local Environment. A wide variety of typical environments such as coastal areas, inland areas, industrial exposures as well as a large range of soil conditions were necessary in the Test Divisions. In selecting the Divisions a balance between Metropolitan and Country areas was aimed at.

Animals and Insects. By selecting areas widely scattered through the eastern States it was expected to obtain exposure to a wide variety of ants, termites, rodents, birds, etc.

After considerable research the following Divisions were selected:

Queensland: Cairns, Rockhampton and a Brisbane Metropolitan Division.

New South Wales: Newcastle, Wollongong, Wagga and a Sydney Metropolitan Division.

Victoria: Mildura, Frankston, Dandenong and a Melbourne Metropolitan Division.

Fig. 5 shows the location of these areas in relation to broad climatic zones.

General Procedure

To install a new item in test areas under the Controlled Field Trial System, the Central Office Engineer takes the following steps:—

(i) Orders Material Required. This is usually done through the normal purchasing procedure. The contracts are endorsed to provide for delivery of the items to the special test divisions and special labels are provided to the supplier so that there is little possibility of the material going astray.

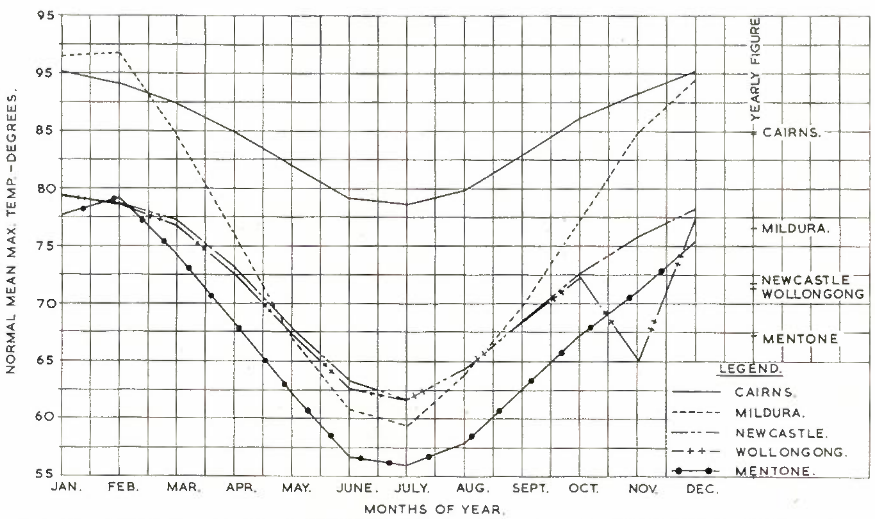

Fig. 1.—Normal monthly mean maximum temperatures for some of the Test Divisions (N.B.—Mentone is in the Frankston Division).

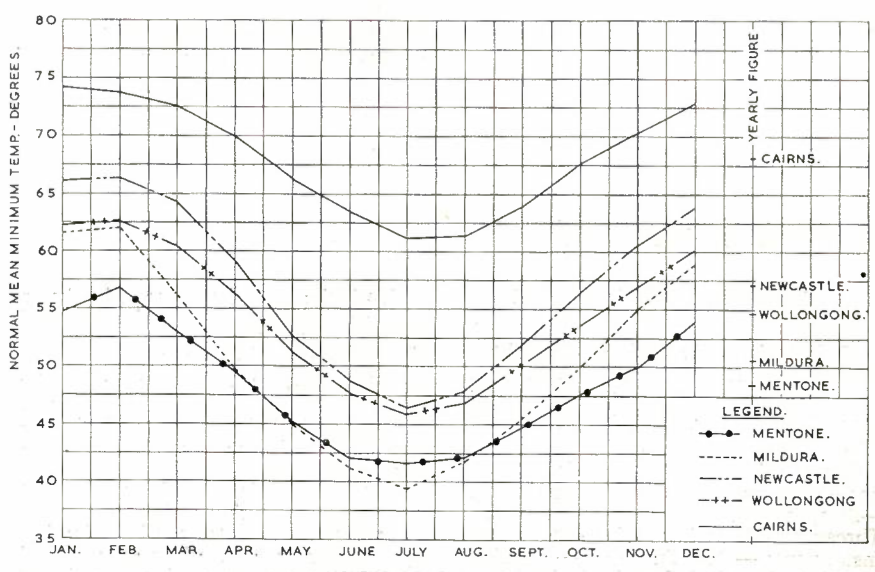

Fig. 2.—Normal monthly mean minimum temperatures for some of the Test Divisions.

*See page 299, Vol. 12, No. 4.

(ii) **Prepares Project Notes.** These notes give a summary of the developments leading to the production of the new item and detail the procedure to be followed to instal the test items. They also tell what observations are to be made, what frequency of observation is required and specify how the information will be recorded. Advice is also given of the action necessary in the Test Division to secure the test material.

(iii) **Sends Project Notes to Test Divisions.** When the material is about to be delivered from the Manufacturer the C.O. Engineer sends a copy of the project notes direct to the Divisional Engineer in each Test Division and sends copies to the Assistant Director Engineering for the information of the Supervising Engineers and the Training Section. This helps to keep the Linemen's Training Schools informed on new developments and in some cases, gives them the opportunity of making their own trials of the new methods.

On receipt of the project notes and the test material the Divisional Engineer proceeds at once to instal the test items in the selected test areas. The test material is installed as part of the normal installation work of the Division thus ensuring that it is exposed to normal installation procedures and conditions. Care is taken to permanently label all test installations in an appropriate manner to avoid unscheduled interference with the test.

Channel of Communication

An important aspect is the provision made for direct personal contact between the Central Office Engineer who designed the new item and the Field Engineer who is responsible for the test installation and the recording of the field observations. The C.O. Engineer maintains close contact with the Field Engineer throughout the test. Reports summarising field observations are sent direct from the Field Engineer to the C.O. Engineer at specified periods, and the C.O. Engineer makes regular visits to the Test Divisions to make his own direct observations, so that accurate transmission of detailed technical data proceeds as smoothly as possible.

Recording of Information

Divisional Engineers in Test Divisions normally allocate the field tests to a Group Engineer who keeps a diary in which the tests are recorded. The actual data recorded varies somewhat for each test, but includes the following:—

Field Test No.
Title
Date Installed
Location
Observations.

The frequency of observations and the specific points to be noted are specified in the Project Notes.

Current Projects

Some of the tests currently in progress in Field Test Divisions are described briefly hereunder:

P.V.C. Covered Aerial Wires. The behaviour of P.V.C. as an insulant for outdoor wires is being checked in Test Divisions. Various types of P.V.C. covered wires have been erected in test areas and long term observations of the condition of the P.V.C. are being made.

Polythene Covered Aerial Wire. This is a parallel test to the previous one and is to test the relative performance of polythene as an insulant for outdoor wires.

Integral Bearer Drop-Wire. Various designs of drop-wire of the type in which a steel bearer and two copper conductors are covered by the one integral covering of insulant are being tested, the prime purpose being to arrive at the most economical design in terms of bearer wire size and copper content.

Two-pair Buried Wire. A 2-pair buried wire is under test to see if it can be used in place of 2-pair plastic cable for subscribers' lead-ins.

Two-pair Drop Wire. Two designs of two-pair drop-wire are under test to ascertain which design is preferable and to assess the field of use of a 2-pair drop-wire as compared to the use of multiple runs of single pair drop wire.

Long Distance Telephone. A Research Laboratory designed telephone for use over long lines is under test in one Field Test Division.

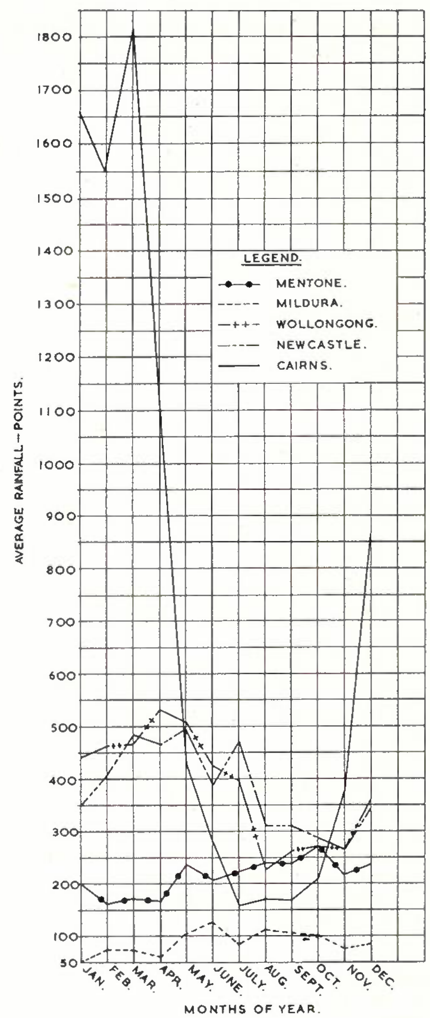

Fig. 4.—Average monthly rainfall for some of the Test Divisions.

Wooden Jointing Pits. Pressure treated pine wood jointing pits are under test in all Test Divisions to establish the suitability of this type of pit, particularly for country areas where transport and storage requirements favour a wooden pit assembled on the job.

Modified 40-lb. Press Type Jointing Clamp. The 40-lb. Jointing Clamp for press type sleeve joints on open wires has been modified to provide a means of using the clamp to cut 40-lb. wires, and prototypes are under trial in Test Divisions.

Aluminium Subscribers' Spindles. An aluminium spindle designed to replace steel spindles has been installed in all Test Divisions to gather installation experience and long term behaviour characteristics.

Plastic Pits. Jointing pits made from rigid P.V.C. are under test in all Test Divisions to determine how this economically produced pit behaves under field conditions.

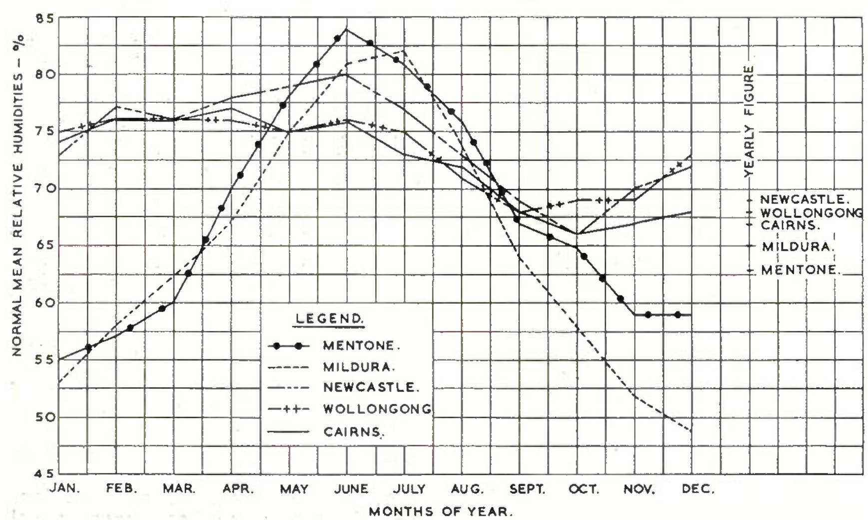

Fig. 3.—Normal monthly mean relative humidities for some of the Test Divisions.

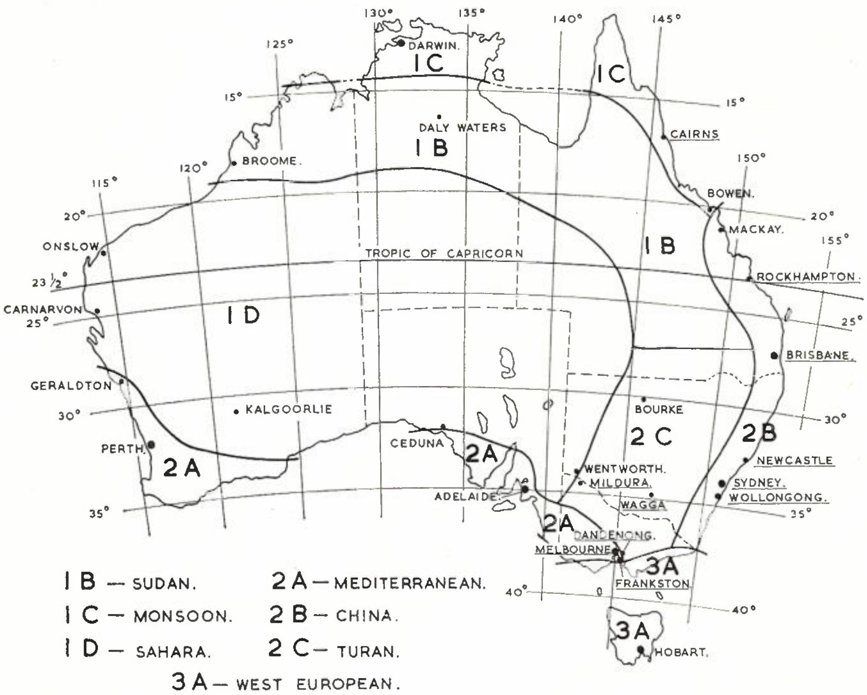

Fig. 5.—Location of the Headquarters (underlined) of each Field Trial Division in relation to the broad climatic regions of Australia.

THE DRIP POINT CORROSION FIELD TRIAL

The following detailed description of Field Trial No. 1, the first in the new system is a typical example of how alternative methods and materials are given a controlled field trial.

Description of Problem

For some years now trouble has been experienced at the point of connection of the bridle wire to the line wire, particularly in C.B. or auto areas where the terminations are exposed to moist air conditions. Films of moisture on the insulation provide paths for leakage currents between wires of a pair or to earth causing corrosion of the bridle wire conductor at positive potential, the corrosion occurring at the point where the bared wire emerges from the insulation. (See Fig. 6.)

Experience indicated that the problem was not likely to be solved by attempting to seal over the bared bridle wire after the drip point connection has been made. Most sealing compounds which were suitable for field application broke down under the influence of sunlight and rain. Early attempts at overcoming this trouble indicated that the most promising method was the use of guard wires which were interposed between the point of failure of the bridle wire and the source of the leakage currents and which acted as sacrificial anodes.

Reports received from the field on the one hand and from research laboratories on the other indicated a divergence of opinion as to which metal was the best to use for guard wires. Also there were some specially bad areas where corrosion appeared to proceed so rapidly that the guard wires were failing from 6 to 12 months after installation.

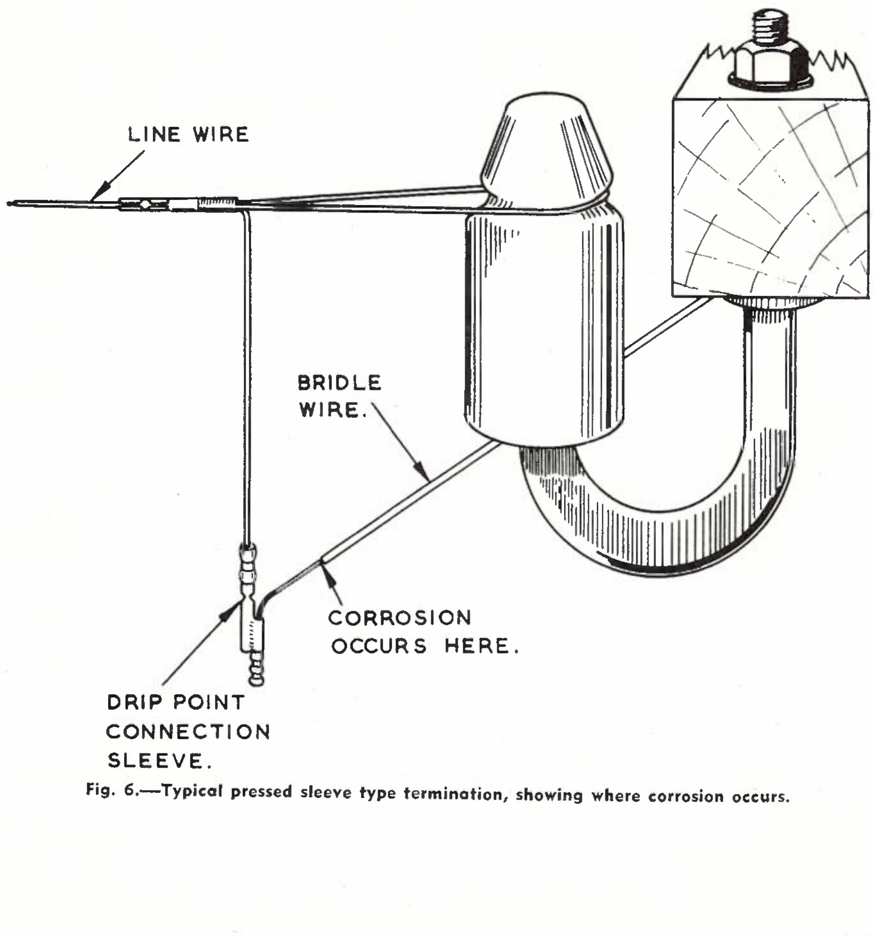

Fig. 6.—Typical pressed sleeve type termination, showing where corrosion occurs.

Purpose of Trial

In February, 1957 a field trial on methods of combating drip point corrosion was launched. There had been previous attempts to set up test poles at various locations, but these had not been satisfactory because often the terminations were replaced without informing the Central Office Engineer. Under the newly established Controlled Field Trial Procedure it was expected that accurate information would be obtained.

Specific points on which information was required were:—

(i) How long does an unguarded termination last in the various areas?
(ii) What is the most suitable material to use as a guard wire?
(ii) What is the best way to fit the guard wire?
(iv) What is the best special measure to adopt for those areas where the guard wire fails prematurely?

Procedure Adopted

In all Field Trial Divisions one terminal pole was set up as follows:—

Arm	Pair	Material	Method (See Fig. 7)
1	1.1-1.2	Soft copper	Method A
	1.3-1.4	Monel metal	Method A
	1.5-1.6	Nichrome wire	Method A
	1.7-1.8	Soft copper	Method A
	1.9-1.10	Monel metal	Method B
2	2.1-2.2	Nichrome wire	Method B
	2.3-2.4	Soft copper	Method C
	2.5-2.6	Monel metal	Method C
	2.7-2.8	Nichrome wire	Method C
	2.9-2.10	No guard wire fitted	Control pair

In this way the three different materials—monel metal, nichrome and soft copper and three different methods of winding it around the bridle wire insulation were tested. In addition, an unguarded control pair was installed on each pole.

At selected areas where conditions were known to be bad, three special methods of prolonging the life of drip point connection were tested. The areas selected were:—

Port Noarlunga, South Australia
Wollongong, New South Wales
The Entrance, New South Wales
Dee Why, New South Wales

Port Noarlunga and Dee Why are not normally in the Field Trial System but were selected on this occasion because experience showed that conditions in these areas promoted rapid drip point corrosion. The methods tested at these places were:—

(i) **Hood Insulator.** This was a small porcelain insulator which was a close fit over the bridle wire and which was intended to shelter the point where corrosion normally occurs (see Fig. 8).

(ii) **Modified Guard Wire.** By increasing the amount of guard wire in the circuit and by distributing the effects of the corroding currents over as large an area as possible it was hoped to develop a guard wire technique which would give adequate protection in these special areas (see Fig. 9).

metal to corrode away before the bridle wire is exposed to the corroding circuit (see Fig. 10).

Results:

(i) **Life of Unguarded Termination.** Prior to this trial it had been claimed that in certain areas an unguarded termination had a life of only six weeks. The shortest life found in this trial was one of seven months at Port Noarlunga, South Australia. The next shortest was at Wollongong, New South Wales, where a control pair failed after 1½ years' service.

One reason established for the previous claims of a very short life is the impression held by some that a guard wire had failed when corrosion of it commenced. A guard wire is expected to corrode and only fails when it has been completely corroded away.

At Newcastle, New South Wales, an unguarded 20 lb. bridle wire termination failed in less than 3 months. This result is interesting, particularly in view of the proposed introduction of 20 lb. wire as the standard for terminating subscribers' wires.

In dry inland areas unguarded terminations show very slight evidence of corrosion and should last indefinitely.

(ii) **Best Material.** All guarded terminations at all test poles lasted the full period of the test. There was some indication that monel metal and nichrome wires were standing up better than the soft copper guards. However, this is probably due to the fact that the corrosion product of a copper wire is a bright green and very obvious, whilst that from the two other materials is a dull white and is more difficult to observe. Research Laboratory Tests (See R.L. Report No. 4981) confirm that there is very little difference in the action of the three materials. Copper guard wires have the advantage that no special wire has to be stocked and the soft copper is easier to fit than

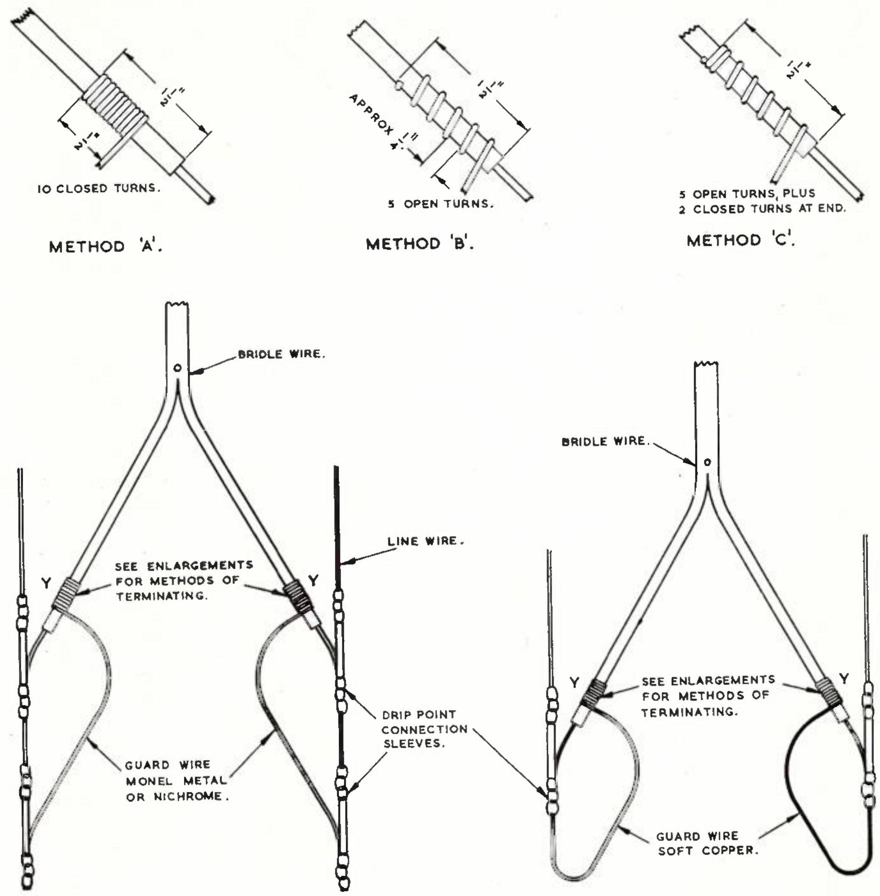

Fig. 7.—The three methods tested in the Drip Point Corrosion Field Trial. (N.B.—It is general practice to guard both + ve and – ve wires, to save identifying the + ve leg and to provide against reversals.) Distance yOy was made the same for each pair of wires in the Test.

the harder monel metal or nichrome wires. It has been decided, therefore, to standardise on soft copper as the material for all guard wires and no further purchases of monel metal are proposed.

(iii) **Best Method.** Although not conclusive the test has shown that 10 close turns as prescribed at present are not as effective as five open turns. The close turns tend to act as one unit, whilst the open turns have to be broken down individually. It is therefore, proposed to adopt five open turns followed by two close turns as the standard method. The close turns are added to ensure a tight termination to the guard wire.

(iv) **Special Measures.**

(a) **Hood Insulators.** Several failures occurred after 12-18 months' service whilst a standard soft copper guard wire on the same pole erected at the same time, though badly corroded, were still intact. It was definitely established therefore that the hood insulators were ineffective. It was claimed that the hood insulator would work by keeping the point of corrosion dry. In actual fact by sheltering it from the washing effect of heavy rain it only succeeded, if anything, in allowing a salt layer to be formed more rapidly.

(b) **Modified Guard Wire.** As was expected the guard wires showed evidence of corrosion. It was thought that the modified method of fitting the guard wire would distribute the corroding effects

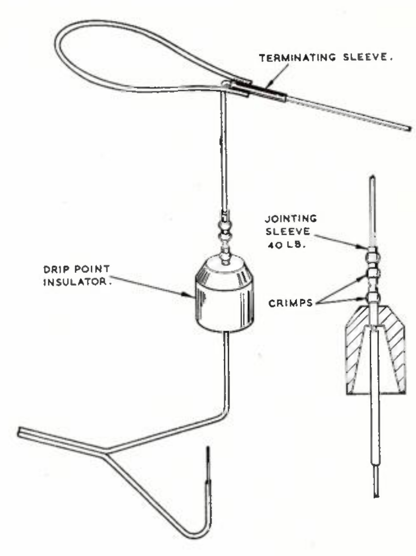

Fig. 8.—The Drip Point (or Hood) Insulator method of combating corrosion.

over a large area of copper wire including the line wire, and that this would delay its attack on the critical point of the bridle wire. The test was not continued long enough to establish this, but there are indications that this method of fitting allows pockets of moisture to exist which would accelerate the corrosion.

(c) **300 lb. Jointing Sleeves.** After nearly two years' service in this trial the 300 lb. sleeve showed considerable corrosion, but most of the sleeve (well over 95%) was still intact so that it would be several years before it was all corroded away. This idea originated in South Australia where an original installation installed in 1954 is still intact.
It has been decided to adopt the 300 lb. sleeve termination as the standard method for combating corrosion in those areas where inadequate protection is obtained from a guard wire.

General Information

It was found in one Division that when drip points on drop wire lead-ins were protected by guard wires corroding currents caused trouble at the house ends of the leads and these had to be protected also. A further point is that as the life of the drip point connection is increased it is expected that in some areas the line wire termination will eventually fail, due to corroding currents which occur over the surface of the line insulators, spindles and cross-arms.

Summary of Conclusions:

(i) The standard method of protecting drip point connections in "normal" areas will in future be by extension of the soft copper bridle wire terminated on the bridle wire insulation by five open turns followed by two closed turns.

(ii) No further purchases of monel metal will be made.

(iii) In specially corrosive areas a 300 lb. jointing sleeve is the recommended method of preventing corrosion.

(iv) Although not included in the trial, information recently received indicates that the life of a drip point connection may be prolonged by coating the termination with a special grease containing powdered copper similar to "Kopra-Kote". This grease may be applied over any additional guard wires or sleeves fitted as sacrificial elements as well as over an unguarded termination. However, its ability to remain on the wire over a long period has not yet been definitely established.

CONCLUSION

The controlled Field Trial system for external plant and materials and its application to the problem of drip point corrosion has been described. The new system overcomes difficulties met when organization growth and rate of technological change cause a break down in the formal methods of communication.

The new system has proved very effective and a method of accurate transmission of technical data from field test to the Design Engineer has definitely been established. In addition to the successful conclusion of the Drip Point Corrosion problem, trials on 20 lb. bridle wire and 6½ lb. drop wire have been successfully completed. These trials proved on the one hand that 20 lb. bridle wire is adequate and that savings compared to the old 31 lb. wire could be safely made, but indicated on the other hand that 6½ lb. drop wire was too light and should not be adopted.

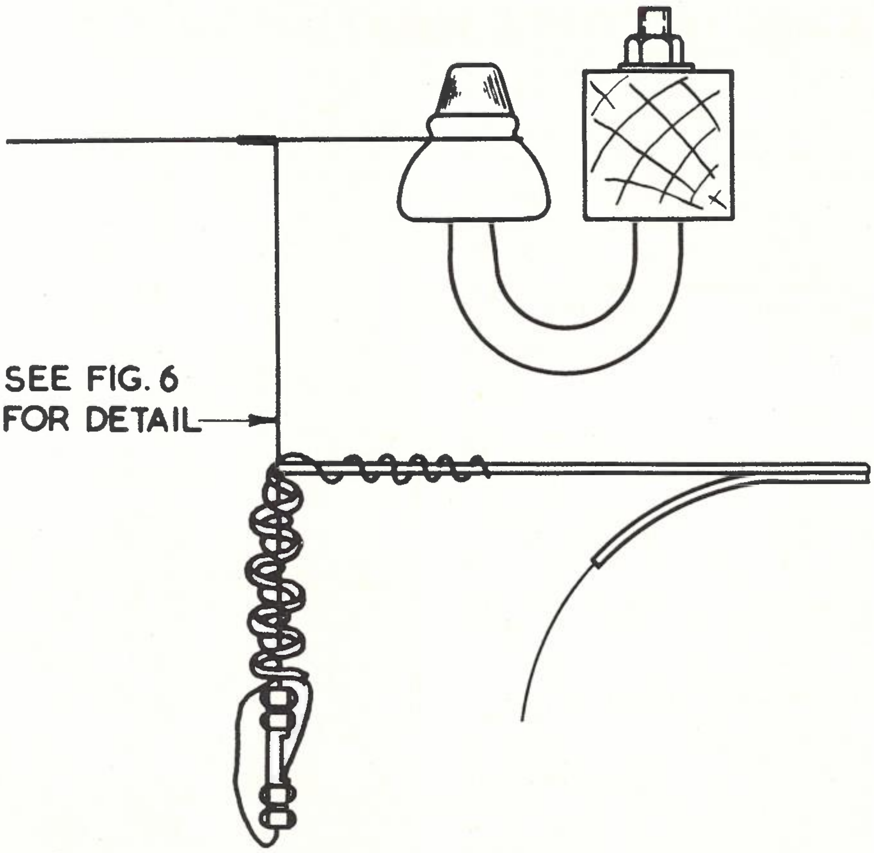

Fig. 9.—Modified Guard Wire method. This method was also used to terminate 6½ lb. wires in another trial and is a suitable method of providing a mechanically strong termination for small wires. The procedure is to twist the covered wire around the line wire, terminate in the drip point sleeve and then wind surplus bare wire back over the twisted covered wire on the line wire, finally terminating on the bridle wire insulation in typical guard wire fashion.

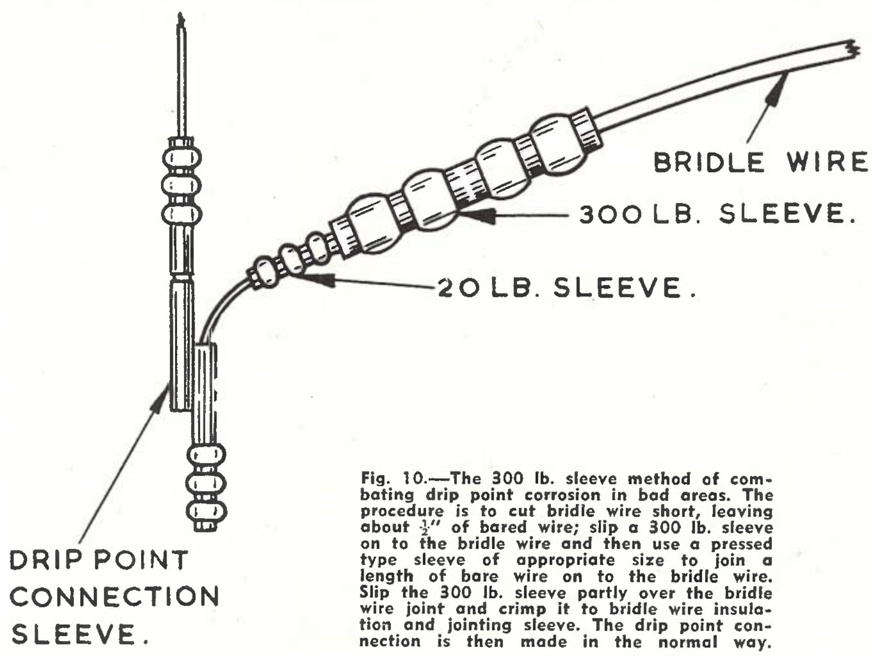

Fig. 10.—The 300 lb. sleeve method of combating drip point corrosion in bad areas. The procedure is to cut bridle wire short, leaving about ½" of bared wire; slip a 300 lb. sleeve on to the bridle wire and then use a pressed type sleeve of appropriate size to join a length of bare wire on to the bridle wire. Slip the 300 lb. sleeve partly over the bridle wire joint and crimp it to bridle wire insulation and jointing sleeve. The drip point connection is then made in the normal way.

A C.B. MULTIPLE P.B.X.

*A. B. WILSON**

When a telephone subscriber requires the installation of a multiple P.B.X. the standard practice has been:

- to modify a country type multiple C.B. switchboard suite;
- to design and have manufactured the special exchange line relay sets, and
- to procure a special relay rack.

This procedure has a number of disadvantages:

- Country type multiple C.B. switchboards are not always readily available;
- labour and material expenditure on the project is quite high, and
- a large amount of room space is required to accommodate the equipment.

When a Sydney subscriber requested the installation of a three position multiple C.B. P.B.X. suite, the possibility of fitting a multiple unit to the centre position of a three position suite, using 80 line A.P.O. lamp signalling switchboards, was considered.

CONSTRUCTION

The multiple unit was assembled from 16 SWG mild steel and designed to ensure that the top and bottom frames are similar to and matched the P.B.X. and the P.B.X. cover. This allowed the fitting of the unit to the top of the centre P.B.X. with nuts, bolts and washers, and the use of the existing P.B.X. cover for the top of the unit. This method of attaching the multiple unit requires no structural alterations to be made to the P.B.X. carcase, which can thus be restored to normal working at a small cost.

Fig. 1 shows the multiple unit fitted with drilled metal strips for the attachment of the multiple jack strips. Four terminal blocks (Block No. 31 29/27) were mounted in the unit and inclined at an angle of 30 deg. from the horizontal. This permits easy access to the terminal blocks for installation and maintenance purposes. Full constructional details are given in drawing number N-B 7137.

Fig. 2 shows a multiple unit fitted to the centre position of a three position P.B.X. suite.

ENGAGED TEST

With reference to Fig. 3, a description of the engaged test is as follows:—

Extension to Extension Call. — The Operator answers the calling extension with the **rear cord** and tests for busy on the required extension Jack; if this extension is engaged, then the negative battery via 300 ohm resistor YB, charges condenser QA, and as the Operator's circuit is coupled to QA, she receives a most distinct click in her receiver circuit. The test is effective with either front or rear cords.

Exchange to Extension Call.—The procedure is similar to that on extension to extension calls, but to ensure that the B relay does not operate on the engaged test and so disconnect the exchange line call, a 100 ohm resistor YT is connected in parallel with the 200 ohm earth winding of B relay via a break spring set B4; YT prevents relay B from operating on the earth winding. This modification of the B relay operate circuit already exists on earlier P.B.X. circuits in order to prevent B relay from operating to battery via the extension call lamp, when plugging into the extension Jack. Springset B4 is therefore in situ in the cord circuit relay sets.

On extension to extension calls, B relay operates on the 200 ohm battery winding and B4 operated removes the 100 ohm shunt from the earth winding.

POSSIBLE APPLICATION

By fitting a multiple unit to each P.B.X. a four position multiple suite could be provided. The capacity of such a suite would be 320 extension lines, 60 exchange lines and 12 tie lines. An installation of this capacity has been carried out at the New England University.

CONCLUSION

In certain circumstances a P.B.X. provides a subscriber's telephone requirements more efficiently than would a P.A.B.X. Some examples are:—

(a) A business with a high volume of

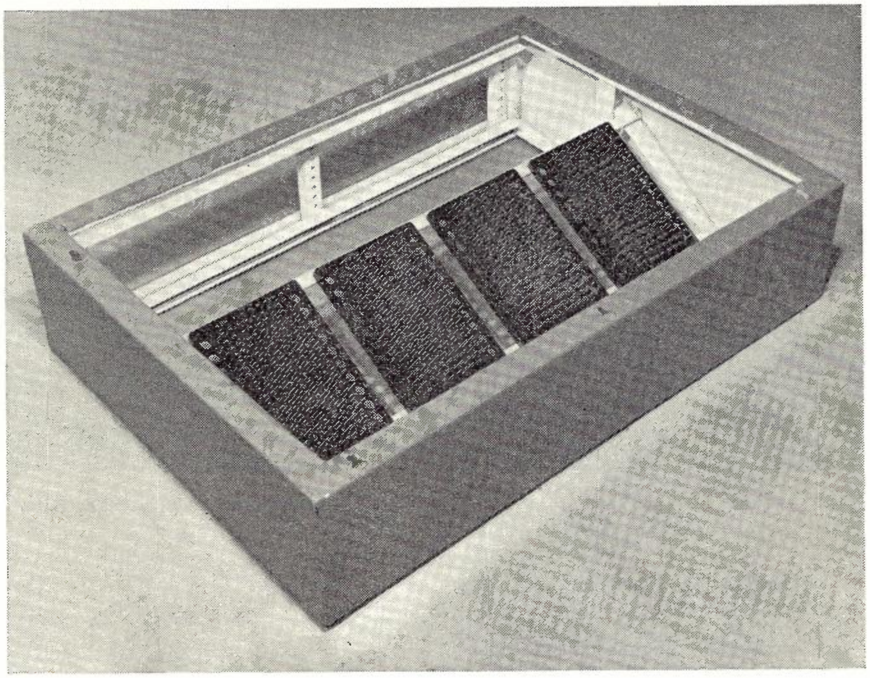

Fig. 1.—Multiple Unit.

MULTIPLE WIRING DETAILS

With reference to Fig. 4, from the multiple Jacks to the local Jacks a six-wire termination is required, five of these wires being accommodated on the terminal blocks mounted in the unit, the sixth wire being extended from the local Jack to the multiple Jack and commons both Jack sleeves. Only two wires for the local Jack are required, one from the sleeve and one from the auxiliary spring No. 7. This allows the sleeve battery on the local Jack to also provide engaged test battery on the multiple Jack, the extension being extended to the local Jack via the normal terminating block.

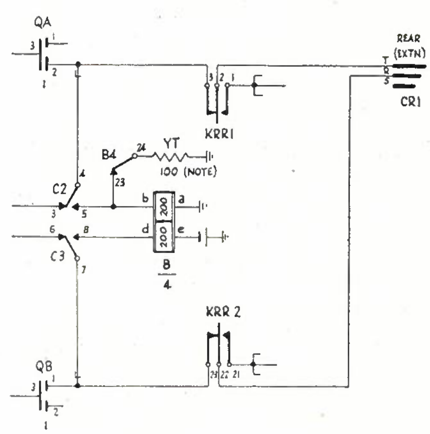

Fig. 3.—Modifications for Engaged Test.

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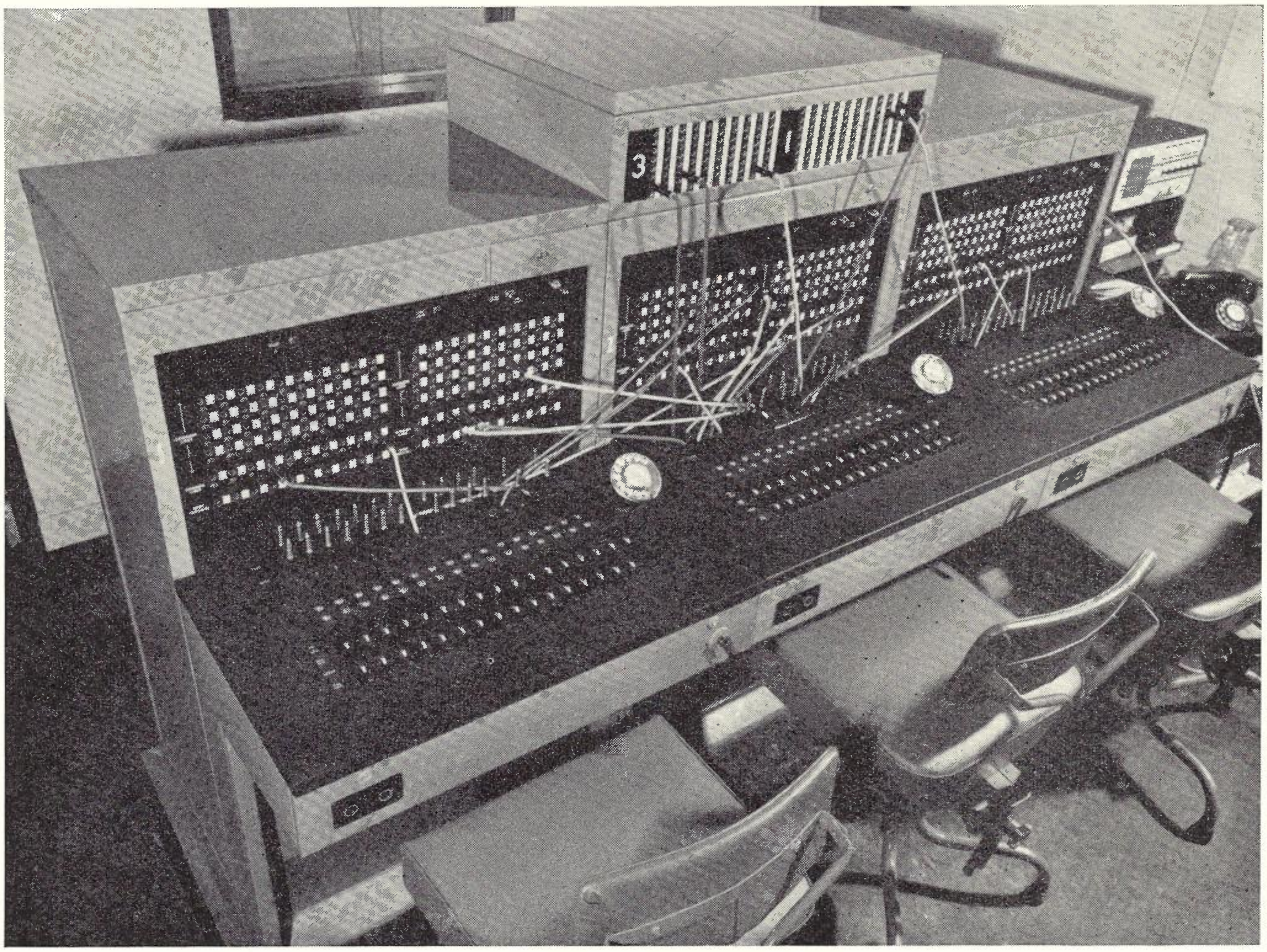


Fig. 2.—An Installed Multiple P.B.X. Suite.

inward telephone traffic and a low volume of outward traffic.

(b) A business with a low volume of interhouse traffic and/or making extensive use of the restricted exchange access facility.

(c) A Tourist hotel where the specialised local knowledge of the P.B.X. Operator is in keen demand.

Normally where the extensions of such subscribers exceed the capacity of a two position P.B.X., it is necessary to adopt transfer working. This requires the undesirable use of double cord switching. A P.B.X. suite fitted with a multiple unit provides an effective and economical solution. It is noteworthy that these advantages are enhanced in that the Lamp Signalling P.B.X. retains the characteristics of trapping follow-on calls, and efficient lamp supervision.

Seven multiple P.B.X. suites of this type have been installed in subscribers' premises. The facilities provided by the suites have proved to be satisfactory, and no doubt there are other locations where a similar arrangement would be the most suitable means of providing the service required by a subscriber.

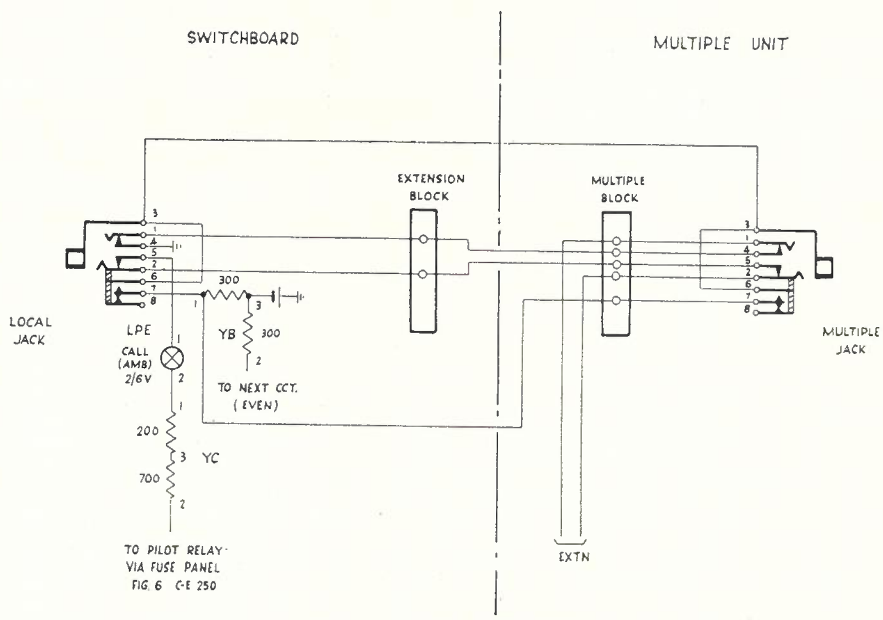


Fig. 4.—Multiple Unit Wiring.

SUBSTATION INSTALLATION MANAGEMENT AND PRACTICES IN THE SYDNEY METROPOLITAN AREA

*M. J. POWER, A.M.I.E.Aust.**

INTRODUCTION

A good deal of the Department's direct contact with the public is by means of the staff engaged in providing service at the subscribers' premises. In a city such as Sydney where many new multi-storey buildings of modern design are being provided, the Substation Installation staff providing block wiring meets a challenge to initiative and intelligence. Extensive redevelopment, involving demolition of old buildings, requires constant attention to ensure that pre-wiring of buildings is done at the most favourable stage and constant co-operation with architects and builders is essential.

The accompanying map of Sydney, (Fig. 1) indicates the location of Substation Installation Depots and Subdepots and the areas controlled by each depot. As will be seen the inner city area is served by three main depots, i.e. Dalley, Central and Haymarket. Other depots are located at Newtown, Lidcombe, East, Coogee, Peakhurst, St. Leonards, North Parramatta, Pennant Hills, South Strathfield, Redfern, Balgowlah and Chatswood. The staff attached to any depot is generally controlled to between about 20 and 40 men as it is considered that most efficient work is performed in this staff range.

SUBSTATION DEPOTS

Locations. Substation depots are located within exchange buildings or in rented premises. Line Depot sites are preferred as co-operation between the external and substation installation staff is important for the smooth and efficient provision of service. With this in mind, future effort will be directed towards pooling internal and external depot features such as stores and perhaps transport, to improve efficiency.

The greater part of the Sydney Substation Installation depots are on exchange premises but generally exchange development will in time force a search for other quarters. The presence of a substation depot in an exchange has some benefit, particularly when relay apparatus requires adjusting and testing before being taken to the subscribers' premises and the exchange facilities can be used to do this. However, this is not a matter of great consequence and exchange premises have been chosen generally because they were available and reasonably appropriate.

Depot Layout. A standard layout for a typical substation depot has been developed and is shown in Fig. 2. It is possible that no such building will be provided in its entirety, but its application has been mainly in its use as a basis for fitting in with space made available. It can be used by Buildings Branch and the Engineering Division, in rapidly checking space and room provision. A depot along the lines of the one illustrated is proposed for Lakemba in Sydney. It is a low cost building which will admirably meet the Substation need in the area and ensure co-operation between external and internal groups in giving service to the public.

Management. The staff attached to a Substation Depot can carry out the work required on a territorial, a functional or a combined territorial-functional basis. In the territorial organisation the depot territory is divided into say three different areas which could probably coincide with exchange areas. A Senior Technician and his staff carry out all work within a single area. In a functional organisation the work over the whole depot area is divided into say new lines with small miscellaneous works, and larger P.B.X. and intercommunication works. Separate staffs service the whole area attending only to the particular class of work allotted to each. Some advantages of a territorial organisation are that—

(a) Travelling is reduced to a minimum, and
(b) Local knowledge of a particular area is more readily acquired by the Senior Technician.

On the other hand, staffing groups can become too inflexible to meet changing load conditions within Senior Technicians' areas and there can be a tendency to do the easy telephone orders first, resulting in a delay in carrying out P.B.X. and intercommunication installations. In the functional control a separate staff concentrates on P.B.X. work without interference.

In practice very good results have been obtained with the combined territorial-functional organisation. In this way all telephone orders requiring four hours or less work within a certain area are allotted to a Technician who drives his own motor vehicle. Sufficient material is taken each day to adequately cover a day's work. In this way the mobile Senior Technician will drive his own vehicle and control a number of

*See page 465.

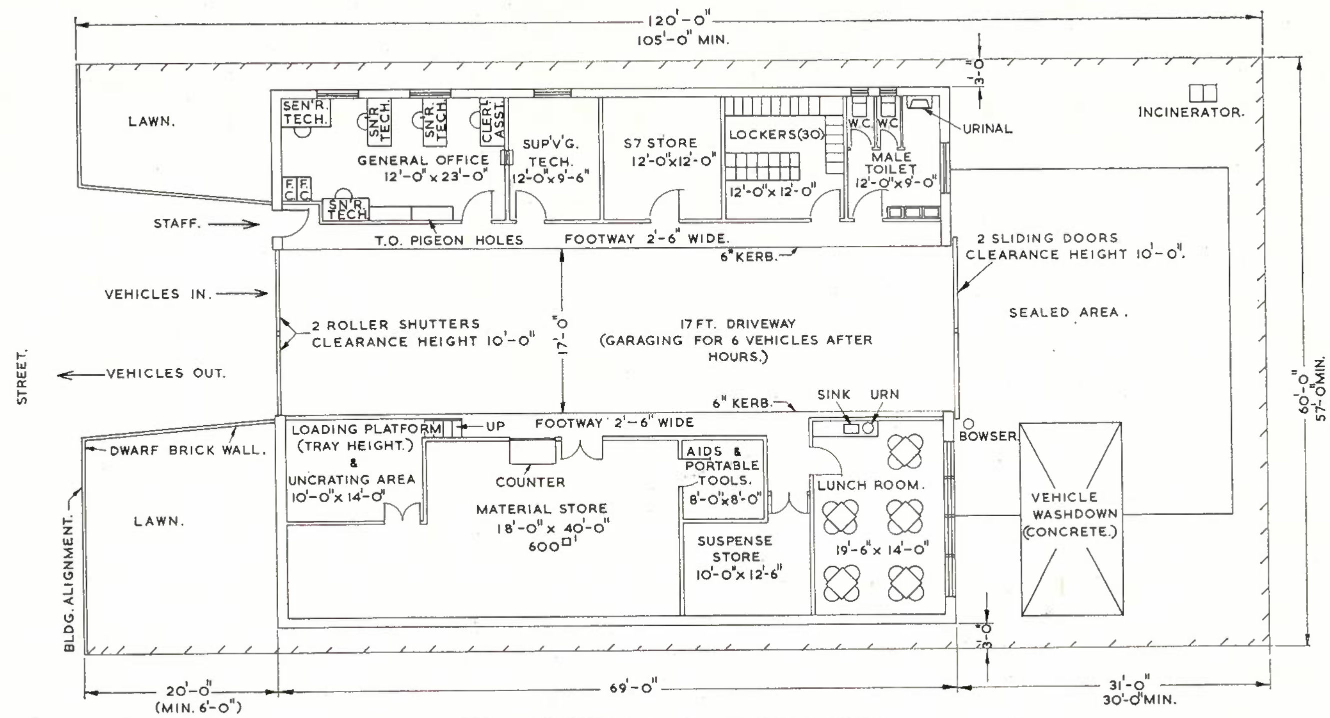


Fig. 2.—Standard layout for substation depots.

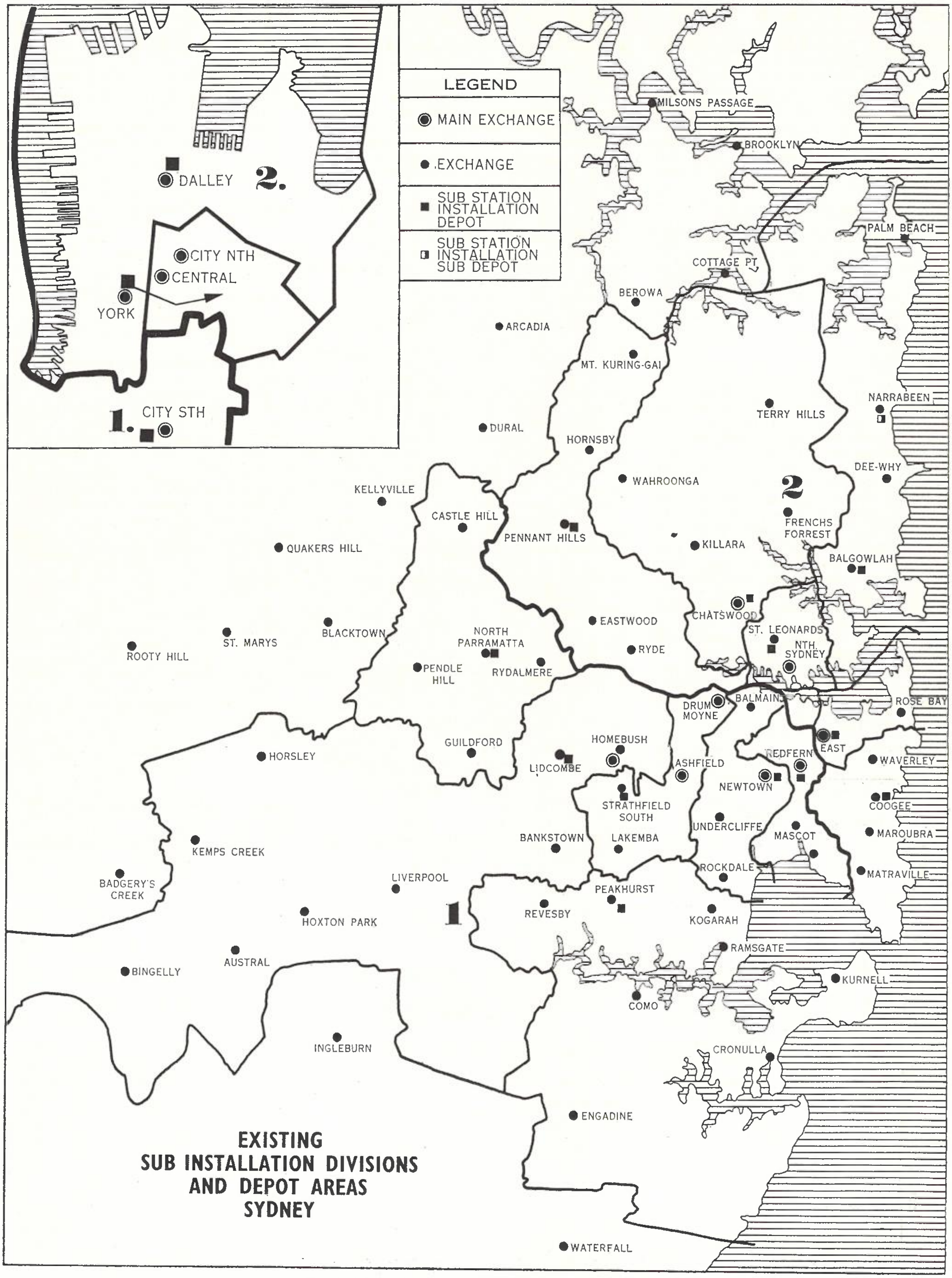


Fig. 1.—Depot location within the metropolitan area.

Technicians each driving their own vehicles. The major portion of the depot transport is thus under the control of the mobile staff as the P.B.X. and A.10 staff require much less transport. This organisation results in swift attention to the short time telephone orders and concentrated effort without interruption on P.B.X.'s and large installations. In this way there is no tendency for the development of an unbalance between long and short jobs.

SUBSTATION STORES

There are fifteen substation installation stores in Sydney—one with each Depot—and continuous effort is made to increase stock turnover speed and reduce stock holdings to the minimum consistent with efficient operation. Schedules of approved items for a store are available, and are adhered to as closely as possible.

Where advantages are apparent, mobile stores with a Technician driver are used and, in the favourable setting, prove very successful. Tools for replacement purposes and loan for specific jobs are also held in store. In this way most effective tool usage is achieved. The issue of large tools to a specific officer and held on that officer's tool kit can result in these tools being out of use for long periods. It has been found that the tool usage time rises when they are pooled and issued for specific tasks only. The number of such expensive tool items is correspondingly reduced and a procedure developed to ensure their regular maintenance attention.

The necessity to maintain good supplies of material for Substation work is a matter of the highest importance and should shortages of essential items develop, difficulties involved in rationing, quickly result in largely inefficient and time consuming functions in both the Engineering and Telecommunication Divisions, which further interfere with the primary object of giving good service to the subscriber.

TELEPHONE ORDERS

Substation Depots. In Sydney the average number of telephone orders held is of the order of 10,000 and about half of these are for new telephone services. All telephone orders fall into the category of:

1. On hand or being satisfied.
2. Waiting Technician,
3. Waiting linework,
4. Waiting material,
5. Waiting subscriber.

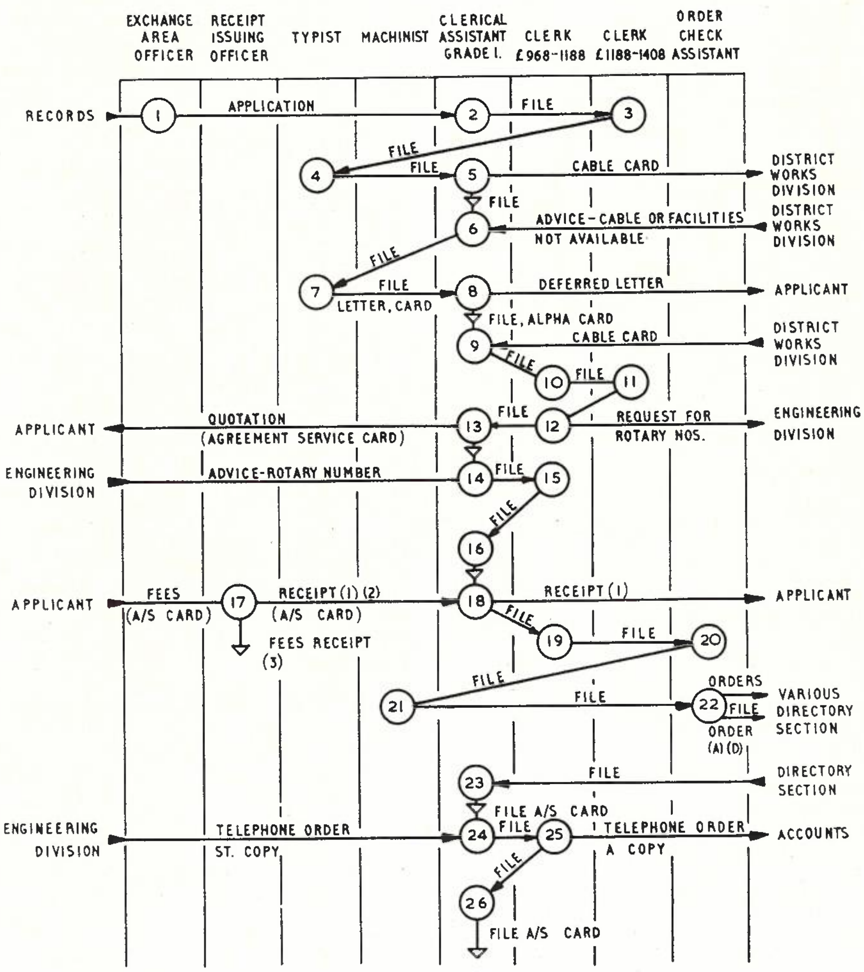
Of the 10,000 telephone orders held there could be, to give a normal delay of one day from completion of line work on new lines and three weeks on non-urgent miscellaneous telephone orders,

1,500	On hand
2,000	Waiting Technician
5,000	Waiting linework
400	Waiting material
1,100	Waiting subscriber
10,000	Total

The telephone order completion rate is approximately 2,500 per week and the average total staff occupied on this work 300. This staff is controlled by two Engineering Divisions, each being responsible for half the Sydney Metropolitan area as indicated in Fig. 1.

Commercial Branch. The method of handling various typical service requirements from the first application by the intending subscriber, to the final receipt of the telephone order by the technical and line field staff is given in detail in the following flow chart showing the distribution of telephone orders:

A STRAIGHT LINE SERVICE



TELECOMMUNICATION DIVISION TELEPHONE ORDER PROCEDURE.

MEASURING PRODUCTIVITY

The telephone order is not a sure guide to productivity for comparing working groups as some depots have a greater percentage of larger works than others, due to the character of the district. It is thus necessary to apportion load as points and to do this a suggested basis is:—

P.B.X.'s—cord	80 points
P.B.X.'s—cordless	16 points
A.5's and A.10's	100 points
Intermediate	4 points
Duplex	4 points
Portables	4 points
New Lines	1 point
Minor Miscellaneous	1 point

By allotting points some comparison can be made between the productivity of substation depots operating in industrial and residential areas.

RECOVERY OF TELEPHONE APPARATUS

In most cases this is achieved without trouble, but a disproportionate amount of technician's time is spent in following up the difficult cases. It is essential that all apparatus due for recovery be accounted for and many cases require the combined efforts of the Engineering Division, Telecommunications Division and Investigation Branch to effect recovery.

SPECIAL FACILITIES

Non-Switching Units. Some delay is experienced in supplying non-switching units to subscribers as, due to the special needs of each particular case, a separate quotation and manufacture is involved in each instance. Efforts have been directed, with some success, towards reducing delays and lowering costs by adopting some measure of standardisation in cabinet design and facilities. It is hoped to proceed further along these lines.

Multiple P.B.X. Installations. A number of instances are occurring in Sydney where, due to the subscriber's telephone service needs and to avoid the cost of providing a P.A.B.X., a multiple P.B.X. installation is requested. The standard A.P.O. P.B.X. switchboard is used and a multiple provided on the top of the middle position. Such an installation is described by Mr. A. B. Wilson in this issue.

WIRING BUILDINGS

A large proportion of older buildings were designed without taking into account modern telephone needs, so that efforts to conceal cables involve inconvenience and extra cost to both the subscriber and the Department. Telephone needs arise quickly in unpredictable positions and disfigurement is considerably reduced if wiring has been planned in advance during building construction. When careful provision is made for riser shafts for wiring between floors and horizontal ducting on floors, installation and re-arrangement work can be carried out speedily and efficiently with little inconvenience.

It is advisable to plan building wiring on the broadest possible lines, on the assumption that the use of the building could change over the years and wiring flexibility between floors and within floors will be essential.

It is important that every avenue be explored to procure information on the proposed erection of new buildings. People interested in building operations, such as architects and engineers, are encouraged to inform the Department of their coming project. Substation installation staff subscribe to newspapers in the building industry, lists of council building permits are obtained and studied regularly and technicians in the field report to their Engineering office the progress of building operations in their areas. As each project comes to notice, the interested architect is approached to ensure that adequate allowance for telephone wiring is made. Such an approach is generally welcomed by the architect, who appreciates the necessity to conceal wiring and thus improve the appearance of the building. Full details of decisions reached at such a conference are provided in writing to the field substation staff. Follow-up action during the course of the construction thus ensures that promised wiring access facilities are being provided. It has been found desirable in Sydney, due to the great volume of new building work, to operate a card information system covering current projects, the cards being retained in the Divisional office.

In the previous figure the point "x" represent final terminal points for wiring, there being "n" points in all where "n" is any positive integer. It is proposed to examine the quantity of cable required to feed the terminal points from a side position, shown at "A" and that required if the distribution point is central, shown at "B". It is assumed for this purpose that the final distribution points are each "d" feet apart and that the same cable size feeds to each point.

It will thus be seen that the total cable can be assessed as an Arithmetic Progression when "S_1" is the total cable required for the feed from position "A" and "S_2" the cable for the feed from position "B". Then—

$$S_1 = d + 2d + 3d + \ldots nd$$

$$= \frac{n}{2}(d + nd)$$

$$= \frac{nd}{2}(n + 1) \text{ feet of cable.}$$

Also $$S_2 = \frac{2n}{4}\left(d + \frac{n}{2}d\right)$$

$$= \frac{nd}{2}\left(\frac{n}{2} + 1\right) \text{ feet of cable.}$$

It is thus apparent that S_1 is greater than S_2 and

$$S_1 - S_2 = \frac{nd}{2}\left(n + 1 - \frac{n}{2} - 1\right)$$

$$= \frac{ndn}{4}$$

$$= \frac{n^2d}{4} \text{ feet of cable.}$$

Additional cabling required, expressed as a percentage of S_2, is thus given by:
Percentage extra cable

$$= \frac{S_1 - S_2}{S_2} \times \frac{100}{1}$$

$$= \frac{n^2d}{4} \times \frac{100}{\frac{nd}{2}(n/_2 + 1)}$$

In most cases n will be much larger than one and then $(n/_2 + 1)$ approximates to $n/_2$.

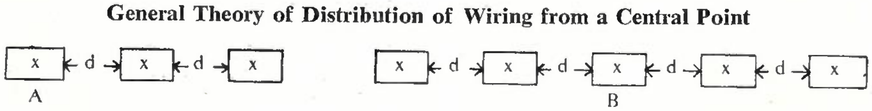
Thus

$$\text{Percentage extra cable} = \frac{n^2d}{4} \cdot \frac{100}{\frac{n^2d}{4}}$$

$$= 100\%$$

That is, feeding from an end position requires twice as much distribution cable.

General Theory of Distribution of Wiring from a Central Point



VERTICAL WIRING DISTRIBUTION

Riser Shafts. In all multi-storey buildings it is necessary to run cables vertically from the M.D.F., which is generally placed on the ground floor, and a riser shaft is generally provided for this purpose. The riser shaft thus facilitates vertical cabling and conceals these cables and the associated secondary distribution boxes. The shaft rises directly from the ground to the top floor and should be placed centrally with respect to the distribution area which it is to serve. Its placing is dictated by the theory of central point wiring distribution which has been demonstrated. Riser shafts should be sited only on the permanent structure of the building.

Shaft Sizes. Vertical riser cables for telephones are mainly multi-pair cables which do not have a large cross-sectional area. However, it is desirable in many cases to install the secondary distributing boxes within the shaft itself and a shaft size of 18" x 9" (minimum) would normally be required for a building of six floors. Buildings in excess of this size would necessitate shaft dimensions of approximately 30" x 12" (minimum) as the vertical cables would be more numerous. Floor apertures, to allow cable to pass through the structural floor, will vary from 6" x 2" to 12" x 3", the actual lineal dimensions depending on whether the cables are box-formed in a group or affixed side by side. The latter arrangement is preferred as it allows more rigid fixing of the cable and permits easier access.

In small buildings of low telephone density the riser shaft sizes are much smaller, and a shaft 9" x 6" would suffice. It is convenient in such buildings to have feed conduits terminate within the riser shaft as this facilitates maximum cable concealment and ease of wiring from the riser shaft to the telephone outlet point.

Riser Shaft Construction. In large buildings, riser shafts should, if possible, be recessed into the wall fabric of the building. When enclosed they form in effect a vertical series of cubicles (Fig. 3). When this is not practicable a shaft may be constructed on the face of the walls. In some buildings a series of utility service shafts, grouped together, but partitioned, is provided.

Joint Use of Shafts. A separate vertical riser shaft for telephone cables is very desirable but not essential. If necessary, telephone riser cables may jointly use a shaft with electricity cables (or some other utility service) but, in such cases, partitions giving physical separation should preferably be installed. In any adoption of joint use with electrical power cables, the separation between the services must satisfy the requirements of the relevant Electrical Wiring Rules issued by the Standards Association of Australia. Rule 125 reads:—

"Clearance from gas and sprinkler pipes, telephone and bell wiring, etc. Conductors, cables, metallic sheathings and conduit shall be separated from gas, hotwater or sprinkler pipes, telephone, bell or other cables, or metal conduits not forming part of the electrical installation, by one inch rigid spacing or one-quarter inch of

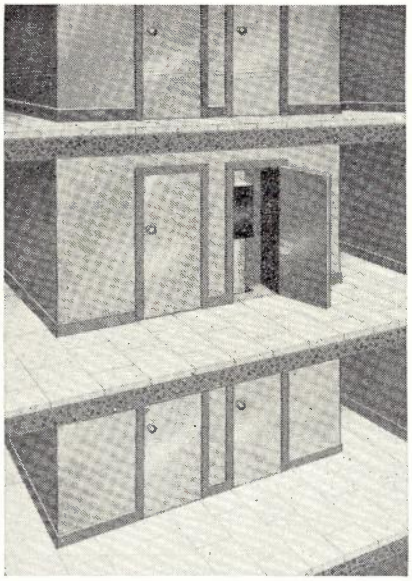


Fig. 3.—Recessed riser shaft.

durable insulating material overlapping the points of contact or crossing one inch in all directions, or by an approved insulating crossing."

This applies to voltages not exceeding 650 volts. With higher voltages a greater separation is necessary, i.e.,

(a) High voltage multi-core cable (exceeding 650 volts)—a minimum clearance of 12 inches.

(b) High voltage single-core cable (exceeding 650 volts)—a minimum clearance of 18 inches.

Running Boards. To facilitate the securing of cables and to avoid the risk of corrosive or abrasive action if cables were to touch concrete walls, a one inch dressed-timber board should be affixed in the full length of the riser shaft and, if necessary, along any main horizontal basement runs. This should be wide enough to allow for any future development.

Access to Riser Shafts. Access to the riser shaft should be provided at each floor level. This access should be from a corridor or other common space to avoid undue disturbance of office occupants. Access should be provided by a hinged door, or other suitable means, of sufficient height to give a technician reasonable access to the cables, distribution box and also any underfloor ducts feeding from the riser.

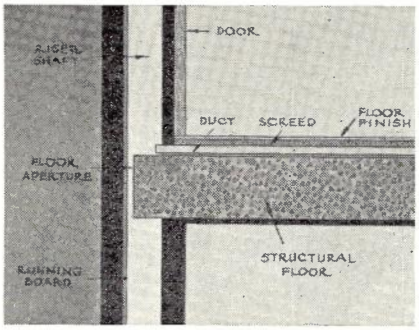


Fig. 4.—Riser shaft in cross-section.

Hinged doors are preferable to screw-on panels, especially where several services are using the same riser, because of possibility of failure to replace panels properly after work has been carried out. Panels are also subject to disfigurement around the screw holes. Hinged doors should always be fitted when a distribution box is located inside the riser as it may be necessary to carry out work on this fitting at fairly frequent intervals.

In buildings with high ceilings it is desirable for a removable panel to be fitted between the top of the access door and the ceiling. Within the riser shaft area it facilitates easier access to underfloor conduits if the screed is omitted from the riser as shown in Fig. 4. At each floor the riser shaft should be provided with a light, and also with a power outlet, to allow the use of a soldering iron when any rearrangements are required at the distributing box.

Buildings Without a Riser Shaft. In some small buildings, e.g., small to medium sized blocks of flats, the provision of a riser shaft is not essential. In such cases, short lengths of pipe (preferably 2 in. I.D.) should be set in the floors to provide floor-to-floor access for telephone cables. A wooden running board should be provided at each floor from pipe to pipe for the accommodation of the telephone cables. This running board may be enclosed if desired, providing a small section of the cover immediately over the associated secondary telephone distribution box is readily removable.

Prefabricated Floors. The "lift slab" technique of floor construction necessitates forming a floor aperture in an identical position on each floor BEFORE the concrete-pouring stages. At the same time corresponding conduit runs for intra-floor reticulation should be installed, terminating at such apertures. After the floor's elevation to its fixed position, a shaft or inter-connecting running board can be built up to link the various apertures.

HORIZONTAL WIRING DISTRIBUTION

Experience has shown that the positions of few desks or other locations for telephones are completely static, so that any distributing system based solely on initial requirements will fail when telephone removals or rearrangements are required. An important feature of a system, therefore, is positional flexibility. This applies particularly in multi-floor buildings where there are large undivided areas with telephones remote from walls or partitions.

The subject is treated under four main headings:—

(i) Systems concealed in the floor.
(ii) Floor feeds from suspended ceilings.
(iii) Above-floor-level distribution.
(iv) Segregation of services.

Systems Concealed in the Floor

This system affords maximum concealment and, by adopting pre-planned distribution, the necessary flexibility is provided to allow for future telephone development.

Four general methods for concealing distribution systems in the floor are available:—

(1) Seamless screwed steel conduits (circular section).
(2) Ducts—plastic or metal.
(3) Cellular Steel Decking—constructed so as to allow integral ducting.
(4) Floor troughs.

Seamless Screwed Steel Conduit. The circular steel conduit system (using conduit of internal diameter up to 1½") is suitable for a building where the telephone density is not likely to be heavy and where the telephone locations are defined at the outset. It may also be applied in a large building as a feed to facilitate secondary distribution (supplementary cable runs between two distributing boxes or from a large duct system as a spur run). It cannot, as a rule, be used for main runs in sizes sufficiently large or where considerable development is expected, although in a small building where the ultimate requirements would not exceed 15 telephones per floor its use would be satisfactory if floor depth permitted.

Conduit ¾" diameter will accommodate three individual services, and 1" conduit up to six individual services. 1¼" screwed conduit will allow the passage of up to two 20-pair cables, and will be suitable for intercommunication systems. In small offices with few telephone points a layout as shown in Fig. 5 would suffice.

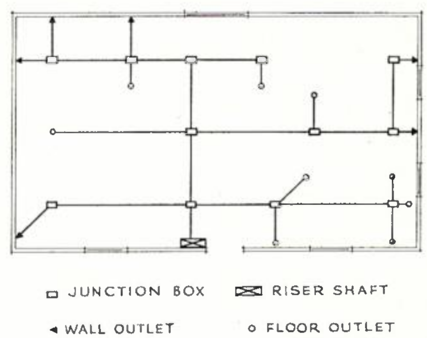


Fig. 5.—Conduit layout in a small office.

Junction boxes or draw boxes may be used where two or more conduits form a junction or where there is a change of direction of more than 75° (approx.). On long straight runs draw boxes should be inserted at 40 ft. intervals to facilitate cable drawing. The conduit should run straight between draw boxes—if this cannot be achieved there must not be more than one bend between boxes. Every effort should be made to prevent conduit, after laying, from becoming distorted. If conduit is bent downward between draw boxes any condensation will collect instead of draining into the draw box. Draw wires should be left in all conduits to provide for drawing-in the cable. These draw wires should be of non-ferrous metal if there is a likelihood of the conduit being unused for a lengthy period. Pending installation of cable, conduit ends should be plugged to prevent ingress of dirt or moisture.

Where a telephone outlet, served by an "in the floor" conduit system, is situated on a wall or column, a bend should be used as the use of an elbow could cause damage to the cable being drawn into the conduit. As an alternative method, a junction box may be set in the floor close to the skirting, to avoid the use of an elbow at the change of direction of the conduit. Fig. 6 shows

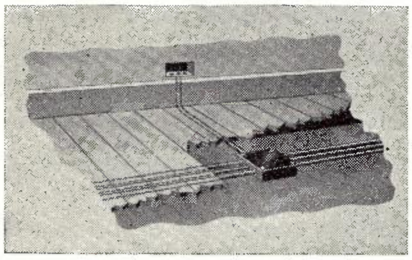


Fig. 6.—Method of extending conduit to a wall outlet.

a method of extending conduit if wall mounting of apparatus is required. The covers of draw boxes should be at floor level in order to permit inspection, maintenance or later rearrangement of cable. Draw boxes should not be installed at locations where there is a hazard of moisture ingress. To provide the actual telephone outlet, a bend is fitted at the end of lateral conduit run, or via a three-way round junction box if the outlet is situated at an intermediate point. This would permit the use of a commercial conduit type of floor attachment, and the conduit should have a thread at floor level. If an aluminium pedestal type floor attachment is to be used, a round junction box instead of the conduit elbow may be fitted at the end of the lateral run. In any "in the floor" distributing system, it is desirable that outlets at floor level be proofed against moisture or dirt ingress. Spare outlets should be plugged for the same reason.

Duct Systems. Before considering any duct distributing method it is essential to appreciate the difference in the application of conduit grids and duct systems. As mentioned previously, the use of conduit is limited by low cable-carrying capacity and the need to define telephone outlet positions at the outset. In large buildings where telephone density is high and the nature of tenancy is uncertain in the early stages of planning, conduits would be less suitable than a duct system.

The actual layout of a duct system varies with the character of the building in which it is to be installed. Having decided upon the positions of the risers and of the telephone outlets, consideration should then be given to deciding upon the most suitable system of duct layout to interconnect them. One point which is common to all layouts is that there should be a sufficient number of ducts leading out of the riser to prevent congestion in the ducts near the riser, where the greatest number of cables will be concentrated. The three principal systems of duct layout are the grid system, the corridor system and the perimeter system.

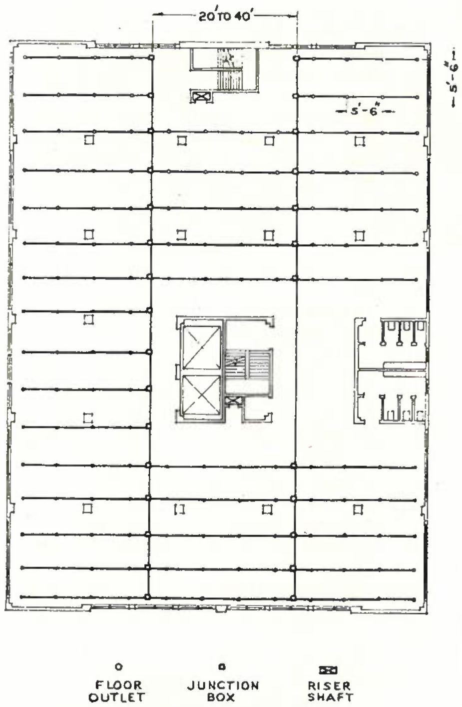


Fig. 7.—Duct layout—grid system.

The grid system (See Fig. 7) is particularly suited to a large undivided floor area where there is a relatively high telephone density. Parallel distributing runs, 5 to 6 feet apart, are arranged so that they are immediately below the sites likely to be occupied by rows of desks, etc., on which telephones may be required (the closer the ducts the greater the flexibility of the system). Feeder ducts cross at right angles, at intervals of 20 to 40 feet, and are connected to the distributing ducts by means of junction boxes. Cables are run from the wall-mounted distributing box to the feeder ducts, either in large-sized conduit or in an extension of the feeder

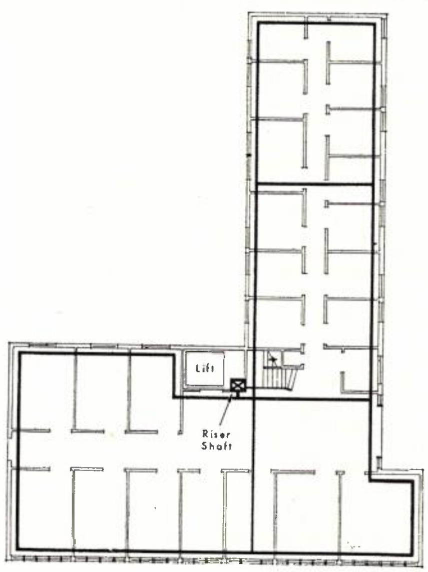


Fig. 8.—Duct layout—corridor system.

ducts, from under the floor to the distributing box.

In floor areas wth internal walls or partitions a corridor system of ducting may be used (Fig. 8). With this system, a main duct is run along each principal corridor and a subsidiary duct is run from the main duct into each room.

Perimeter duct systems (See Fig. 9) are similar to the corridor system except

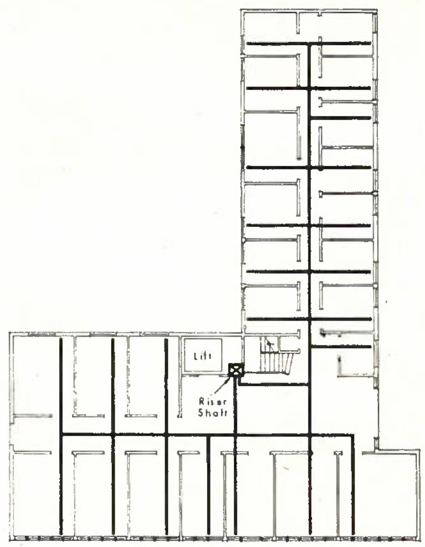


Fig. 9.—Duct layout—perimeter system.

that the main duct runs parallel to the outer perimeter wall instead of along the main corridors. Subsidiary ducts are run from the main duct into each room which cannot be served direct from the main duct. The perimeter system should only be used to meet special conditions. It has the disadvantages of necessitating working through a number of intermediate rooms to run a cable to a room remote from the risers, and since the junction boxes would be inside the rooms, there is a risk that they would be concealed and obstructed by office furniture.

As an indication only, it may be accepted that a feeder duct requires a minimum area of 3 square inches and a distributing duct requires a minimum area of 2 square inches. Figs. 10a, 10b, and 13b show typical ducts.

Metallic ducting is usually of rectangular section. Generally it is of steel, iron or brass, and should have suitable corrosion resistant finishes both internally and externally. Within a metallic ducting system, it is essential that electrical continuity be maintained throughout the whole system; this necessitates bonding and earthing the various runs. Plastic ducting is usually in elliptical section. Since plastic ducting is an elec-

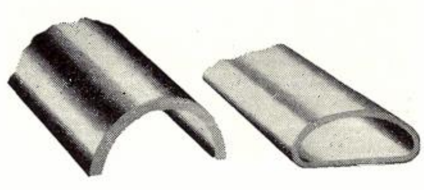


Fig. 10.—Two types of non-metallic ducting.

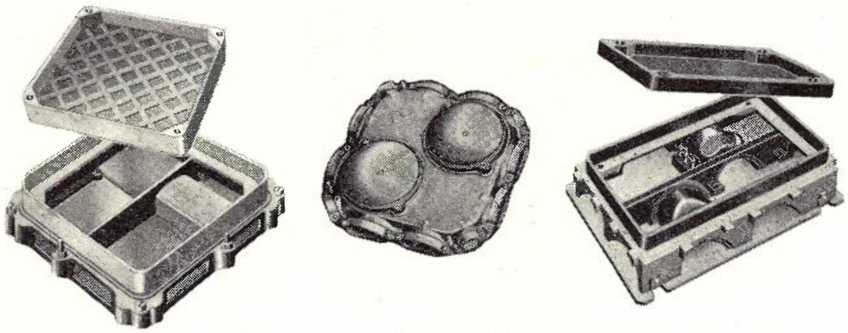


Fig. 11.—Junction boxes used with ducting.

trically non-conducting material, it is necessary to run an earthed bonding wire between metal junction boxes. Bare copper wire 7/.029 is suitable as an earth wire for this purpose.

Several forms of duct attachments are used in these systems. Junction boxes are usually made of metal, suitably treated outside and inside to be corrosion and rust resistant. The removable cover of the junction box should have designation symbols showing the type of service installed within each compartment of the box. Figs. 11a, 11b, 11c, show typical two-way junction boxes. It is necessary that the cover of a junction box should be flush with the finished surface of the floor in order to facilitate access if any rearrangements are required at a later date. This may necessitate laying junction boxes and ducting on a cement pad to maintain a floor-level finish. Floor coverings should be suitably cut or finished for this purpose.

If the telephone points are likely to be numerous, a distributing box is sometimes fitted near each feeder duct. Some systems of ducting make provision for inserting a small distributing box within the junction box. Junction boxes fitted at floor level should be waterproofed by seals or gaskets. Fig. 12 illustrates the use of two-way junction boxes in a dual duct system.

A duct outlet is also required to allow the cable within the distributing duct to rise to floor level at a position where the telephone is required. Usually, each duct system has a specially designed outlet, but care should be taken to see that any outlet used is adaptable to the floor attachment which is to be affixed to it. Elbows of short radius should not be used as they hinder cable drawing-in operations. Figs. 13a, 13b illustrate typical outlets. Usually each duct system has a specially designed floor attachment which is placed at the duct outlets and houses the telephone terminal block. Duct-end closures are provided to close-off the end of a duct run, or they may be adapted to allow insertion of a conduit carrying a riser cable.

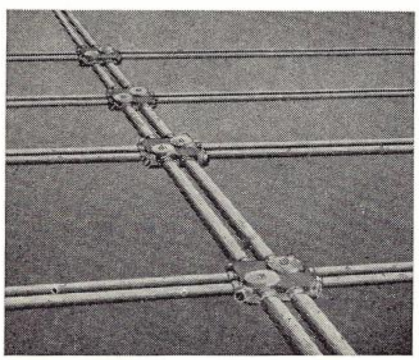
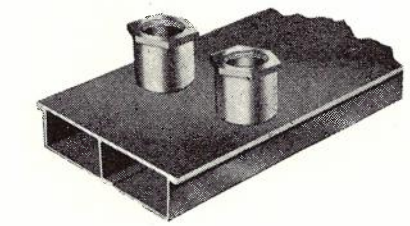


Fig. 12.—Two-way junction box in a dual duct system.

(a)



(b)

Fig. 13.—Duct outlets. (a) Plastic ducting. (b) Metal ducting

Cellular Steel Decking. The majority of duct systems are separate entities provided solely for the distribution of cables. However, in methods of floor construction using steel decking, ducts are provided integrally with the steel decking.

A feature of this system is the high degree of flexibility in telephone positions that it is possible to obtain.

The decking is supplied in various forms, and one example of its application may be seen in Fig 14. As may be seen in this illustration, the integral distributing ducts run in one direction only and feeder ducts have to be provided at right angles to the distributing ducts in order to feed the latter from the riser. The method of gaining access to the runs from the floor surface varies with each system. With some systems specialised equipment and attachments are necessary while other systems have a prepared outlet to which a floor attachment may be affixed.

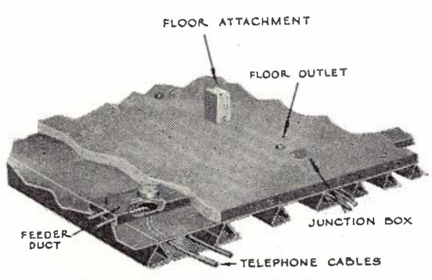


Fig. 14.—Steel decking cable distribution.

Because of these variations in cellular steel decking design and the numerous attachments available, the above descriptions are merely representative of the types available from commercial manufacturers.

Floor Troughs. Occasionally, screed thickness and other features of floor construction prevent the installation of a duct system. In such cases, floor troughs can be formed in the floor during the period when the floor is being constructed and the arrangement of the troughs, complete with covers, can provide a satisfactory distribution system to which all earlier remarks on layout and outlet positions, etc., can be applied. However, any method which involves the removal of floor covering and subsequent channelling of the floor composition should be avoided since it is both difficult and costly. The trough covering at floor level should be removable at trough junctions or at any other convenient access point. The inside surfaces of a trough formed in concrete should be finished smooth and preferably painted with a suitable sealing paint to prevent any possible reaction between the concrete and the telephone cable.

Where a wooden floor is provided, wooden or metal cabling troughs will provide convenient accommodation for telephone cables. Detachable floor boards at convenient points over such troughs could serve as access covers. With any system of troughing, it is essential that the floor covering should be cut along the edges of the covers to prevent deterioration of the covering caused by frequent removal of the trough cover. Small openings may have to be cut in any obstructing floor joist to allow the passage of the cable.

Although floor troughs are an economical means of cable distribution it is, in most cases, difficult to prevent vermin and moisture ingress.

Floor Feeds from Suspended Ceilings

Suspended ceilings with detachable panels are now frequently provided and, where this is a feature, it is possible to utilise the space between the ceiling panels and the floor above to provide the equivalent of a grid outlet system. This system is economical since no feeding or distributing ducts are required. Cables can be added at any time, providing arrangements can be made for the removal of the ceiling panels on the route the additional cable is to follow. Fig. 15 shows a typical application of such cable distribution.

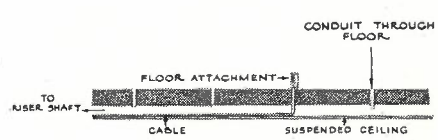


Fig. 15.—Suspended ceiling distribution.

If there is no assurance that the ceiling panels can be removed when and as required, there is no alternative to the provision of a complete system of conduits or ducts. Where the space between the floor and the detachable ceiling panels is utilised, conduit should be provided to carry the cable from the distributing box to the suspended ceiling space. The outlets, for full flexibility, should be provided at approximately 5 feet intervals in both directions, i.e. in 5 feet squares. Short lengths of conduit are necessary to carry the telephone cables from the telephone outlets, through the floor, to the space below.

The obvious disadvantage of this system is that it is necessary to serve the outlets on one floor from the ceiling below, and, in a multi-occupier building, this could result in inconvenience to tenants occupying the floor immediately below when any future rearrangement or maintenance is required. To meet this contingency, arrangements may be made to insert conditions in the tenancy contracts permitting right of access to P.M.G. technicians.

Above-Floor-Level Distribution

Whilst the use of a distribution system concealed either in the floor or in a suspended ceiling offers maximum concealment of cables and facilitates efficient layout, telephone cables may sometimes need to be run above floor level, and this can be done by taking advantage of skirtings, picture rails, partitions, etc.

Skirting Runs. Skirting boards and picture rails with cabling channels provide an adaptable means of running cables, and Fig. 16 shows typical applications of these ducts for this purpose. To provide access to the cable channels, easily-removable panels should be placed at all corners, and at other strategic positions such as the centre of long runs and near possible telephone outlets.

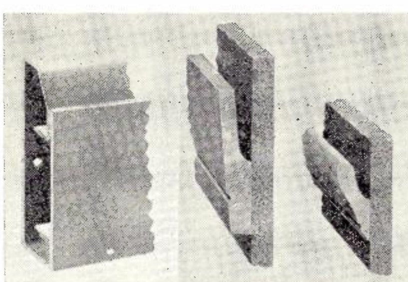


Fig. 16.—Cable channels
(a) Skirting boards. (b) Picture rails.

It is essential that these panels shall not be obstructed by adjacent partitions, etc. Where metal skirting is used, any cable outlet should be insulated with a bush to prevent cable friction against the metal.

Partitions. Partitions, wooden or metal, may be used to accommodate telephone cables. Before deciding to use partitions for the accommodation of telephone cables, consideration should be given to the permanency of the partitions as, if they are later to be removed or rearranged, difficulty may arise in providing alternative cable routing. To allow cable to traverse doorways, buried conduit should be provided. Even if partitions are available, it may be advisable to provide under-floor distribution instead of relying on the permanency of the partition.

Cavities. Features in the design of large buildings often present means of concealing cable distribution in cavities or other free spaces which are a by-product of the building technique. Fig. 17 illustrates an internal wall with an integral cavity designed to allow cable drops from a channelled picture rail to the skirting. False ceilings can also be utilised for lateral distribution if space and accessibility permits. However, any cavity or free space where ready access is not available should be avoided.

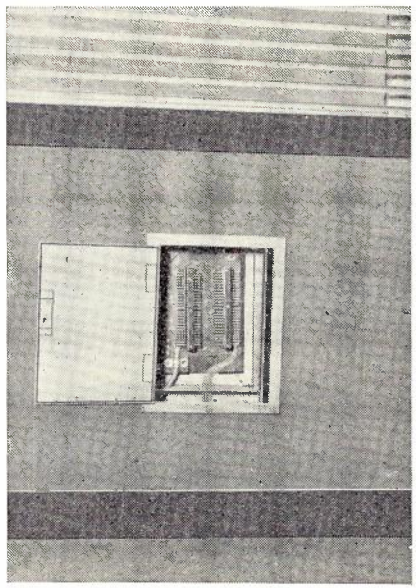


Fig. 17.—Wall cavity housing and distribution box.

Cover Strip. The use of a cover strip over the surface of the floor, for concealing small-sized telephone cables, is regarded unfavourably (except in short lengths of up to 6 feet) due to the poor appearance of such installations and to the difficulty of providing satisfactory waterproofing. Furthermore, with some installations there would be a definite pedestrian hazard. The use of cover strips should never be included in the plans for the provision of a distribution system for new buildings.

Specialised Distributing Applications

Hospitals and Hotels have a common aspect in as much as the provision of telephone cable accommodation in these premises can be determined with reasonable certainty in the planning stage, and the problem of large undivided office space does not arise. In hospitals and hotels there is not likely to be much difference between the initial and ultimate requirements, and, generally, the design of a cable-distributing system need make only small provision for future developments. In addition, the cables on each conduit or duct run can all be drawn in at the one time, thus avoiding the more difficult operation of pulling new cables over the old cables at a future date. Where long runs of more than 40 feet are involved, it is advisable to make provision for subsidiary distributing points. This permits the use of large-sized cables between the distributing box for the floor concerned and the subsidiary distributing box, in lieu of using several smaller-sized cables the full length of the run. In this way a reduction is realised in the amount of conduit necessary as, in a given cross-sectional area, more wire conductors can be accommodated in one multi-pair cable than in a number of small-sized cables. It has also the advantage of reducing the length of conduit through which the one-pair cables must be drawn.

The use of distributing boxes in the above premises brings about the attendant problem of any future maintenance, as hospitals and hotels have areas in which public access is not permitted. It is therefore required that the positions of any distributing boxes be so placed as to permit ready access.

Factories. In factories, apart from the administration areas, telephone positions are relatively few and, to a degree, are difficult to position with accuracy in the planning stage. It may be possible to provide adequate cabling facilities either by means of a wall channel or by means of timber battening for surface wiring. Difficult cable runs may at times be anticipated and considerably improved by providing buried conduit. Industrial hazards are a large factor in determining conduit requirements, e.g., high-roofed factories where telephones are required on both sides of the factory, or factories where there are travelling overhead cranes with uninsulated electrical wires are instances where it would be dangerous to provide overhead cabling and where buried conduit should be provided.

Factories (and also hospitals) frequently consist of groups of buildings on one site, served from the one private branch exchange. Thus, in addition to the distribution of cables *inside* the buildings, the method of cabling *between* the various buildings must be considered.

Flats and Home Units. Provision for concealing telephone cable is also required in buildings designed for flats or for division into home units. These buildings vary considerably in character and various modern trends in building construction, such as increased use of concrete construction, the absence of picture rails and skirting boards, etc., have tended to restrict facilities for telephone cable distribution. It is important, therefore, that the design of the building should make provision for concealed conduit to facilitate the running of the necessary telephone cables. Fig. 18 shows a typical conduit layout where the flats are grouped around a common entrance. If the halls and rooms of a block of flats are provided with skirting boards and/or picture rails these would provide a possible, but less satisfactory, means of extending the telephone cable

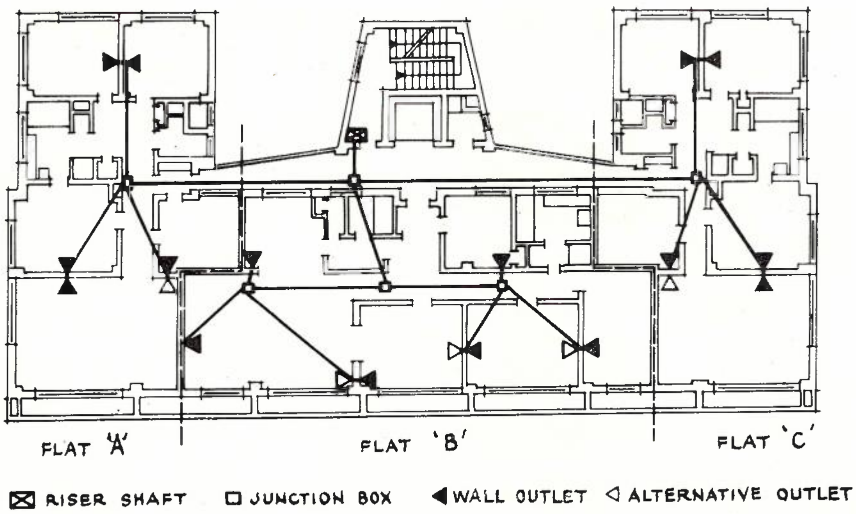


Fig. 18.—Conduit layout for flats with a common entrance.

from the entrance point to the telephone position.

Segregation of Services.

Separate duct systems (or other types of distribution system) will need to be provided for the electric supply and for the telephone cables, and where these are distributed alongside one another in a combined duct system it is essential that full segregation of the two services should be provided in the ducts, junction boxes and outlets. The duct system should be bonded and earthed.

In those cases where private communication systems are provided in a building, in addition to P.M.G. facilities, a separate duct system should be provided for accommodating the cables and wires of the private system. Fig. 19 shows a typical 3-way junction box illustrating the segregation of the three services.

Although rigid separation between the P.M.G. cables and the cables of a private communication system is not always essential for safety reasons, segregation into separate ducts is highly desirable, particularly on those runs where the number of cables will be large, because:—

(a) There would be a possibility of damage to P.M.G. cables when the contractor's technicians were drawing in new cables. The P.M.G. Department would have no control over the type of draw wire used.

(b) Electrical interference from one circuit to another. This will depend upon the character and magnitude of the currents or voltages and lengths of run concerned in each installation.

(c) Difficulties, such as circuit identification, which occur when one duct serves more than one user.

(d) The danger of cables becoming interlocked.

(e) There would be inadequate supervision over the replacement of covers of junction boxes, etc.

(f) General safety requirements. A hazard would exist if the voltage between any two conductors, in a duct, or between any one conductor and earth, exceeded safe limits.

(g) Two smaller ducts will bear compressive loads which may be put on the floor, better than a large single duct.

The purpose of the individual ducts should be clearly marked on the appropriate plans, and, where possible, on the ducts or duct covers themselves.

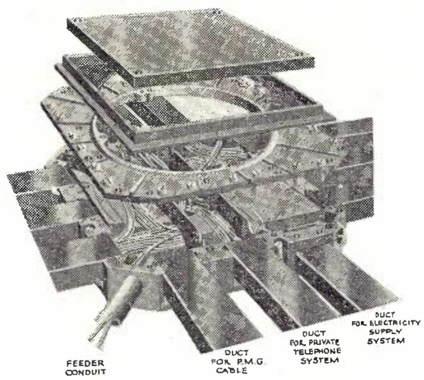


Fig. 19.—Junction box with full segregation of three services.

GENERAL COMMENT

Experience has shown that the most efficient and flexible distribution system is achieved when either an "in the floor" system or a "suspended ceiling" system is supplemented by the use of channelled skirtings and partitions.

MATERIALS AND METHODS

Future prospects for improvements in substation productivity are linked with new materials and new methods of carrying out substation work. The use of plastic insulated cable is now general. The encouragement of staff suggestions and a higher engineering effort directed towards the study of methods of performing the basic tasks is proving advantageous. Methods study has been directed towards terminating wires and the use of new material to be adapted into the field of Telecommunications.

THE TOWNSVILLE-MAGNETIC ISLAND SUBMARINE CABLE

*K. W. WALLACE, A.M.I.E.Aust. and H. J. RUDDELL, A.M.T.C.**

INTRODUCTION

A submarine cable linking Townsville and Magnetic Island had been proposed prior to World War 2, and in 1942 a 70/40 D.H.W.A.P.I.Q.T. cable was laid. Following a cable fault caused by this cable being caught by a ship's anchor during a period when Cleveland Bay was littered with war-time shipping, six pairs only were useable. These six pairs together with two phantom circuits derived, provided adequate trunk provision until natural development of Magnetic Island as a settlement, holiday and tourist resort demanded additional trunk provision.

To cater for immediate requirements and future development a 74 pair cable has been laid providing circuits on a 4-wire basis with receive amplifiers only, using standard 4-wire networks at Townsville and Picnic Bay. Dial lines are to be provided on a loop dial basis, calculated loop resistance being 670 ohms for Picnic Bay circuits and 750 ohms for Arcadia Bay circuits. All circuits to Townsville are to be lined up to an overall –3db equivalent.

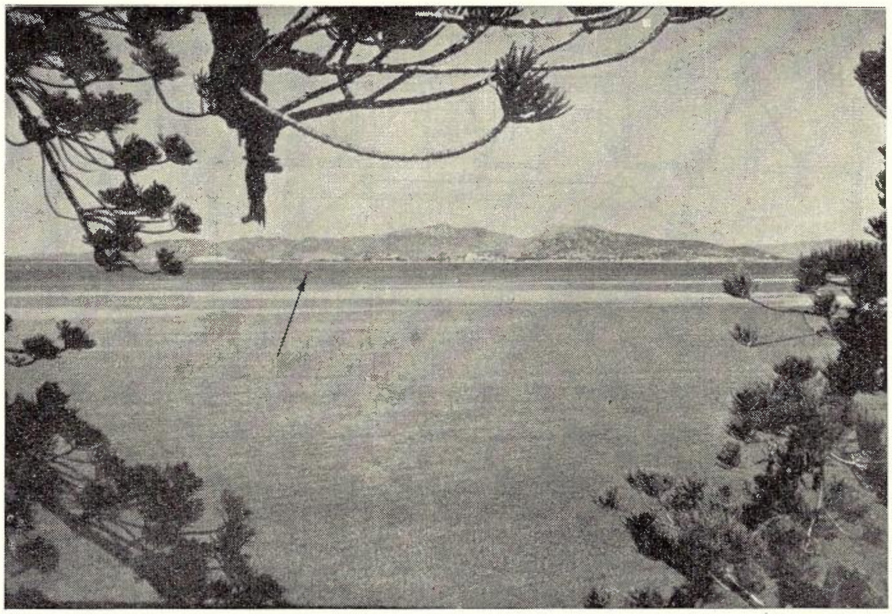


Fig. 1.—A view of the 5½ miles cable route looking from Magnetic Island towards Townsville. The pontoon indicated by the arrow may be observed working at No. 8 joint.

CABLE CONSTRUCTION

The cable consists of a 74 pair 10 lb. conductor with .015" thick polythene insulation (Fig. 2). The conductors are bound by two layers of "Mylar" film and the whole sheathed in .03" thick polythene containing polyisobutylene and carbon black. Covering this unit are protective layers in the following order.

(i) .004" thick brass teredo tape with suitable overlap to resist marine borer attack.
(ii) .09" thick black polythene sheath.
(iii) Armouring layer of .192" dia. steel wires.
(iv) .09" thick black polythene outer sheath.

GENERAL PREPARATIONS

There were several preliminaries which required attention and these were:

Cable Drums. Cable drum dimensions were 7' dia. x 4' wide, weighing 4¾ tons. The drums came from the factory with small reinforcing plates surrounding the spindle holes. These were replaced with 24" x 24" plates each side, bolted together through the drum with long bolts.

Gassing. In an endeavour to discover whether the cable had been damaged in transit, the cable on drums was placed under gas pressure. This introduced a problem with sealing of cable ends. This precaution itself later proved to be a problem when epoxy resin joints were being poured, in that air continued to issue from the cable in small quantities during the pouring process even though the cable had been open for some 6 to 8 hours.

Sealing Cable Ends. After much experimenting, cable ends were sealed by setting molten polythene in a mould fitted over the cable end, which had been prepared by cutting back step fashion the various polythene sheathings to present about 1" of each sheath for bonding with the molten seal. A valve stem was moulded in one end to permit gassing. While these "home made" seals performed well, the essential molecular structure of the polythene compound was changed from soft pliable form to hard brittle wax form by excessive heating. It was found also that polythene did not bond or adhere to the rubber or metal of the valve stems enclosed in the seal. Fortunately however, the seal was sufficiently water-tight at this point.

Cable Markers. Marker buoys were manufactured from 4' lengths of 4" dia. bamboo laid horizontal with a 16' length of 2" dia. bamboo attached vertically with 2' protruding on the lower side and having a 30 lb. counter balance weight attached to the lower end. Three pennants red, white and red were attached at the top portion of the mast.

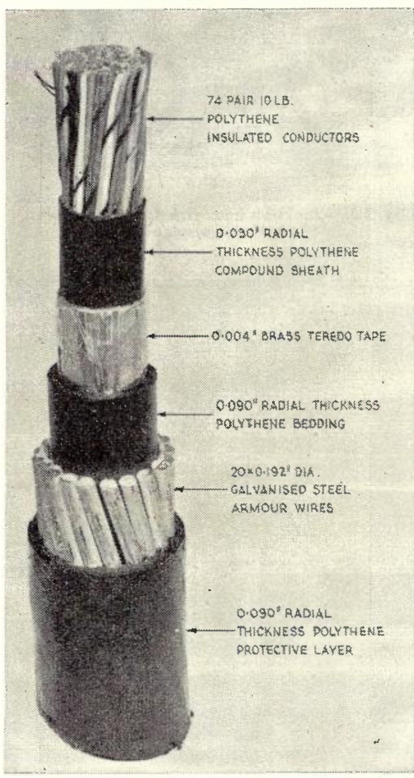


Fig. 2.—Construction of Townsville-Magnetic Island Submarine Cable.

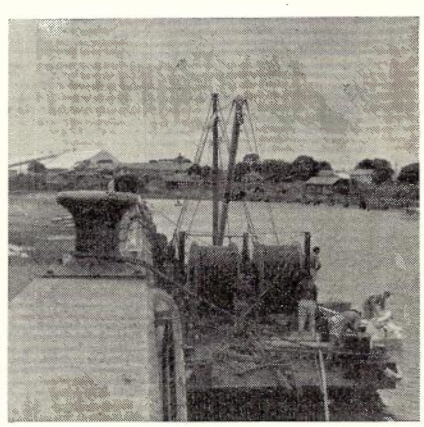


Fig. 3.—Front view of barge showing: 1.—lay-out of supports. 2.—Guying arrangement. 3.—Fair Lead, Main Cable Brake and Bow Sheaves. Cable was fed from drum, through Fair Lead, Brake, Bow Sheaves round the prow of the barge and under the barge.

*See pages 465 and 466.

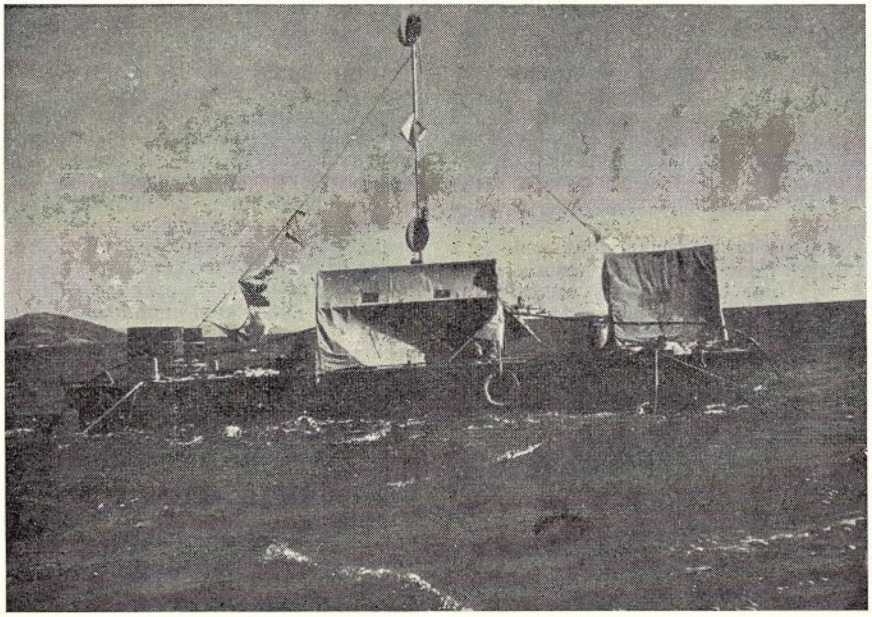


Fig. 4.—The pontoon on which jointing was carried out, showing cable ends passing through the jointer's tent. The second tent was used to protect encapsulating materials from the weather.

Navigation. Guidance of the cable laying craft was to be by theodolite mounted in the Townsville Strand and transceiver communication between barge and shore. Unfortunately as the route was roughly east west, sun glare from the sea inhibited guidance in the early stages, but adequate "sighters" were available on shore, and steerage of a straight course presented no problem.

Material Handling. Loading cable drums on the barge into the cable supports presented a problem in that the barge was about 15′ below the level of the earth fill wharf where cable had been stored. This was readily overcome by using a 10-ton mobile semi-trailer crane with an adequately extendable jib.

CABLE-LAYING BARGE

Cable laying was carried out by the local staff of the Townsville Engineering Division following careful consideration of these problems:—

(a) Overall length of submarine cable was approximately 5.5 miles.
(b) Maximum water depth approximately 35 feet with extensive shallow shelving of both shores.
(c) Strong water currents and gusty rising south-easterly winds.
(d) Availability of suitable craft which could be adapted to submarine cable work.

A suitable cable-laying craft was obtained by hiring an iron barge 50′ x 14′ with an available working space of 30′ x 14′ and draught of 2′ (see Fig. 3). The barge was powered by a 35 h.p. Gardner motor. The shallow draught of the barge enabled both shores to be approached very closely, facilitating the landing of shore ends. The maximum capacity of the barge was 22 tons.

In designing drum holding equipment to be mounted on the barge decking, stability of the craft was checked when a load of petrol in 44 gal. drums was being transported to the Island, by having approximately $2\frac{1}{2}$ tons loaded along one side of the barge. A tolerable list resulted and design proceeded.

Problems overcome by the final drum holding arrangement, which mounted two cable drums side by side, each 7′ dia. x 4′ wide and weighing $4\frac{3}{4}$ tons were:

(a) Deck space available 30′ x 14′, allowed adequate space round the drums for manhandling.
(b) Permitted storage of a miscellany of emergency and essential equipment.
(c) A fair lead with bow sheaves and main cable brake could be installed so that cable could be fed over the front end of the barge, permitting complete control of barge steering.
(d) A raised wooden hatch cover had to be tommed and reinforced.

Design. The three main supports were upright lengths of 6″ x 5″ R.S.J. beam with footings manufactured from lengths of 6″ x $\frac{5}{8}$″ iron. Channel iron struts were welded from the footing ends to a point just below the drum axle bearing. A short acutely angled strut was welded from each of the outer supports to the edge of the barge. Support footings were tacked to the iron deck by weld. As the centre support had to be sited on the large wooden hatch cover this support was held firm by flat iron $1\frac{1}{2}$″ x $\frac{5}{8}$″ overhead struts from each side support, and $\frac{3}{4}$″ rod struts at the lower end to each side support. Fore and aft crossed guys were fitted from the top ends of side supports to assist the acutely angled strut at the side and provide fore and aft stability for these supports. Fore and aft guys were fitted from the top of the centre support.

As 3″ solid iron axles were to be used with the drums, axle bearings consisted of cups made by splitting $3\frac{1}{2}$″ G.I. pipe. These were welded into the web of the beam between flanges and a section was cut out of one flange. With the structure fitted together there was only $\frac{1}{2}$″ play between supports for axle side-play. A short protruding guide was welded to the supports at bearing level to facilitate drum loading. With grease, the $4\frac{3}{4}$ ton drums rolled very well on these bearings.

Drum speed was controlled by a drum-brake consisting of a crossarm pivoted on the lower $\frac{3}{4}$″ rod strut and bearing on the rim of the drum.

The fairlead, main cable brake and bow sheave were mounted along the

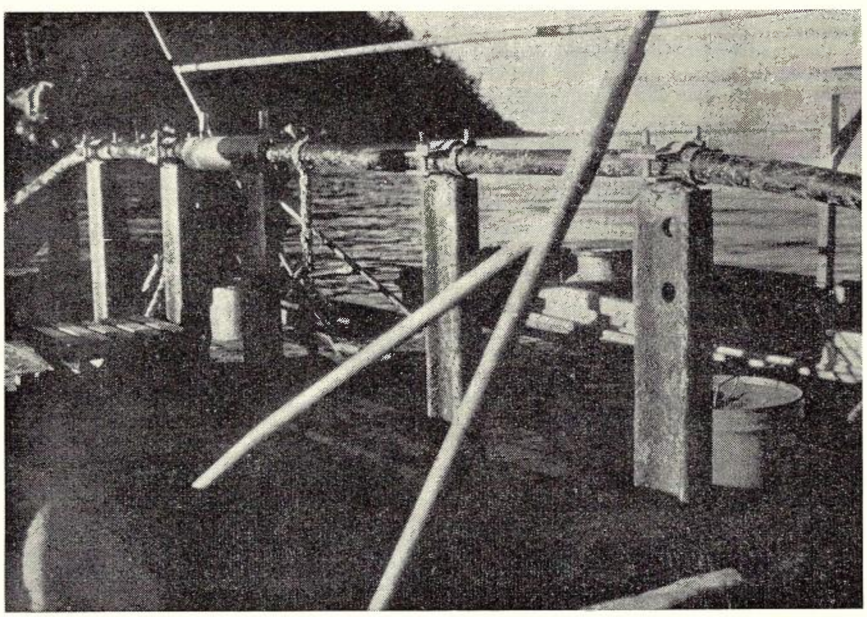


Fig. 5.—Cable support and clamps used to position and hold cable for jointing.

20′ length of twin 6″ x 3″ wood bearers projecting 3′ beyond the barge prow.

CABLE LAYING OPERATIONS

To take advantage of wind and water current assistance, it was decided to lay cable from Magnetic Island towards Townsville. The barge approached the Island shore clear of coral and rock outcrops well up into shallow water and 350 yards of cable was manhandled ashore until the end was picked up by truck and towed to the shore manhole. The cable was pulled over the front end of the barge and before heading to sea the barge was turned about and cable loaded through fair lead and bow sheaves equipment. The cable drums were rolled manually and the barge headed to sea weaving a route through known coral outcrops. Drums were kept rolling manually to avoid cable being bent too sharply over the bow sheaves. Speedy action by the men avoided tangling of loose cable loops on the drum and enabled the inner end to be captured in large wire loops nailed to the drumside preventing flogging against supports.

The lead end of the second drum was clamped to the tail end of the first drum with 3 yards over-lap using small back plates tightened over polythene slippers. This was allowed to sink to the sea bed tied to a marker buoy. During the first day 4,000 yards of cable was laid and two drums loaded on the barge ready for the following day.

For the second day it had been hoped to lay 6,000 yards and possibly land the Townsville shore end. Unfortunately a nail was observed stuck into the sheath during laying of the second last drum. Laying operations were stopped and the barge anchored while damage was checked. The nail penetrated to the conductors and the cable was cut and sealed ends were clamped and buoyed for later jointing.

The shore end was landed early on the third day, with the barge being able to nose right into shore on a rising tide.

JOINTING OPERATIONS

For jointing at sea a wooden pontoon 35′ x 15′ was fitted out with approved signal mast, large jointers tent mounted centrally, small jointers "tool" tent in one corner with the rest of the deck space allocated for anchors, life raft, tool box, miscellaneous gear, etc. (See Fig. 4). The pontoon was tendered by a 35 h.p. launch capable of seating twelve. The signal mast carried 2′ red disc, 2′ white diamond, 2′ red disc on 6′ centres. The mast consisted of 1½″ pipe fitted into a socket welded to a 24″ x 24″ plate and was guyed fore and aft.

To support and clamp the cable in a jointing position a support consisting of 4 two foot high uprights welded to a 12′ length of rail in turn welded to two 4′ cross pieces for stability (See Fig. 5). On top of the uprights small back plates were welded to form part of the clamps which were completed by bolting back plates over the cable. Here again polythene slippers were used in the clamps for protection of cable sheath. Cable was led over the ends of the pontoon by large pulley wheels mounted on 18″ x 9″ footings, to prevent damage by the chafing movement of the pontoon.

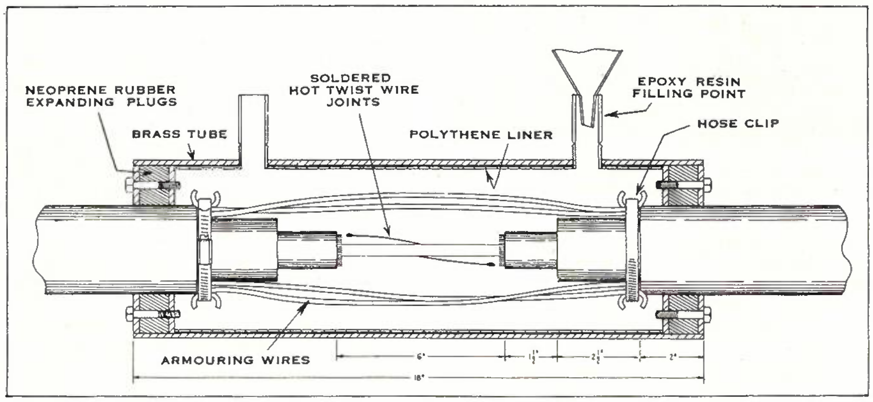


Fig. 6.—Construction of Townsville-Magnetic Island Submarine Cable Joint.

To set the pontoon in position each day, spreading out 5 anchors, jointing and pouring the epoxy resin took approximately 8 hrs. In the mornings weather was good until about 11.00 a.m., thereafter deteriorating to maximum discomfort from 3.00 p.m. onwards with rising wind and sea. On one occasion jointing was abandoned for 4 days while seas were whipped up by 25-30 knot winds. During this period jointing was completed but epoxy resin was not poured owing to flexing of the conductors caused by flexing of the cable over the pontoon ends. Ten joints were completed at sea. These were schedule jointed in accordance with factory test sheets and three were schedule jointed and sign balanced at sea.

CABLE JOINT DESIGN

Basically the joints consist of jointed conductors and armour wires surrounded by a brass tube, the ends of which are sealed and the cavity filled with an epoxy-resin compound, see Fig. 6.

The conductor wires were joined by the "hot-twist" method with soldered tip, see Fig. 7. This method was preferred to the usual paper, polythene, or silicone grease-filled sleeves because a positive conductor joint protected against ingress of moisture by a continuous insulant was obtained without the disadvantages of air entrapment or grease contamination usually associated with sleeve encapsulation. The hot-twist method was carried out in joint openings of maximum length 6″, in order to provide room within the limits of the joints for the exposure of at least 1½″ of each individual layer of polythene as illustrated in Fig. 6.

Connection between the armour wires on adjacent ends were made by first installing on each end an expandable hose clip around the exposed armour wires and close to the cut edge of the outer polythene sheaths. The number of wires in the final joint was reduced to the same number as in the cable by bending

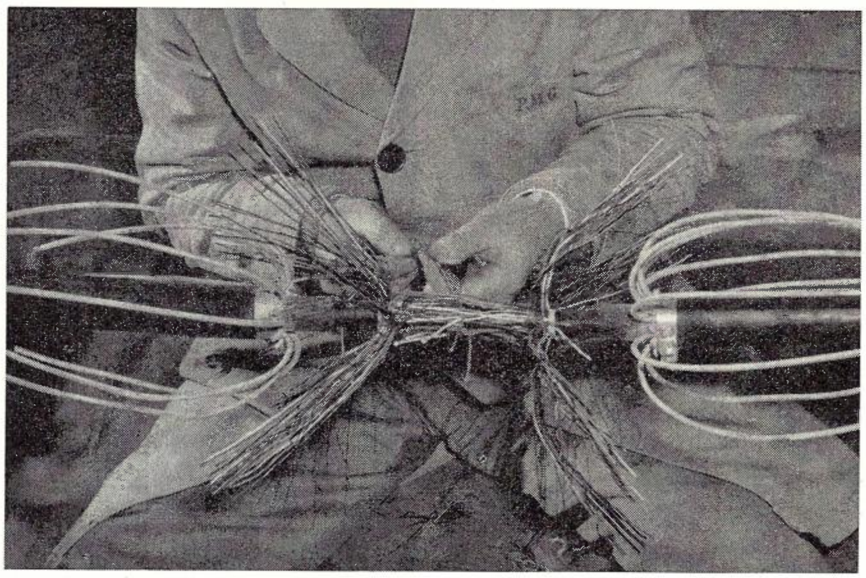


Fig. 7.—Jointing of conductor wires by the hot-twist with soldered tip method. Also shown is the "stepped-down" polythene sheaths; the expandable hose clips, and the short ends of each alternate armour wire.

each alternate wire sharply back against the hose clip and removing the excess, ½″ from the bend. The remainder were laid around the conductor joint and held in place by inserting the ends under the loosened hose clips. After readjusting the hose clips, these wires were bent back and the excess removed ½″ from the bend as before. As this method terminated each wire with a hook bent over the hose clip in the opposite direction to its neighbour, see Fig. 6, the total combination resulted in a mechanically strong junction.

Each junction of conductor and armour wires so formed was then surrounded with an 18″ long, 3½″ O.D. × 10 S.W.G. brass tube, the ends of which were sealed with expanding plugs on the principle of the B.P.O. pot head joint for plastic cable. The brass tube was lined with a tight-fitting polythene insert to prevent adhesion of the casting compound to the brass. This operation was necessary as laboratory experiments had shown that the adhesion of the casting compound to the brass tube was so great that the shrinkage which occurred as a direct result of the chemical exotherm after the compound had gelled drew the compound away from the internally situated polythene cable. The armour wires, being well encapsulated in the compound, were also drawn outward leaving a well-defined air gap around the polythene layer. Radial cracks extending from the polythene to the brass tube also developed in the cured compound, probably due to the armour wires resisting full distortion, see Fig. 8.

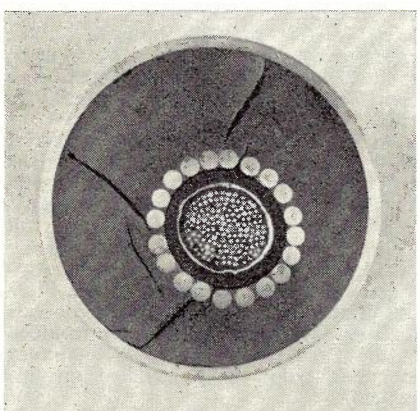


Fig. 8.—A cross-sectional view of the encapsulated joint without polythene liner showing strong adhesion to the brass tube; a defined air-gap around polythene sheath, and radial cracks in the casting resin.

The cavity of each brass tube was filled by pouring a suitably formulated epoxy resin compound into the brass tube inclined approximately 15° to the horizontal. Two 2½″ × ⅝″ I.D. brass cylinders were brazed on to each brass tube 2″ from either end to act as filling and air escape points. By pouring into the lower cylinder, air was forced out as the compound rose in the tube. When full, the tube was brought back to the horizontal and a head of the compound maintained at the filling point to compensate for any which subsequently penetrated the cable voids. After the epoxy resin had hardened, 2″ of the brass cylinders were removed to leave ½″ thread sections on to which were screwed standard ½″ brass end caps to complete the brass tube as a watertight unit.

REASON FOR CASTING RESIN

As the brass tubes may be regarded as totally enclosed vessels they will protect the joints from ingress of moisture providing the outer layer of polythene on the cable remains undamaged. The likelihood of the outer sheath remaining intact, however, is very doubtful since it may be holed by abrasion on the sea bottom, by teredo worm attack, or have been damaged during laying operations. The main function of the casting resin, therefore, is to block any possible water path to the joint by tightly gripping all polythene sheaths and conductor wires and to penetrate the air-space down the core of the cable and around the armour wires, see Fig. 9.

Also, as the primary function of the armour wires in this type of cable is to provide strength for handling, laying, and possible recovery of the cable, the armour wires at the joint must have strength and rigidity at least equal to that of the cable itself. Laboratory experiments had proved conclusively that wires embedded in suitably formulated casting resins exhibit tensile strengths far in excess of the original wires.

FACTORS INFLUENCING CHOICE OF CASTING RESIN

Resins used for encapsulation include epoxies, polyesters, phenolics, polyurethanes, polysulphides and silicones. Within each of these main groups considerable variations in properties are possible by selecting different combinations of base resins, curing agents or hardeners, diluents, plasticisers, fillers and cure schedules.

There is no one system which will meet every encapsulation requirement. The epoxy resin group was chosen because its compositions offer a remarkable combination of properties, notably: good physical, chemical and electrical characteristics, low shrinkage during cure, homogeneous polymerisation, outstanding surface wetting characteristics and low water absorption. Its disadvantages are: risk of skin irritation from amine hardeners, short pot life of liquid compositions and great cost.

Epoxy resins are available as liquids or low melting point thermoplastic solids which can be converted to cross-linked thermosetting resins by the addition of either liquid or solid curing agents at room or elevated temperatures.

The environment in which the potting of the submarine cable joints took place ruled out the use of materials which required the use of heat to bring about a cure. Consequently, the compound was based on a medium viscosity epoxy resin, cured by a polyamine adduct-type hardener. Experience has shown that the hardener used rarely caused allergic irritation of the skin and was capable of producing high strength resins capable of withstanding the loads likely to be applied to the armour wires. The resin was modified with a polysulphide liquid polymer — a low-viscosity resin that cures to an elastomeric solid — to impart good knock resistance to the cured resin and so prevent shattering due to sudden impacts.

The epoxy resins cure or harden by exothermic addition polymerisation without the evolution of water or other volatile materials, which largely accounts for the low shrinkage obtained during casting. The shrinkage, due partly to the

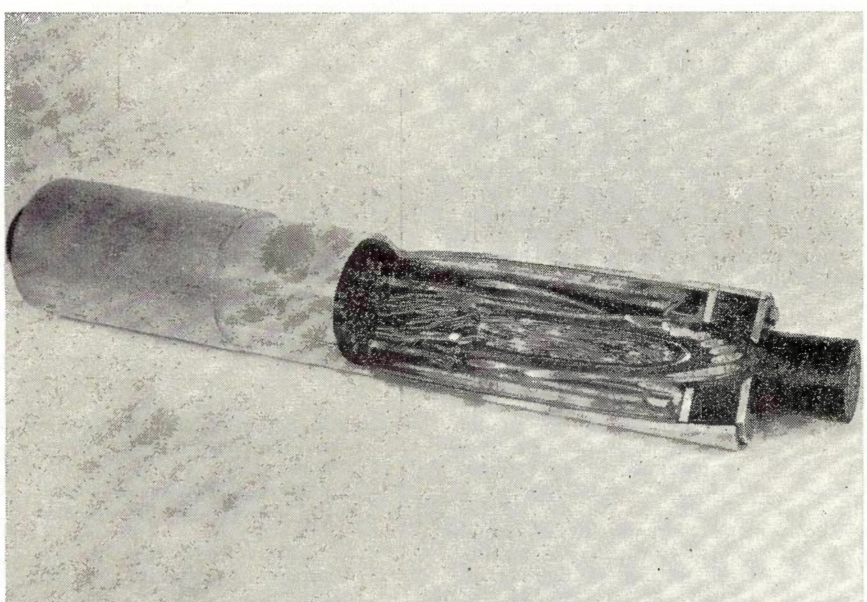


Fig. 9.—A cut-away section of the completed joint clearly showing the brass tube with polythene liner; encapsulation of the hot-twist conductor joints; penetration of the conductor and armour wires by the casting resin; the "stepped-down" polythene sheaths; the hooked ends of the armour wires around the hose clips; and the B.P.O. type expandable end seal.

conversion of monomer to polymer and partly to cooling from peak exotherm temperature, was of great importance in the submarine cable joint, for, although epoxy resins show outstanding adhesion to most surfaces, they exhibit no affinity for thermoplastic materials such as the polythene sheath. Watertight seals, therefore, could only be obtained by a shrink-tight fit of epoxy resin compound around the polythene. Obviously high exotherms were desirable to obtain maximum shrinkage but this was limited by the relatively low melting point of the polythene insulant (approx. 110°C). Consequently, exotherms of not greater than 110°C under normal pouring conditions were ensured by the proportion of hardener used whilst consistent 95°C exotherms were attempted by varying the temperature according to ambient temperature at which the compound was poured into the brass tube. The pour temperatures to yield the desired exotherm at any given ambient temperature were obtained from a graph compiled from controlled laboratory tests. The ambient temperature during actual operations ranged from 15°C to 25.5°C and the pour temperatures were varied from 39°C to 29°C accordingly.

The good physical properties of an epoxy resin mix hardened by a so-called cold curing agent can be greatly improved if the rapid cure is followed by an afterbake at a higher temperature. This practice, of course, was impossible in the case of the submarine cable but the action of surrounding the joint with insulating material (hessian bags) immediately after the compound had reached its peak exotherm utilised the heat generated during cure to more than treble the cooling-down period, usually 3-4 hours. As it is considered improbable that the compound would have reached its maximum strength on cooling even under these conditions, a minimum time of 12 hours was allowed to elapse before the joint was finally prepared by capping the ⅝" I.D. brass cylinders and lowered to the sea bottom.

CONCLUSION

Cable joints were successfully carried out on the specially designed polythene-sheathed submarine cable using a method unique in that each joint is protected threefold against ingress of moisture, i.e., the "hot-twist" with soldered tip conductor joints, encapsulation of the conductor joints in epoxy resin compound and enclosure of completed joint within a brass tube with B.P.O. pot head type end seals.

The approximate cost of installing the cable was as follows:—

Incidentals:

Barge, Pontoon, Launch, Crane, Portable Welder £600

Special supports and fittings £110

Manhours 950

The entire job was completed successfully and the cable meggered satisfactorily after being installed for several weeks.

C.C.I.T.T. CONFERENCE, NEW DELHI, 1960

The second Plenary Assembly of the International Consultative Committee on Telephony and Telegraphy (C.C.I.T.T.) was held from the 21st November to 16th December, 1960, in New Delhi. At this Assembly some 375 delegates from 56 countries of the world finalised studies which had been in progress since the first Plenary Assembly in Geneva in 1956. The C.C.I.T.T. was formed at the 1956 Plenary Assembly by amalgamating the C.C.I.F. (Telephony) and C.C.I.T. (Telegraphy) and is responsible for examining problems and preparing recommendations in the fields of national and international telephony and telegraphy. The C.C.I.T.T. and its companion Committee, the C.C.I.R. (Radio), operate within the International Telecommunications Union which is a specialised agency of the United Nations.

The work of the C.C.I.T.T. is conducted in study groups and working parties, each group dealing with a particular aspect of the telecommunications field. These study groups examine and discuss current problems both by correspondence and at periodical meetings held between Plenary Assemblies.

Australia has taken a part in the activities of the International Telecommunications Union for many years and has made numerous contributions to the study of various problems. It is interesting to note that it was on the motion of the Australian delegation in 1956 that the new name for the combined C.C.I.F. and C.C.I.T. was adopted in the form C.C.I.T.T.

The team which represented Australia at the New Delhi Conference comprised Mr. C. J. Griffiths, Deputy Engineer-in-Chief, as Leader, with Messrs. L. M. Harris, R. D. Kerr and E. R. Banks from the A.P.O. Engineering Division, Messrs. A. C. Beckwith and M. G. Stevens from the A.P.O. Telecommunications Division, Messrs. A. E. Shepherd and E. C. Harcourt from The Overseas Telecommunications Commission (Australia) and Mr. H. B. Wood as company representative from Standard Telephones & Cables Pty. Ltd. (Australia). The membership of this team enabled Australia to be represented in study groups covering most phases of the Conference Agenda and this larger representation is an indication of the increasing tempo of advances in the techniques of telecommunications and its influence upon international operations.

The work of the Conference was subdivided broadly into three headings:—

Study Group Discussions—21/11/60-7/12/60.

Plan Sub-Committee for Asia and the Far East—29/11/60-2/12/60.

Plenary Assembly—8/12/60-16/12/60.

Study Group discussions covered the following fields:—

Study Group	Subject
1	General Transmission Problems.
1/1	Specification of Trunk Lines.
1/2	Use of Lines for Telephony.
1/3	Use of Lines for Telegraphy.
2	Co-ordination of Operation and Tariffs.
2/1	Telegraph Operation and Tariffs.
2/2	Telephone Operation and Tariffs.
2/4	Telephone Semi-Automatic or Automatic Operation.
3	Introduction of Radio Relay Links into the General Network.
4	Maintenance.
5	Protection against Disturbances.
6	Protection of Cable Sheaths and Poles.
7	Vocabulary, Symbols.
8	Telegraph Apparatus and Facsimile.
9	Telegraph Transmission.
10	Telegraph Switching.
11	Telephone Switching.

An important aspect of the discussions was the question of world-wide switching and signalling on a semi-automatic and automatic basis. Great impetus had been given to this question by the rapidly expanding inter-continental system of submarine telephone cables providing large numbers of high grade channels and also the prospect of deriving large blocks of channels using earth satellites in the future. Australia has a special interest in this problem because of the expected completion of the Pacific cable early in 1964 and the Australia to New Zealand link of this cable early in 1962.

As a result of the discussions a special study group has been established by the C.C.I.T.T. charged with the task of presenting to the next Plenary Assembly, to be held in Moscow in the spring of 1964, plans and technical solutions for world-wide automatic telephony. Australia took an active part in these Plenary discussions and Australian proposals for world-wide numbering were included in the Conference Report as an annex to the question to be studied on this subject.

On the telegraph side Australia's position in the field of telegraph development was recognised when Mr. R. D. Kerr was elected Chairman of Study Group 8 dealing with telegraph apparatus.

Under the new convention for the administration of the I.T.U. approved in Geneva in 1959 the role of the C.C.I.T.T. in providing technical assistance of a consultative nature to new and developing countries was strengthened. Technical assistance was a key topic at the Conference and the existing organisation was modified to allow greater emphasis to be placed on this aspect of C.C.I.T.T. work. In particular, a working party was formed under the Chairmanship of Mr. E. R. Banks (Australia) with the responsibility of study-

(Continued on page 471

OUR CONTRIBUTORS

S. C. HILTON

S. C. Hilton, author of the article "Expired Air Techniques of Artificial Respiration", joined the Department as a Trainee Lineman in 1940. He qualified for entry to the Third Division and at present holds the position of Sectional Clerk in the Regional Works and Services Section, Brisbane. For almost the entire period since 1948 he has been employed as an acting Group Engineer in the Lines Section and for the last 3½ years has been temporarily attached to Central Office. He originated and compiled the Linemen's Handbook series and has also been engaged on the preparation of other publications and engineering instructions. As a surf life saving instructor and examiner for some years, Mr. Hilton gained considerable practical experience in artificial respiration. He was the Department's delegate to the International Convention of Life Saving Techniques held in Sydney in March, 1960.

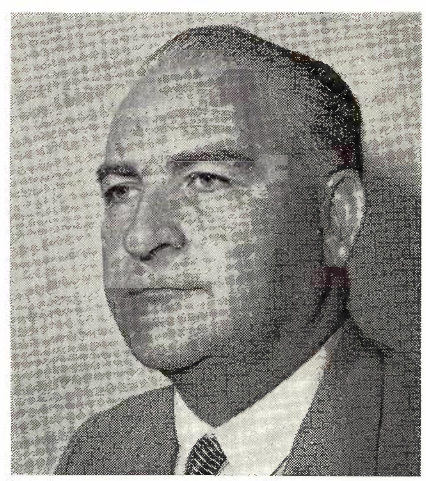
M. J. Power, author of the article "Substation Installation", is Supervising Engineer, Metropolitan Equipment Installation Section, Engineering Division, Sydney and is the Chairman of the N.S.W. Committee of the Telecommunication Society of Australia. He has had a long and active association with the Society and took over the responsibilities of State Sub-Editor following the departure of the Sub-Editor at that time, Mr. E. Sawkins, to Melbourne in 1956. Mr. Power has taken a prominent part in the installation of automatic exchange equipment during a period of heavy growth in the post-war years. He has made valuable contributions to the Telecommunication Journal and is active in furthering the development of ideas and the dissemination of information. He is an Associate Member of the Institution of Engineers (Australia). As Chairman of the Main Control Committee, House and Finance, New South Wales Division of the Australian Postal Institute, he has the responsibility for business control of the Institute. He has also carried out the functions of Chairman of a number of Committees whilst a member of the Professional Officers' Association.

M. J. POWER

A. B. Wilson, author of the article "A Multiple P.B.X.", joined the Department in Sydney as Technicians Assistant in 1945 and qualified as Technician and Senior Technician in 1952. He was engaged in Exchange and Substation maintenance until 1955 when he became a Technical Instructor Grade 2. He qualified as Engineer in 1956 and worked as Group Engineer in Metro Service and Substation Installation Divisions in Sydney. Since June, 1957, he has been specially concerned with problems of block wiring and provision of services in large office buildings and home units in Sydney.

K. W. WALLACE

K. W. Wallace, co-author of the article "The Townsville-Magnetic Island Cable," joined the Department in Queensland as Technician-in-Training in 1946 and transferred as Clerk in 1947. He was appointed Cadet Engineer in 1949 and in 1953 commenced as Engineer in Primary Works, Aerial Division, Brisbane. In 1957, after one year in Metropolitan District Works and three years' experience on major aerial construction works throughout Queensland, he went to Townsville Division where he currently holds the position of Group Engineer.



A. B. WILSON

R. W. E. HARNATH

R. W. E. (Bill) Harnath, co-author of the article "Some Thermal Problems in the Design of Coaxial Cable Telephone Systems," began his career in a bank, and studied accountancy. After two years in Army Signals and four years in the R.A.A.F. "Tels. and Radar", he completed a C.R.T.S. Associate Diploma in Radio Engineering at the Royal Melbourne Technical College, in 1950. In 1947 he joined the engineering staff of Trimax Transformers Pty. Ltd., and was responsible for the electrical and mechanical design of a wide range of communications equipment, and negotiations with various Departments and private firms. Having "seen how the other half lived", he joined the Department in 1955, entering the Long Line Equipment Section, Central Office. Since 1959 he has been Acting Divisional Engineer, Specifications, in the Works Programme Sub-section. Apart from communication engineering, his interests include management and methods, with a strong preference for problems "off the beaten track".

H. J. RUDDELL

I. A. Newstead, author of the article "Review of Telephone Traffic Engineering", joined the Public Service in 1940 at a Clerk in the Customs Department. He served with the R.A.A.F. from 1942-46 and after discharge took up appointment as Cadet Engineer. Following experience in Country Installation and Metropolitan Service Divisions, he acted as Divisional Engineer, Traffic and Trunking Studies in 1953, being subsequently appointed to that position and was promoted to Sectional Engineer, Systems Planning in 1957. In 1958, he was awarded a Public Service Scholarship for one year's post-graduate study in the subject of Telephone Traffic Engineering. The programme included representation at the Second International Teletraffic Congress at The Hague in July, 1958, and post-graduate study at the Imperial College, London, in Probability Theory and Statistics.

For the latter work Mr. Newstead has recently been awarded a Diploma of the College. Since his return he has been associated with the Regional Network Planning Group, Central Office, which is concerned with forward planning for the implementation of the new National Telephone Policy. Mr. Newstead holds the degrees of Bachelor of Science and Bachelor of Arts from Melbourne University and is an Associate Member of the Institution of Engineers, Australia.

I. A. NEWSTEAD

H. J. Ruddell, co-author of the article "The Townsville-Magnetic Island Cable", joined the Department as a Chemist Grade 1, in June, 1955. Prior to this he had 19 years of industrial technological experience in the oil industry and in the manufacture of general chemicals, rubber and plastic products. In June, 1959, he was promoted to the position of Chemist, Grade 3, where he is responsible for the investigation, development and application of plastic materials in communication equipment. He has been actively associated with the use of epoxide resins is the Department and wrote an article on this subject in Vol. 12, No. 2 of the Journal. He obtained the Diploma of Applied Chemistry of the Melbourne Technical College in November, 1949.

N. M. MACDONALD

N. M. Macdonald, co-author of the article "Some Thermal Problems in the Design of Coaxial Cable Telephone Systems" joined the Department in Melbourne in 1938 as a Cadet Engineer. He graduated Bachelor of Science at the University of Melbourne in 1941 and qualified as Engineer in 1942. After experience in the Victorian Transmission, Country, and Lines Sections he was transferred in 1947 as Divisional Engineer, Cable Carrier and Special Projects in the Long Line Equipment Section, Central Office. Since 1952 he has been Sectional Engineer in charge of the design, procurement and installation of all types of long line equipment. He has been associated with this Journal as Editor since 1950 and is currently Editor-in-Chief. Mr. Macdonald has contributed several articles to the Journal previously. He is an Associate Member of the Institution of Engineers, Australia.

T. C. Tyrer, co-author of the article "Some Thermal Problems in the Design of Coaxial Cable Telephone Systems", is the holder of a Diploma of Mechanical and Electrical Engineering (Footscray Technical School) and a B.Mech.E. degree (Melbourne University). After employment with the Army Design Directorate and subsequent service with the Royal Australian Engineers he was employed for two years by the Department of Works, Queensland, as a Mechanical Engineer, Gr. 1. In 1949 he joined the firm of J. Kitchen & Sons Pty. Ltd., and was later appointed their Construction Engineer. In May, 1956, Mr. Tryer commenced as an Engineer, Gr. 3 in the Buildings Branch, P.M.G., Central Office. He occupied the position of Acting Senior Engineer as from December, 1958. His duties included the consideration of the engineering content of building proposals, specialised investigations and the preparation of engineering instructions. Whilst with the P.M.G. Department, Mr. Tyrer became interested in electronic data processing techniques and attended lectures on the

T. C. TYRER

subject at the Melbourne University and Melbourne Technical College. In June, 1960, Mr. Tyrer joined the Commonwealth Serum Laboratories as a Senior Engineer, where he is responsible for the design and planning of plant and buildings.

C. I. Cruttenden, author of the article "Notes on the Development of Electronic Exchanges", is a native of Western Australia. Mr. Cruttenden qualified as an Engineer in 1929 and gained experience as Engineer in charge of the Northern District of that State. In 1936 he transferred to Headquarters in Melbourne and has since held a number of positions in the Telephone Equipment Section of which he is now a Supervising Engineer. Mr. Cruttenden, who is an Associate Member of the Institution of Engineers, Australia, has for many years been closely associated with the investigation of new switching techniques and their introduction into the network. In particular, he took a leading part from 1945 onwards in the introduction and development of the now nation-wide operator trunk dialling and switching scheme. More recently, as Sectional Engineer, Network Planning, he headed the group which initiated the investigation into switching systems and recommended the adoption of crossbar for application to the Australian local and trunk networks in the immediate future.

C. H. HOSKING

C. H. Hosking, author of the article "Laying the Melbourne-Morwell Coaxial Cable," joined the Department in Melbourne in 1936 as a Clerk and was appointed Cadet Engineer in 1937. After a period as Engineer in the Lines and Telephone Equipment Sections, he acted as Divisional Engineer Training (Technical) Victoria. In 1949 he was appointed Divisional Engineer, Lines Section, Central Office, where he worked in the Work Methods and Practices Subsection. He transferred back to the Victorian Administration as Divisional Engineer, District Works, in 1956 and in 1959, commenced acting as Supervising Engineer, Coaxial Cables, in the Victorian Administration. His first task in this position was the laying of Australia's first long distance coaxial cable from Melbourne to Morwell and he is now engaged on the Victorian section of the Sydney-Melbourne cable. Mr. Hosking graduated Bachelor of Science from the University of Melbourne, 1940.

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REFERENCES:

1. (I.S.) refers to a short article appearing in an "Information Section".
2. (T.N.I.) refers to a short Technical News Item.
3. C (i) (ii) (iii) (iv) are page references to the covers of the Journal.

ANSWERS TO EXAMINATION QUESTIONS

SENIOR TECHNICIAN

(Complete answers to all questions in examination papers are not given. Instead the Journal now includes answers to a few questions only from a number of recent papers. The questions selected for inclusion are those answered poorly, or of special interest or of a type not covered in recent issues of the Journal.)

C.C.I.T.T. CONFERENCE, NEW DELHI, 1960 Continued from page 464

ing a question allotted to Study Group 11 (Signalling and Switching) which was specifically framed to aid countries in the formulation and development of their switching networks. This, once again, was an endorsement of the interest that Australia has shown in the field of technical assistance not only in the C.C.I.T.T. but through such organisations as the Colombo Plan.

They *Plan Sub-Committee* for Asia and the Far East, which held its first meeting in Tokyo in May, 1959, had the responsibility of bringing the Tokyo plan up to date. This involved a review of traffic information and revision of plans recording radio circuits and main arteries of communication in the area. In the latter connection this involved proposals for a submarine telephone cable south from Japan to Indonesia and a Commonwealth cable from Australia to Hong Kong, Malaya and Singapore via New Guinea and North Borneo.

The *Plenary Assembly* reviewed the reports and recommendations of the study groups and dealt with general matters of management until the next Plenary Assembly in 1964, including such items as organisation of study groups (some major changes were made to the existing study groups), programme of work for study groups, finance and technical assistance to new and developing countries.

This was the first time that the Conference had been held outside Europe and represented a new era in worldwide co-ordination of national, international and inter-continental telecommunication networks and was an index of the rapidly increasing interest of the new and developing countries of Africa, Asia and Latin-America in the problems of these networks. Australia has much to contribute to this development.

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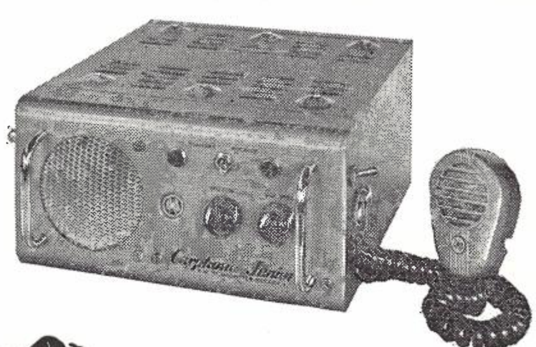

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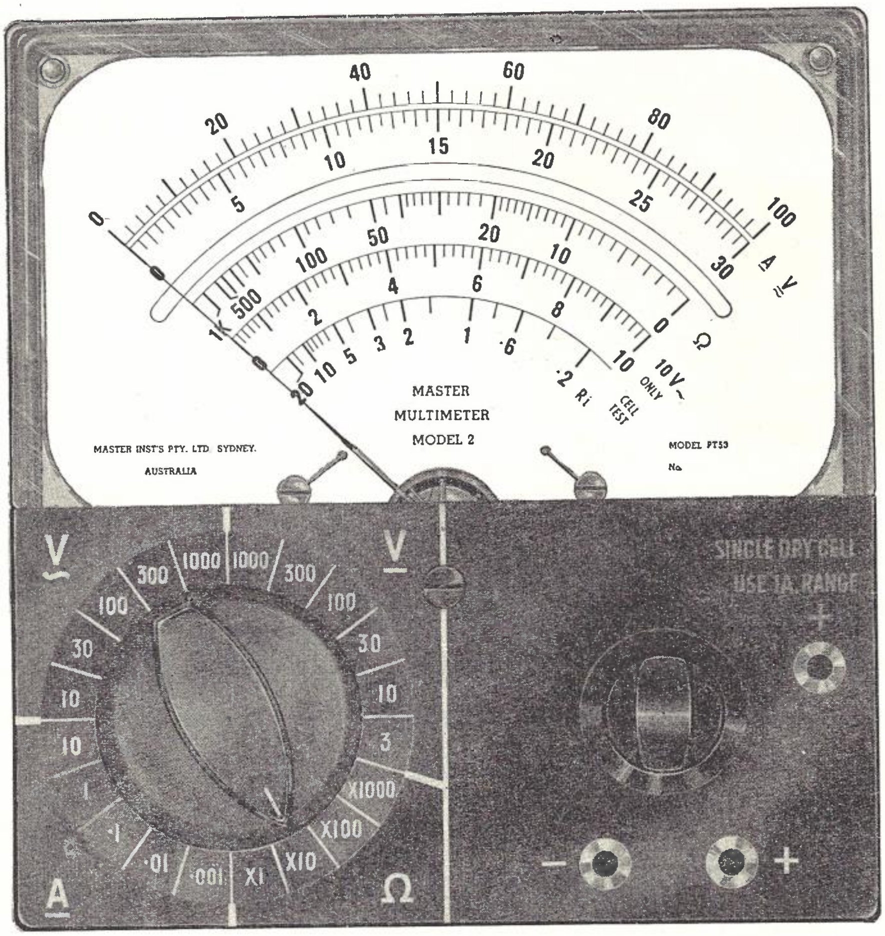

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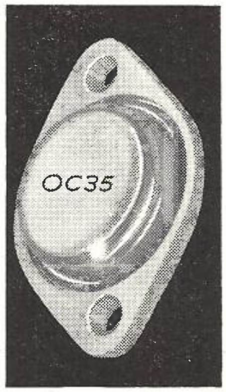
OC35

industrial power transistor



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V_{ce} max. (I_c = 6A)	-32V
I_c max.	6.0A
p_{tot} max. (at mounting base temperature 45°C)	30W
T_j max. (continuous operation)	90°C
T_j max. (intermittent operation 200 hours max.)	100°C
$\bar{\alpha}'$ (at I_c = 1A)	25 to 75
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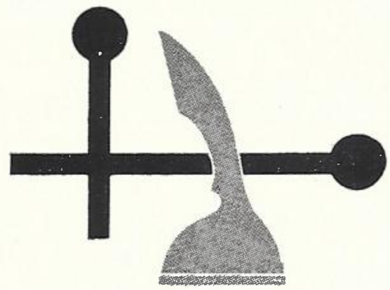

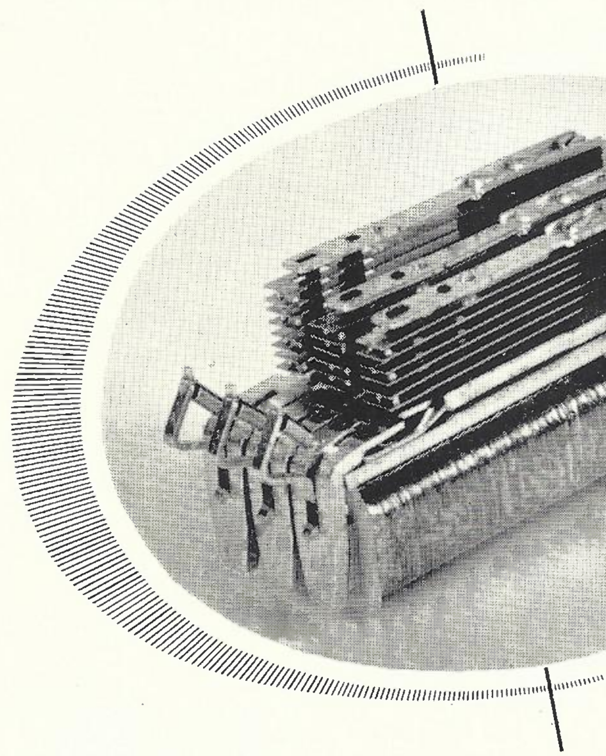

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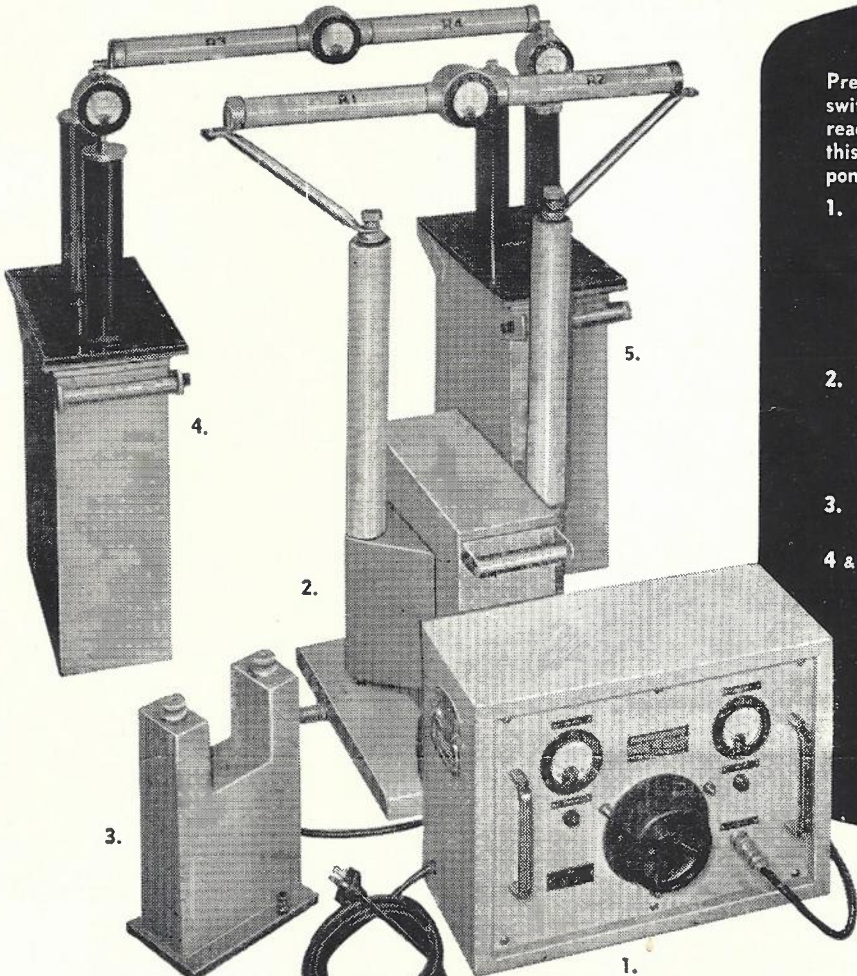

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