TELECOMMUNICATION JOURNAL OF AUSTRALIA

Errata: Vol. 18, No. 3.

1. Pages 266 to 269 are out of order. The correct order is Pages 267, 266, 269, 268.

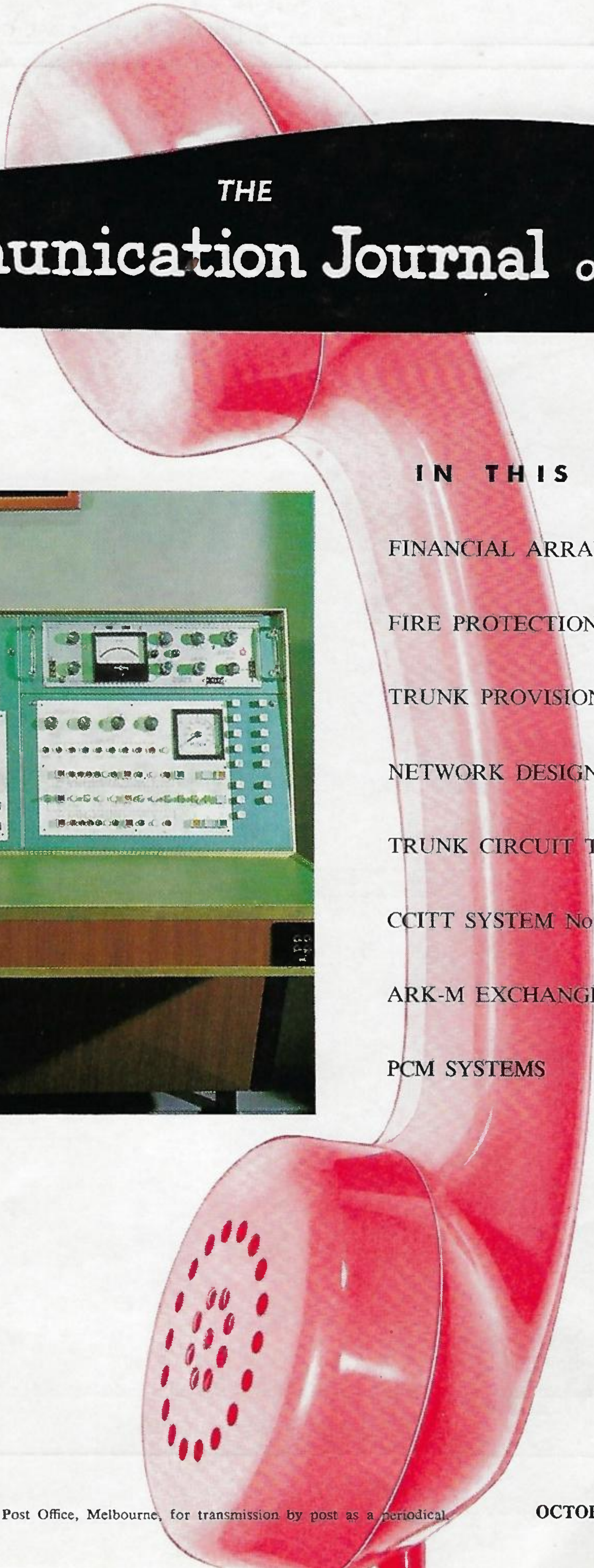
2. **Page** 271, **Fig.** 10: JF relay should have earth connected directly to it, not battery as shown.

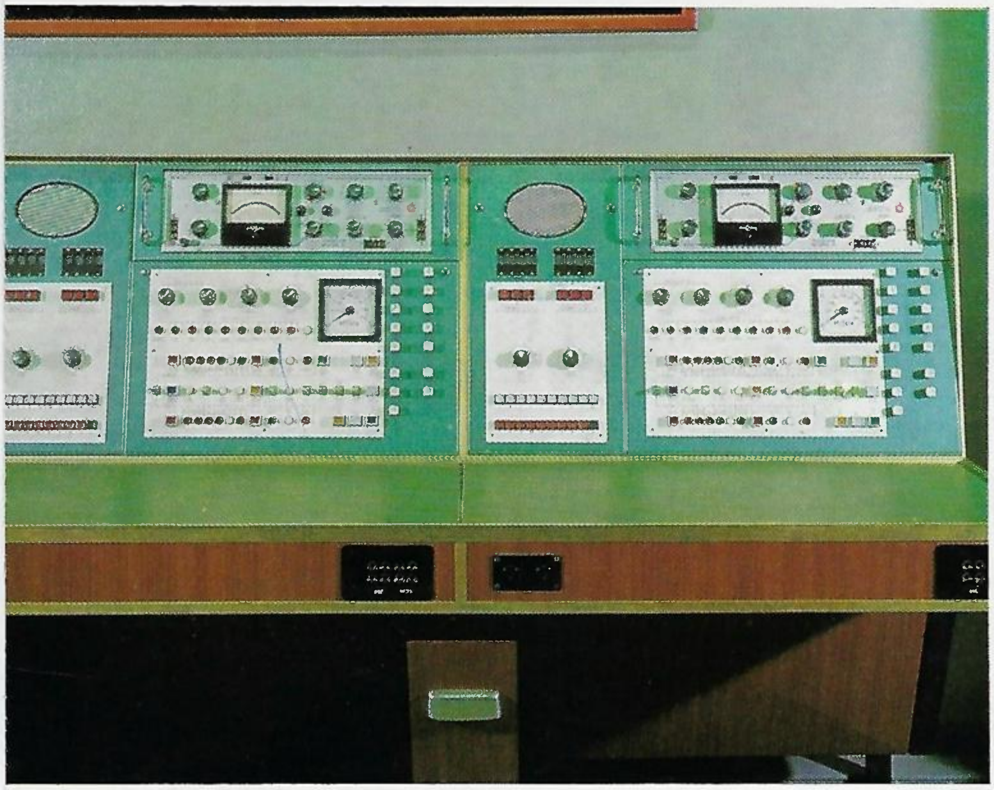
3. **Page** 282: Fig. 2 should read **Fig.** 3.

4. **Page** 288: In 3rd last line of Answer 1 (a) (i) 8E/8R should be 8E/9R.

THE

Telecommunication Journal OF AUSTRALIA





IN THIS ISSUE

VOL. 18 No. 3 Registered at the General Post Office, Melbourne, for transmission by post as a periodical. OCTOBER, 1968

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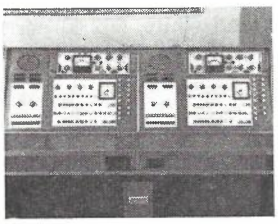

COVER
Trunk Test Console
Haymarket Exchange

The TELECOMMUNICATION JOURNAL of Australia

The Journal is issued three times a year (in February, June and October) by The Telecommunication Society of Australia. Commencing with Volume 15, each volume has comprised three numbers issued in one calendar year.

The Journal is not an official journal of the Postmaster-General's Department of Australia. The Department and the Board of Editors are not responsible for statements made or opinions expressed by authors.

Residents of Australia may order the Journal from the State Secretary of their State of residence; others should apply to the General Secretary. The subscription fee for Australian subscribers is 1 dollar per year, or 40 cents each for single numbers. For overseas subscribers the fee is 1 dollar and 50 cents per year, or 50 cents for single numbers. All rates are post free. Remittances should be made payable to The Telecommunication Society of Australia.

Information on how to prepare manuscripts for the Journal is available from members of the Board of Editors.

Contributions, letters to the editors, and subscription orders may be addressed to:

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CAB CIRCULATIONS AUDIT BOARD

Audited average circulation for year ending 31 March, 1968: 5652.

NEW FINANCIAL ARRANGEMENTS FOR THE POST OFFICE

Editorial Note: This address was presented by Mr. T. A. Housley, C.B.E., Director-General, Australian Post Office, to the P.M.G. Engineers Group, Professional Officers Association (Victorian Branch), on July 17, 1968. Mr. C. J. Griffiths, First Assistant Director-General (Engineering Works) and Mr. A. F. Spratt, First Assistant Director-General (Management Services) supported the Director-General in the discussion which followed the address.

The subject of this address and discussion is 'The New Financial Arrangements for the Post Office', but in order to understand, and appreciate, the new arrangements under which the Department now operates, a brief run-down of the arrangements which applied up to June 30, 1968, is desirable.

FORMER SYSTEM

As a Department of State, funds for the operation of the Post Office were provided each year by Parliament under the Appropriation Acts, with separate appropriations for Capital Works and Services (Assets) and Ordinary Services (Operating). These appropriations were related to estimates prepared by us, and were based upon costs applying at the time of preparation. Additional funds were voted later, usually in June of each year, to cover the increased costs, such as higher wage rates, which occurred during the financial year.

Funds were provided primarily under five classes of expenditure, namely:—

Labour
Incidentals
Materials
Mail services, and
Miscellaneous special services,

and within these primary headings, under various items, for example, salaries, wages, overtime, etc. Funds provided for a type (or even item) of expenditure could not be used for any other item of expenditure without Parliamentary approval, and savings on one item could not, in theory at least, be used to meet any over-expenditure on another item. However, with the approval of Treasury, a limited degree of flexibility did apply.

Revenue earned by the Department was credited to the Consolidated Revenue Fund of the Commonwealth and was not available to meet asset or operating expenditure.

In fact, the Post Office, as the largest business undertaking in Australia, was subject to the same Parliamentary and Treasury controls as the smallest administrative Department of the Public Service.

It will be evident that this type of financial control by the Treasury was quite inappropriate to a Department such as the Post Office which, as a business undertaking, should have greater freedom to react to the changing demands for its services and to manage its operations.

FACTORS LEADING TO ESTABLISHMENT OF NEW ARRANGEMENTS

As far back as 1953, the inadequacies of the former Treasury system of financial control of the Post Office were recognised by the Joint Parliamentary Committee of Public Accounts which, in that year, examined the accounts of the Post Office. In its report the Committee indicated that the financial arrangements then operating were not suitable for a business undertaking such as the Post Office.

In 1959, the Government appointed an Ad Hoc Committee of five members, three of whom were from the business community, one from the Department of the Treasury and one from Post Office Headquarters, to examine various matters relating to the financing of the Department's operations, and the basis of preparation of the commercial accounts of the Post Office. Among other things, the Report of this Committee made it quite evident that the financial arrangements for the Post Office were not appropriate to the effective operation of the Department, having regard to its dual role of a Department of State and of a business undertaking.

Following this Report, and at Cabinet direction, the Department and the Department of the Treasury conducted exhaustive studies of ways and means of varying the financial arrangements to enable the Post Office to operate in accordance with the best business practices.

As a result of the studies, the Postmaster-General and the Treasurer submitted a joint report to Cabinet in April 1967, and the Federal Treasurer, in his Budget Speech delivered to Parliament on the 15th August, 1967, made reference to proposed new financial arrangements for the Post Office.

It is now history that the necessary legislation to give effect to the Government's decision was passed by Parliament during the Autumn Session; and the resulting amendment of the Post and Telegraph Act became effective on the 1st July last when the Post Office Trust Account came into operation.

NEW ARRANGEMENTS — WHAT THEY INVOLVE

As from 1st July 1968 the Post Office will operate within its own trading account into which its revenue will be paid and from which its expenditures will be met. The shortfall between capital and operating expenditures and revenues will be voted by Parliament annually and will be passed to the Trading Account. This short-fall, termed net borrowings, will be appropriated by Parliament as one item of the Budget.

It will be practicable for funds to be transferred between nature votes, for example labour to material, and between what were formerly termed purpose votes, for example telegraphs to subscribers. Treasury approval is required for changes in the approved level of the capital works.

TRUST ACCOUNT OPERATION

The new arrangements will not give the Department a separate bank account.

The new trading account will be known as the Post Office Trust Account and will form part of the overall Trust Fund of the Commonwealth.

The provisions of the Audit Act and Associated Treasury Regulations and Directions will apply.

The Account will have to be maintained in balance or in credit at all times.

The proposal involves fundamental changes in our financial relations with Parliament, Treasury and several other Departments.

The added responsibility which will devolve on the Post Office under this new charter will increase the need for more effective internal arrangements to ensure proper oversight and control of its revenues and expenditures.

These arrangements can best be described as a combined budgetary and cash control system but will not replace the management control systems which currently operate, such as costs analysis, manhour trends, work scheduling and productivity factors. The purpose of the former is to optimise cash operations, whilst that of the latter is to optimise production operations.

FINANCIAL OBJECTIVES

The two main trading activities of the Department, Postal and Telecommunications, will each be given a financial objective in respect of each financial year which they will be expected to achieve. The objectives will be determined by the Postmaster-General with the concurrence of the Treasurer and may be expressed in different terms for the two services as has been done by the British Post Office (8½% on net assets, but before interest for telecommunications, and 2% on total expenditure, after interest for postal). The objectives set for each service will determine the trading results to be aimed for and will of course influence the preparation of operational budgets and any necessary tariff recommendations.

WHITE PAPER

At Budget time each year, the Minister will table a White Paper in Parliament giving details of the estimated financial results of the previous year, the capital expenditure incurred during that year, the sources from which the moneys were obtained and details of the capital programme achievements. The Paper will also indicate the estimated financial results for the year just commenced, capital expenditure proposed, the sources from which moneys will be obtained and the highlights of the proposed programme of works.

CHANGE IN TYPE OF ACCOUNTING SYSTEM

The new system is considered the most appropriate to the Post Office as a business, being based on the best commercial practice of what is called **'responsibility accounting'** — this involves the selection of areas of responsibility in accordance with the organisational structure of the Post Office.

As the old dual system of Treasury (Cash) and Commercial (Accruals) accounting placed the emphasis on capacity to spend rather than on planning to meet pre-determined financial goals, the results achieved were not necessarily consistent with those which would be expected of an organisation operating as a business undertaking.

The method of preparing estimates limited the degree of flexibility and provided little incentive for responsible financial management down the line.

OBJECTIVES OF A RESPONSIBILITY ACCOUNTING SYSTEM

(i) To fulfil the usual accounting and financial functions of the organisation.
(ii) To enable each manager in charge of a distinct area of responsibility to plan the costs and revenues as far as practicable for which he is directly responsible and formulate his own budget.
(iii) To specify the operational results for which each manager is accountable.
(iv) To assist with the control of costs by periodic Budget Performance Analyses.

RESPONSIBILITY AREAS

Because an effective budget control system already operates in the Engineering Division down to local divisional level no break-down in the responsibility accounting area beyond State level is being introduced at this stage as is the case with other Divisions. It is hoped to introduce a breakdown to Branch level next financial year with the preparation of responsibility budgets under the approved headings but even so Works budgets will still continue to be an important feature of our financial and management control techniques.

CLASSIFICATION EXPENDITURE

Instead of the detailed analysis of expenditure which operated under the Treasury system a much reduced classification of expenditure will apply under Trust Account operation. Costs accruing to a responsibility area will fall into two categories; those which are classified directly to the area at point of payment (termed directly classified expenditure) and those which are not charged directly to the area at point of payment but are charged through internal accounting and costing systems (termed costed expenditure).

'Directly Classified' — expenditures that involve concurrent cash payments, such as, staff pay and allowances, hire of vehicles and plant from outside the Post Office, collective schedule and local purchase of materials.

'Costed' — embraces issues of materials from Stores, hire of departmental transport, services provided by Departmental Workshops, etc.

In the past no such distinction has been reflected in the Engineering costing system and this poses one of the problems involved in modifying that system which is management control oriented rather than cash control oriented. However, the wide experience gained by Engineering officers in funds management under the Treasury system should enable the present form of expenditure data to be applied usefully in the cash control function pending variations to the system.

RESPONSIBILITY BUDGETS

A Budget Planning Letter will be issued to State Directors in August each year as a general guide for the preparation of budgets for the ensuing year. The letter will cover:—

(i) Traffic forecasts.
(ii) Financial objectives for trading activities and for Divisions.
(iii) Policy or service standard changes.
(iv) Programmes of revenue stimulation or cost reduction.
(v) Capital works levels to be assumed.
(vi) Assumptions of movements in costs and prices.
(vii) Expected staff levels.

Complementary letters will be issued by Divisional heads at Headquarters to their State counterparts elaborating on their divisional contributions to the overall goals.

As mentioned earlier, an effective system of budget control operates in the Engineering Division but with the new financial arrangements and net borrowings playing such an important part in negotiations with Treasury just as much attention will need to be paid to the operating as to the capital side of expenditure. Budgets for the former will need to be continually analysed at various levels in the organisation to ensure that at State level the overall responsibility budget is a reasonable one. The extent to which such responsibility budgets are extended downwards to Branch or lower levels will depend upon adjustments to the costing system and to experience in operating the new financial system in the first year or two.

BUDGET PERFORMANCE ANALYSES

Where applicable, the Chief Accountant will provide each Area Manager at the close of each month with a statement indicating the actual expenditure matched against the budgeted expenditure for the month and for the year to date.

An Area Manager will analyse his results and initiate necessary measures to correct adverse trends or to stimulate performance should this be indicated.

Directors will also be advising Headquarters of Divisional Branch performance for over-sight by controlling Divisions/Branches at Headquarters.

ADVANTAGES TO BE GAINED BY THE POST OFFICE UNDER THE NEW ARRANGEMENTS

(i) The business nature of the Department's accounting system should lead to better understanding of its overall objectives both within and outside the Department.
(ii) There should be more participation at area manager level in developing plans and objectives.
(iii) A basis for establishing the accountability of each Manager for the operational results achieved in his area of responsibility is provided.
(iv) There should be greater incentive to stimulate revenue — become increasingly sales minded — revenue conscious as well as cost conscious.

Engineers have always been expected to manage their affairs in a businesslike way — providing the service required at a minimum cost. The new system will not change the objective in any way, but will assist Engineers in their work by providing a more up to date and logical financial system framework and better information on which to control the work. The regular monthly examination and reporting system will make sure they think about financial trends regularly and this must have an influence on their other activities.

Engineers will also be required to pay regard to the total financial effects of their operations at an earlier stage of their careers than previously and this can only be to their own good as well as that of the Department.

OTHER IMPORTANT ASPECTS

Reserves

Budgets to State level should not provide for unforeseen contingencies beyond factors covered in the Budget Planning Letter. A Commonwealth provision will be made to cover likely increases in operating costs and no further funds could be expected from Treasury unless some extraordinary factor arose, for example, a wage incease far above that envisaged. Should reserves fall below budgeted levels or operating expenditure exceed budgets, we will be expected to adjust our level of expenditure and/or stimulate earnings. Should these actions fail to correct the position there will generally be no alternative but to adjust the capital works level.

Buildings and Sites Programmes

Present system of separate Votes under control of Works and Interior will disappear and future expenditure will be met from the Post Office Trust Account, enabling greater flexibility in the programming of expenditures and projects. Discussions during 1967/68 paved the way to the more direct working arrangements between these Departments and the Post Office and in fact some of these were introduced during 1967/68. In particular, amounts were set aside as reserves for Buildings and Sites in the event of final expenditure in these areas exceeding the original estimates of the Departments of Works and Interior. The programmed Buildings Vote was $19.5-$20.5 m. ($20.10 m. actually spent) and the Sites Vote was $2.3-$2.650 m. ($2.63 m. actually spent). Simple arrangements for the drawing of cheques to cover the associated payments have been agreed with Works and Interior.

In addition, there is greater flexibility in substitution of items within both Buildings and Sites programmes. Formerly Treasury had to approve such changes, but last year, in anticipation of the new arrangements, the control of such changes passed to this Department in collaboration with the Departments of Interior and Works as appropriate. Although Treasury are no longer concerned in programme changes, we still have to retain controls ourselves in the interest of smooth progress of the programmes — too many changes introduce delays.

Capital Works Funding

The level of the annual capital works programme will still be subject to the approval of the Treasurer, as will any variations to the approved level during a financial year. This control by Treasury will be necessary in the national interest.

In the past the level of the capital works programme has been the expenditure on labour, incidentals, materials issued from Main Stores and direct purchases. Under the new financial arrangements it will represent expenditure on labour, incidentals and total purchases of capital works materials.

In future, more prominence will be given to net borrowings as this will be the only item appearing in the National Budget. The lower this figure can be brought — by cost savings, by revenue stimulation — the better we might expect our prospects of success to be.

There is, therefore, a strong incentive for the Department to improve its business results and to maximise productivity in the expectation of improving the total permissible programme.

Interest Payments

The interest bill for the Post Office in 1967/68 was of the order of $83 m. which is expected to increase to about $95 m. in 1968/69. This amount is required to be paid to Treasury twice a year. As this interest will be calculated on the basis of the daily balance in the Post Office Trust Account it will be important that the credit balance at all times be the minimum necessary to finance efficient operations. The following activities which affect the interest bill will require constant control and attention:—

- Excessive stocks of materials.
- Material and services ordered, delivered and paid for ahead of when required.
- Staff recruited ahead of need or retained after need has passed.
- Unnecessary work performed and inefficient methods and procedures introduced or retained.
- Collection of money owed as promptly as possible and its bringing to account in the Trust Fund as quickly as possible.

Stocks

The old Post Office Stores and Services Account will disappear as a separate entity and all materials purchased by the Department and held in Main Stores, Engineers' Stores or in Departmental Workshops will represent the total value of the Stock Account of the Post Office. The initiative will be with the Department as to the overall level of this Account.

Financial Results v. Service Problem

The affect of operations in the Engineering area on profitability will be mainly related to productivity, minimum stocks of material compatible with productivity, cheaper designs (giving the same or better reliability) and better planning and organisation. We can't pick out profitable works and neglect others required to provide services for which we must accept a commitment under approved Regulations and Tariffs. Due regard to cost must of course be given in the setting of any service standards and reviews of the standards must be made regularly in the light of cost trends and all other factors. Having been set, however, they should not be varied by individuals in the interest of further economies.

Experience throughout the world has shown that when subscribers have been given a particular grade of telecommunication service they object strongly to a deterioration in this service. In general, improvements in technology have in themselves improved standards without extra cost and, in many cases, with appreciable improvements in productivity. Automation is a good example of this. In general, therefore, the trend in service standards is likely to be upwards rather than downwards.

MR. R. S. COLQUHOUN, A.M.I.E. AUST.

Mr. R. S. Colquhoun who was recently appointed as Assistant Director, Engineering, in the Tasmania Administration, began his Departmental service as a Junior Mechanic-in-Training in Sydney in 1938. After service as a Technician and Senior Technician in the Radio and Broadcasting Section he subsequently qualified as an Engineer and was appointed to Newcastle, N.S.W. During 1949 he was associated with the restoration of communication services following serious flooding in the Hunter Valley and until 1953, when he was promoted as Divisional Engineer, he was mainly engaged on external plant works in the Newcastle region. During this period he was involved in the design and construction of augmented junction and subscriber line facilities required when the Newcastle Unit Fee area was extended.

In 1954 Mr. Colquhoun took up the position of Divisional Engineer, Burnie, and was responsible for district works in the north-west region of Tasmania including the first major co-axial cable in that State between Burnie and Launceston. In 1965 he was promoted as Supervising Engineer, Country Section and became responsible for External Plant, Trunk Service and Radio activities. In February 1967 he directed the emergency operations necessary to restore the vast damage caused by bush fire to communications facilities in southern Tasmania. He succeeded Mr. G. W. Larsson as Assistant Director, Engineering, in October 1967.

Mr. Colquhoun has always very actively supported the affairs of the Society and is currently Chairman of the Tasmanian Division. He is an Associate Member, Institution of Engineers, Australia, is a Member of the Royal Institute of Public Administration and a Trustee of the Australian Postal Institute.

MR. R. S. COLQUHOUN

FIRE PROTECTION AND THE AUSTRALIAN POST OFFICE

*EVAN SAWKINS, O.B.E.**

INTRODUCTION

While it is comforting to believe that fires usually happen somewhere else and touch the other fellow, it is a fact that fires happen and, once this is conceded, it must be admitted that no one can be sure where, when and who will be affected and how.

In Australia during the 12 months to 31st December 1967, 213 lives were lost and 2,000 people were reported to have suffered serious burns requiring hospital treatment. The estimated property losses for the year were $97.9 million, which compared with an estimated loss of $62.6 million in 1966 and about the same figure in 1965. The 1967 figure is easily the highest ever in Australia.

These are the estimated life and property fire losses released recently by the Australian Fire Protection Association (A.F.P.A.). The estimates are based on the losses actually covered by insurance companies to which are added estimated amounts for uncovered and bush fire losses.

By way of comparison it is noted that British fire losses last year reached a record total of over £90 million stg. and the losses in the United States increased by over $U.S. 200 million to a total of $U.S.2,070 million, which was also a record.

The following is an extract from one of the publications of the A.F.P.A.:

'The fire waste touches the pocket of every man, woman and child in the nation; it strikes as surely but as quickly as indirect taxation; it merges with the cost of everything we eat and drink and wear. In this, the space age, fire is as great a menace as at any time in recorded history. Knowledge, plus eternal vigilance, are the most effective weapons man can employ in combating fire.'

The Post Office employs over 100,000 people who look after property with asset value around $1,636 million. Cables and aerial plant would amount to $760 million, engineering equipment inside buildings about $560 million, buildings themselves $160 million, vehicles $26 million and so on. The asset value of this property is growing fast and with new capital growth in prospect could conceivably double in a little over five years.

In the Post Office 'value' can have a special meaning. A telephone exchange is of little true value in isolation but linked with telephones and junctions and switching centres in a local, State and National network, it assumes value well in excess of the cost of replacing it if it were to be destroyed. Most Post Office establishments have been built up over the years through the efforts of many people and in practical terms are irreplaceable except over a long period of time. The unique nature of much of this property, the community wide repercussions that would follow its loss and the time needed to replace it are factors which contribute to its true value.

The Post Office has always had, and always will have, a tremendous responsibility to assess fire risk and to design, specify, organise and act with reason to minimise it. Within Australia, without question, there would be no other aggregation of people and property of greater value to the nation.

BROAD INTERESTS OF THE POST OFFICE AND FIRE PROTECTION

The Post Office is primarily concerned with the safety of its staff, the security of its property and the uninterrupted flow of its services. There is one other important consideration however. Especially in rural areas but also in the cities, there is undoubtedly a responsibility to co-operate with other authorities for general community protection. This involves working closely with these authorities and giving expert advice and help as well as meeting their communication needs where possible.

The close involvement of the Victorian Administration of the Post Office with State Government authorities in the development and operation of the State Disaster Plan and in the establishment of Regional Fire Co-ordinating Committees which are to be described in an article in the next issue of this Journal, is a good illustration of a relationship where all of the responsibilities of the Post Office are involved.

FIRES AND THEIR LESSONS

It will be appreciated that Post Office property is made up of the old and the new, the low rise and the high rise buildings, plant along the roads and on mountain tops, and facilities of some sort or another in virtually every place of settlement.

The Post Office has built up a careful approach to the protection of its staff and property in the wide range of circumstances and situations that exist and this approach will be covered in detail in the third article which is to follow in a later issue of this Journal.

Despite the care taken to avoid fires, the occurrence of an actual fire can bring out the importance of care with new realism. It is interesting therefore to consider some cases.

Trunk Terminal, Underwood Street, Sydney

In the early hours of Sunday, 15th June 1947, a fire occurred in the trunk terminal building in Underwood Street, Sydney. Trunk terminal equipment for all systems to the north and south were housed on the ground floor and fire broke out on an upper floor of the building and was subsequently confined to the upper floors. The trunk terminal equipment was not seriously affected by fire but was seriously damaged by water. Part of the report

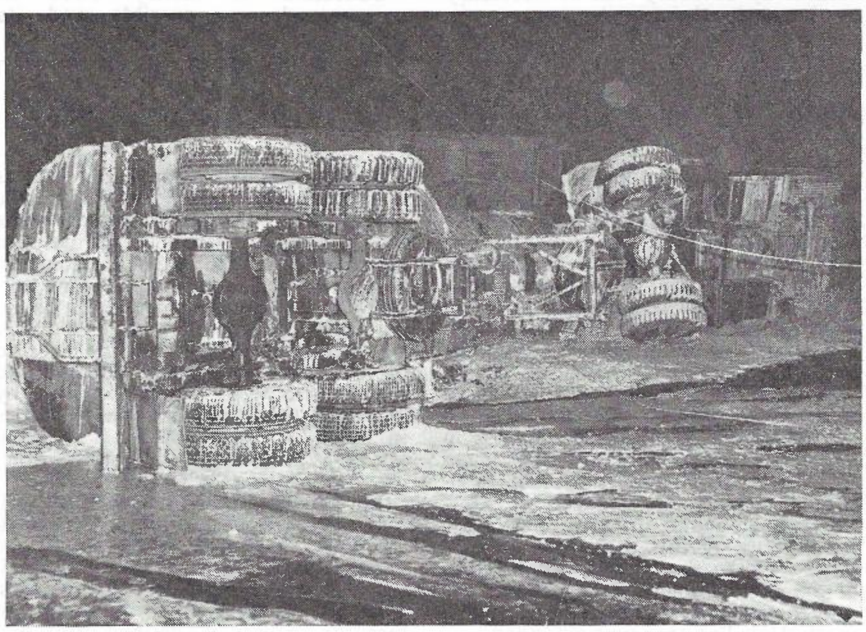

Fig. 1 — Overturned petrol tanker in Ipswich Rd., Yeronga, Brisbane. (Photo by courtesy of the Courier-Mail, Brisbane.)

* Mr. Sawkins is Deputy Director-General, Postmaster-General's Department.

on the fire in the October 1947 issue of this Journal (Ref. 1) reads:—

'Water from the fire hoses, however, poured into the ground floor from all directions; down the stairway and lift well and through the concrete ceiling. When the floor was first inspected in the early morning, the water coming through the ceiling had the character and intensity of a heavy rain storm. Throughout the night and early morning there was about 10 inches of water over the whole of the ground floor, but as from about 8 a.m., the rate of inflow eased and pumps were able gradually to reduce the level. Water continued to fall from the ceiling in gradually lessening quantities (and, later, at isolated spots only) throughout Monday and most of the following day.'

Water damage raises the question of sprinkler systems as these are accepted as the surest form of building protection. The sprinkler heads are normally spaced at about 10 ft centres and are heat actuated. In the event of fire the head in the immediate vicinity operates and discharges at a design rate varying between $4\frac{1}{2}$ and 30 gallons per minute. The operation of the head also alerts the Fire Brigade. Under most circumstances the operation of one sprinkler head will extinguish the fire or at worst hold it until the Fire Brigade arrives. Sprinklers are however, not usually installed in telecommunication areas because of the adverse effect of water on electronic equipment. Telecommunication equipment is designed to very high standards of inherent protection from fire and the prospect of fire occurring in modern installations is remote. The type of protection employed is the smoke detector, a very sensitive ionisation device which will react to small changes in the composition of the air such as the presence of a minute amount of combustion product. In most cases the Fire Brigade will be on the scene in less than 7 minutes and will attack the source of trouble with carbon dioxide.

The present policy is to provide sprinkler systems in mail exchanges as the risk of fire occurring is greater here and there are large numbers of employees to be safeguarded. A particularly serious problem in Mail Exchanges is the transfer of heat and smoke to the upper floors through the many vertical openings which are required in this class of building. The value of a sprinkler system in a mail exchange is that it may extinguish a fire before it spreads and the damage from water as well as fire may therefore be limited. Furthermore much water damaged mail can still be delivered when dry.

Although calling for fine judgment on the part of those attempting to control fires, it must be argued that once people in a building are safe, the aim should be to minimise damage whether from fire or water or smoke which settles a fine conductive carbon deposit on exposed surfaces.

The Underwood Street trunk terminal was in its day a major communications centre but would be considered relatively small compared with new centres developing today. The new Pitt buildings going up in Sydney will house Australia's International Telephone Exchange and large trunk switching and subscriber exchanges. It will cost about $7 million and initially house facilities costing $15 million to provide. The asset value of facilities on the site could exceed $31 million by 1985. It would seem that a new approach to fire protection will be necessary with this building.

Experience throughout the world is that individual fires tend to be much bigger than formerly and fire services are finding themselves at an increasing disadvantage once a blaze gets under way. One of the problems is the trend towards high density use of land in central city areas, a trend which is, of course, not peculiar to the Post Office. Modern high rise buildings, though built of fire-proof material, add to the problem of fire protection by their sheer size and height. The possibility of heavy smoke generation from a small fire amongst the contents of such a building increases risk because air conditioning requires hermetically sealed construction.

The Underwood Street fire also draws attention to the multi purpose building where there is equipment on some floors and office or other activity on other floors. It is possible that staff in the non-equipment areas will be exposed to much the same fire risk as other staff in the building but be less conscious of it. Because of the possibility of quick spread of fire or water damage or smoke, it seems necessary to preserve the same degree of alertness throughout all areas of such a building.

Fig. 2 — The fire-damaged Civic Exchange, Canberra.

Large multi purpose buildings such as the Pitt exchange building strengthen the need for attention to all aspects of sound fire protection — not only sound building construction and fire protection measures and safe internal layout of the building but also good housekeeping, regular fire drills and a continuing awareness of fire risk.

Telephone Cables, Ipswich Road, Yeronga, Brisbane

This was a fire of a different kind and the following extract from an article in the Post Office Lines staff newspaper, 'On The Line', February 1961, describes it well (see Fig. 1):—

'When a sedan car collided with a petrol tanker on busy Ipswich Road in the Brisbane suburb of Yeronga at 6.30 p.m. on November 7, it caused the most spectacular if not the most extensive cable fault of 1960.

'The tanker overturned right outside the Yeronga Fire Station and 3,500 gallons of blazing petrol were flowing down the road almost before firemen realised what had happened.

'The blazing petrol entered two manholes and penetrated 150 yards along our ducts, completely burning out two junction cables and three subscribers' cables. More than 1,700 Yeronga subscribers' services were lost and the Yeronga Exchange was 'off the air' for an hour until the damaged cables could be isolated. Two other exchanges, Sunnybank (750 subs) and Salisbury (1,150 subs) were isolated for eight hours.'

This is one example of a risk that has wide implications. Telephone cable tunnels, ducts and manholes are susceptible to the accumulation of liquids some of which can be inflammable or explosive when in the vapour form. These materials, generally petrol, may come from leakages in underground storage tanks or from spillage from tankers.

Gas or explosive vapours may also accumulate in the conduits and flow into the telephone exchanges via the cable entries. The large amount of air space under the exchange provides the opportunity for an explosive mixture to develop which, if ignited, could cause extensive damage. This possibility will be countered in the future by a policy of sealing the ducts system from the exchange cable well and by providing adequate ventilation in the well.

Civic Telephone Exchange, A.C.T.

The Civic telephone exchange serving close to 5,000 subscribers was totally destroyed by fire on the 22nd September, 1961. (See Fig. 2). It was started wilfully by vandals who threw oil around in the air conditioning room and then ignited it. The loss amounted to some $900,000 and close to 100,000 manhours were involved in the restoration of services, described in detail in Ref. 2. The maximum staff on re-establishment work reached 536 at one stage.

The availability of a large number of portable exchanges and a line depot building on the site capable of quick adaptation to take exchange equipment, supported by a magnificent effort by Post Office staff enabled the cost of restoration and the interruption to service to be minimised. Virtually every subscriber was restored within 14 days.

The Civic fire, and an increasing trend towards remote control, raise the question of fire risks in unattended buildings. On the one hand, a small fire which could have been readily extinguished if someone had been present might grow out of control in an unattended building, whilst on the other hand, there is the thought that because fires are often caused directly or indirectly by human carelessness, absence of staff may lead to a lower fire risk. Whilst this debate is unresolved, closer attention to safe design and use of alarm systems based on smoke detectors seems the safest approach.

Tasmanian Bush Fires

The Tasmanian bush fires in January 1967 destroyed $800,000 worth of Post Office plant, including a 200 line automatic exchange, a 100 line manual exchange, 11 non official post offices (see Fig. 3) and 1,400 poles and associated aerial plant over 150 miles of route; 450 subscribers' instruments were destroyed in burnt out buildings; 470 trunk channels including almost all main routes out of Hobart were interrupted.

This fire disaster, described in Ref. 3, drew attention, as previous bush fires on the mainland have done in their time, to the need for a State Disaster Plan in which the Post Office could usefully play an important role. Also we were reminded of the economic significance of cable and radio telephony as alternatives to open wire construction in high bush fire risk areas.

Bush fires in general highlight a developing service problem. When a rural district is served by a small manual exchange, the non official post office can act as an unofficial control centre in time of fire or flood, can locate volunteers, set up emergency calls and so on. However because there is a demand for continuous automatic service from these communities the Post Office is gradually replacing these exchanges with automatic ones which naturally cannot play the same role in an emergency and can quickly reach a state of traffic overload.

The Post Office has always endeavoured to maintain a service in times of crisis and in any case the

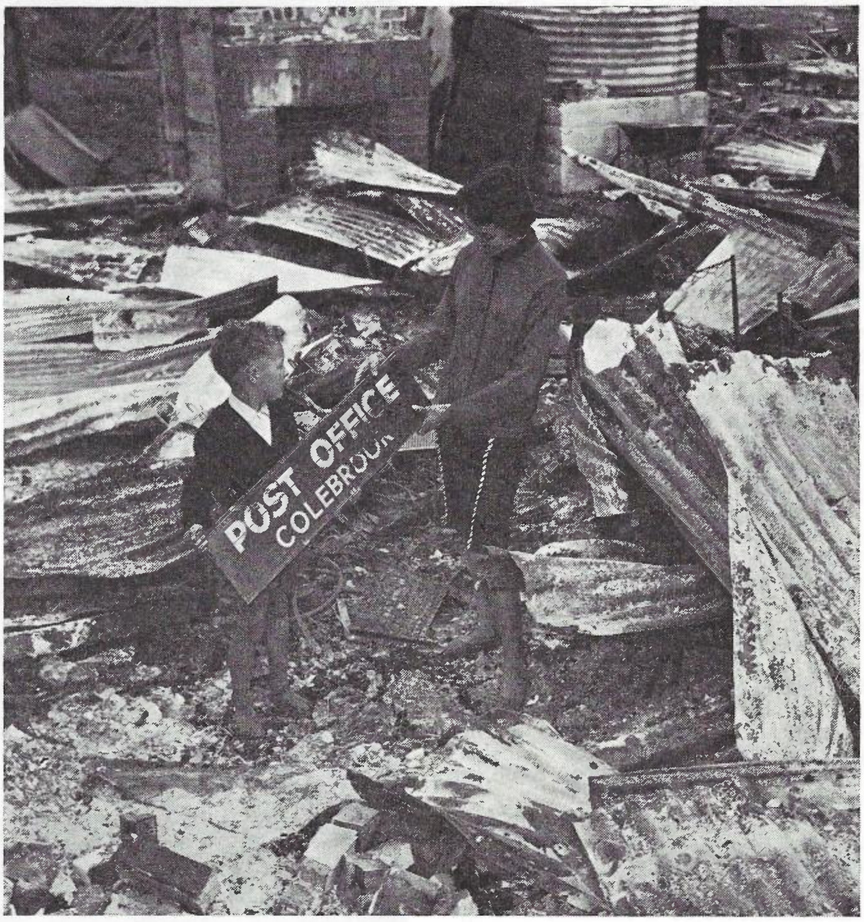

Fig. 3 — The remains of the Colebrook Post Office after the Tasmanian bush fires, January 1967. (Photo by courtesy of the Examiner, Hobart.)

safety of its own staff and property are involved in bush fires. Where the risk in an area is small the cost of the solution to the problem is of major consideration.

Mail Exchanges

On the 27th November 1967, fire caused damage estimated at $750,000 to the Melbourne mail exchange. There were only 150 people in the building at the time although a little later in the day there would have been 500. At Christmas time, on the main shift, there could be as many as 1,500 in the building and as many as 2,400 at the change of shift. The fire was probably caused by burning slag from oxy cutting operations falling into the twin band conveyor enclosure. The twin band conveyor carries mail bags from the ground floor to the top of the 4-storey building in a vertical shaft. The fire started at the bottom of this shaft, ignited the rubber belt and intense heat and flame, greatly strengthened by the flue effect, burst into the operating areas of the building. (See Fig. 4.)

This fire underlines the importance of surveillance over all extraneous activities in a building of appreciable fire loading.

A few weeks after the fire at the Melbourne mail exchange, a fire broke out on 15th December 1967 in the 10-storey parcel sorting office behind the main Manhattan post office in New York City. The following is an extract from information received on this fire by the A.F.P.A.:

'The fire started in a conveyor tunnel in the basement of the 800 ft x 200 ft sxi-story section. Trash had apparently accumulated under a heating duct installed a few inches above the floor and perpendicular to two 48 inch rubber belt conveyors which were about five feet off the floor.

Fig. 4 — The Postmaster-General, the Honourable Alan S. Hulme, inspecting damaged mail after the Melbourne Mail Exchange fire.

'Employees found the trash smouldering and extinguished the fire about 5 p.m. About four hours later, a heavy smoke condition was noticed in the tunnel and the fire department was called.

'The air duct was covered with an insulating material which had an outer layer of asphalt impregnated kraft paper.* The fire had apparently not been completely extinguished by the employees and had smouldered in the insulation for several hours.

'The fire extended to mail bags on the conveyor system and was carried from the basement through the first floor to the second, third and fourth floors of the building. There was very little fire extension on the first floor even though the conveyors were not cut off from the first floor area where they passed through. Burning mail bags were deposited on the second, third and fourth floors allowing the fire to gain a good hold in these areas. These three floors sustained almost total burn out.

'The second floor was used for receipt and despatching of mail, and about two-thirds of the floor area devoted to rail road siding. Six tracks having a total accommodation of 34 rail road cars were located on this floor. The third and fourth floors were devoted to the handling and sorting of mail.

'There was some fire damage on the fifth floor which was used by custom officials but almost no damage on the sixth floor other than smoke damage. The basement suffered some fire damage particularly along the conveyor tunnel and in a larger conveyor switching area where the mail was shunted from one conveyor to another.

'The building itself was fire resistive with concrete encased steel structural members and reinforced concrete floors. There was very little structural damage to the building. The concete did spall in places but in no area was the spalling severe enough to expose the structural steel.'

These two fires draw special attention to mail exchanges as unique fire risks areas. The presence of paper dust and other debris which is hard to control fully, and the possibility of transfer of burning material from one part of the building to another part, are special aspects of the risk situation.

City West Exchange, Melbourne

For every fire that starts, only a few gather strength and live to cause major damage. The great majority succumb to the alertness, initiative and vigorous reaction of those at hand and when recalling fires that have caused substantial damage it is well to remember this.

* The Australian Commonwealth Department of Works specifically excludes such materials from its buildings but they are legally permitted and could be present in leased buildings and in older Commonwealth erected buildings.

One fire that failed to get away occurred in the air conditioning system on the fourth floor of the City West Building, Melbourne, on 25th August 1966. The building houses power equipment and City West Exchange on the basement, ground, first and second floors, the Melbourne Trunk and Carrier Terminal on the third floor, the Automatic Trunk Exchange on the fourth floor, and the Trunk Operating suites and telephonists' amenities on the fifth and sixth floors. At that time a radio terminal was also situated on the roof of the building.

The fire was caused by material drawn in through the air inlet ducts arcing in the electrostatic filter, and igniting mineral oil used instead of a non combustible oil by a contractor during periodical maintenance of the electrostatic filter.

In describing the sequence of events, the Supervising Technician, Automatic Trunk Exchange, reported, 'At approximately 11.30 a.m. one of the staff came to my office and said that smoke was coming from the air conditioning ducts. I immediately went to the unit, switched off the precipitron supply, and opened the metal door on the air intake side. The aperture was full of smoke. The main fan of the unit was switched off to prevent further discharge of smoke to the floor. It was noticed that flames appeared low down on the precipitron framework. An attempt to extinguish this using a Pyrene extinguisher was not completely successful, as the flames continued to break out when liquid from the extinguisher was stopped. One of the staff was instructed to call the fire brigade, and to have a lift ready at the ground floor to bring them to the fourth floor. Other members of the staff were instructed to collect all available extinguishers of all types and to bring them to the scene of the fire. In this way the fire was contained until the fire brigade arrived at approximately 11.40 a.m. At 11.50 the flame and smoke had been controlled, and there appeared to be very little physical damage. The behaviour of the staff under these unusual conditions deserves full credit, as they did all that was required of them without question.'

The Supervising Technician also despatched messengers to other members of the Building Fire Committee, who disabled the air conditioning system on other floors, and arranged for a continuing supply of portable extinguishers to be taken to the seat of the fire.

Later investigation revealed that the fire had been confined to a relatively small area, but that intense heat had been generated in the vicinity. What could have developed into a disaster was controlled by intelligent action immediately the fire was discovered.

THE CHALLENGE OF APATHY

The fire prevention record of the Post Office is better than the national average but, in general, there is need for a continuing effort to improve because of the increasing size and concentration of vital facilities and the serious disruption to service that could occur if these were put out of action. The network nature of both the telecommunication and mail systems is such that the effects of fire, especially at a key centre, can extend well beyond the facilities that are damaged.

Because most personnel will have had little experience of fire situations within the Post Office, it is understandable that, in some quarters, there could be a degree of disinterest, even verging on scepticism, about the risk of fire, the threat to life, and the problems of re-establishment. The better the no-fire record is, in a particular area, the stronger may be this attitude and the more difficult would be the task of developing a sensitive approach to fire risk.

Within the Post Office there is a responsibility on everyone, especially on management including, of course, engineering management to try and ensure that the risk of fire is kept in mind in all work functions and at all times and that there is action within reason to minimise this risk.

Because fires do not occur frequently it is easy for supervisors and managers and others to leave these problems to the specialists — the Fire Protection Officers. On the other hand the Fire Protection Officers are few in number and to be effective, need the continuing interest and support of managers and supervisors and indeed of all personnel.

It seems that what is needed is a strong reciprocal approach with interest and pressure being generated both up, down and across the structure of the Post Office. Everybody must be concerned with this problem. The common objectives are to reduce risk to life as much as possible and minimise interruption to service and damage to property. It is necessary to think about the alternatives and the cost, and weigh these against the risks.

Undoubtedly, it is the little things that do not cost much that count enormously in fire safety, like good housekeeping and being alert and responsive to possible danger at all times.

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TECHNICAL NEWS ITEM

POLYTHENE AS A CABLE SHEATHING MATERIAL

Until 1957 all of the external plant cable used by the Postmaster-General's Department was sheathed with lead. The insulant used was paper wrapped around the wires making a moisture proof sheath an essential requirement. In 1957 polythene insulated and sheathed cables were introduced and although moisture vapour could penetrate the outer sheath, it had little effect on the electrical characteristics of the polythene insulated conductors in the cable.

Experience soon showed that both ants and termites would attack and pierce the polythene sheath and damage the conductor insulation making this type of cable unsuitable for use in many rural areas of Australia, and forcing the retention of lead sheathed cables with their disadvantages of cost, weight and fatigue possibilities.

For some years, Australian cable manufacturers have been exploring the possibility of extruding a thin jacket of nylon over the polythene sheath as a protection from ants and termites. This process has been used on small diameter cables for some time but the application of nylon to cables over 0.5 inches external diameter presented problems, which have only recently been solved. It is now possible to place a nylon jacket over cable of 1.5 inches diameter thereby giving ant protection to plastic insulated and sheathed cables when buried directly in the ground in rural areas.

NETWORK DESIGN FOR S.T.D.

*A. H. FREEMAN, A.M.I.E.Aust.**

INTRODUCTION

One of the most spectacular developments in telephone systems in recent years has been the extension of the distance over which subscribers may dial their own calls. This has reached the point where nearly all administrations have introduced or are planning subscriber dialling facilities for nearly all trunk calls and the prospect of world-wide subscriber dialling seems only a few years away. This development has required major changes in trunk switching equipment and the configuration of the network of trunk lines between switching centres, and this article is concerned with some aspects of these changes. Before discussing them in detail some consideration of the forces which influenced them is necessary.

The essential feature of Subscriber Trunk Dialling is that the work of setting up a trunk call which has formerly been done by a telephonist is performed by a machine. This change can greatly reduce costs. But it must be remembered that the subscriber must co-operate if the system is to be successful because the machine is limited in its ability and the subscriber has to go to the trouble of coding his requests and then dialling nine or more digits. In return for his efforts he is given more rapid service and what he may regard as a rather small reduction in costs which he has no means of checking. However, experience has shown that, provided the service is good and the dialling instructions simple, S.T.D. is welcomed by most subscribers. In order to assist in getting public acceptance most countries, including Australia, have adopted a dialling procedure in which the only coding needed by the subscriber is to decide whether or not to delete the trunk prefix, and in Australia even this is no longer essential and a subscriber who dials national numbers where the local number would suffice is still connected. This should be contrasted with some of the complex dialling instructions which applied in the early stages of the Extended Local Service Area Plan.

In this kind of a network the subscriber has no need to concern himself with the way his call is switched and indeed he has no way of finding out. The network of switching centres and trunk lines is therefore of no direct concern to him. However, in order that he may have this new facility at a comparable or lower cost than the manual network it replaces, drastic changes have had to be made in the form of the network. The reason is that the switching machines cannot do some things that a telephonist can but, on the other hand, have some capabilities that people cannot match. In particular, a telephonist can set up a queue of calls when a trunk route is overloaded and thus more easily make effective use of small groups of trunks than an automatic system, while on the other hand an automatic system can more effectively handle transist switched traffic and rapidly try a wide variety of alternatives.

In all the changes needed to set up an S.T.D. network there are two basic considerations. First of all, the network must perform properly and the subscriber must get a successful call at nearly every attempt, and subject only to this overriding condition the network must be as economical as the skill of the designers can make it.

The design of the trunk network is therefore almost entirely a cost optimisation procedure and the undoubted complexity of modern networks is the result of economic rather than technical forces. It is a matter for pride that a trunk telephone network has the logical ability of a large computer and that the Post-Master General's Department has the staff to design, install, and operate it. Nevertheless the subscriber (our customer) is quite entitled to say, "I don't care how you go about it, but I want value for the money I pay" and unless the more complex network gives him better value we have no right to indulge in it. The added complexity does, in fact, reduce costs and one object of this article is to show how this is done.

SWITCHING PRINCIPLES

Any trunk network can conveniently be regarded as made up of three (3) components; exchanges and/or switching centres where trunks may be interconnected; trunks between these centres: and a switching discipline or set of rules defining which trunk and switching plant will be used for establishing a call.

A group of trunks between two exchanges or switching centres is known as a trunk route and must have sufficient trunks to carry the traffic offered to it. Because telephone traffic is random a large group of trunks is more efficient than a small group and this is illustrated by Fig. 1 which shows the proportion of time that a trunk in a route of various sizes is occupied if one call in 500 is allowed to fail because of shortage of trunks. It will be seen that small routes are very inefficient and even a route of 10 trunks has each trunk idle for nearly two-thirds of the time. A network of exchanges and switching centres has many routes of various sizes and the number and size of them is influenced by the method of interconnection used, or switching discipline.

The switching discipline may be regarded as a specification of the facilities required in the switching equipment; as a description of the actual switching procedure in use at each switching point; or as a description of the facilities available in the equipment. Which of these three alternative views is used depends on the immediate purpose of a particular investigation.

If a new system is contemplated, there may be considerable freedom in specifying the facilities, and an investigation of the effect of a variety of switching disciplines on costs may be necessary. On the other hand, when an existing system is being expanded to meet increased traffic without change of equipment, interest will be directed to the facilities which the current switching discipline employs at each switching centre. These facilities may be less than the full repertoire available, because of a deliberate policy, in which case the specification of the full potential of the switching plant forms a third application of the concept of switching discipline.

Star and Mesh Networks

Although in reality nearly every telephone in the world is part of one huge network, and small isolated networks are exceptional, there are situations where a small group of exchanges can be regarded as an isolated system. For a small network of this kind, there are two fundamental methods of interconnection known as mesh and star networks.

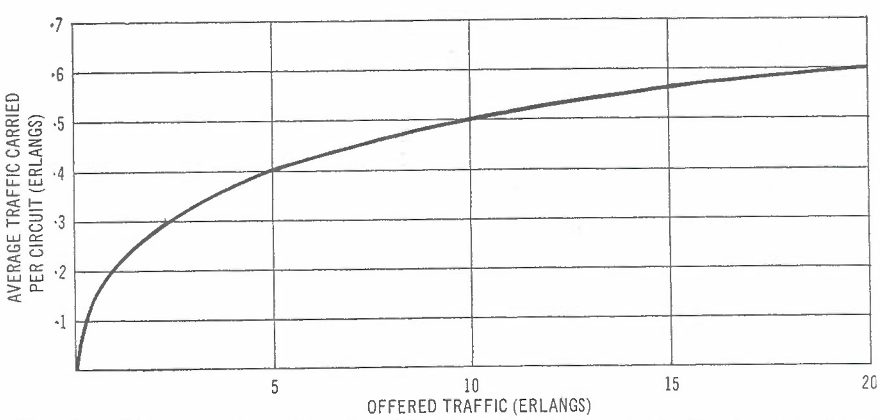


Fig. 1 — Efficiency of Junctions for Different Traffic Values (with Constant Grade of Service).

* Mr. Freeman is Engineer Class 4, Trunk Service and Telegraphs, in N.S.W.

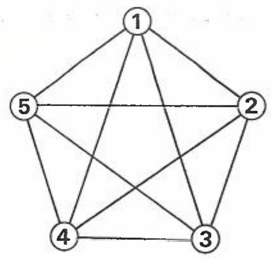


Fig. 2 — Mesh Network.

In a mesh network as shown in Fig. 2 there are individual trunk links between every pair of exchanges. Each link is designed to carry the traffic between the particular pair of exchanges with a planned probability of congestion which is usually between .002 and .02. Each link is independent of every other link, and for a large number of exchanges the number of links becomes very great and the traffic per link very small, so that the efficiency loading of the links will be poor.

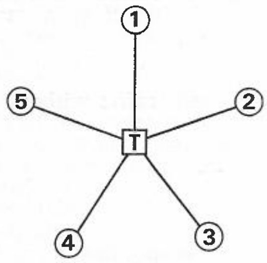


Fig. 3 — Star Network.

In a star network such as Fig. 3, every exchange has a single trunk link to a switching centre, and any call between two exchanges is switched via that centre, using two links in tandem. The number of links required for this system is lower than for a mesh network and the traffic carried per trunk higher. However, each call must traverse the switching centre and use two links so that the distance is usually longer and the total cost of the equipment used for one call is always higher. This offsets some of the gains obtained by increasing the traffic carried on each route. If the traffic is so high that the individual routes of a mesh network are fairly efficient, the gain in traffic efficiency obtained from a star network may not be sufficient to offset the effect of the longer routes. In general then, star networks are more suitable where the traffic is small, and mesh networks where the traffic is high. This conflict between direct routing leading to a mesh network of cheap trunks lightly loaded and tandem routing leading to a star network of dearer trunks, more heavily loaded, recurs throughout all network design investigations.

In most networks the traffic between exchanges is far from uniform and the traffic between two large adjacent exchanges may be a thousand times as great as that between two small exchanges located at opposite ends of the network. However, in such a network it is commonly found that only a few combinations of exchanges have large traffic volumes and the overall costs are lowest with a star network even though there are some large volumes of traffic which would have been better switched in a mesh network.

In this situation a more economical network can be made by providing a basically star network with direct routes superimposed where these are more economical than passing the traffic over the tandem. This type of network has a structure similiar to Fig. 4 and may be designed by starting with a star network carrying all the traffic and transferring traffic to direct routes where justified. For each likely direct route the cost of carrying traffic on a direct route is compared with the savings achieved on the tandem route by removing the traffic, and if the savings exceed the costs of the direct route then it is worth while providing it. The most usual method of making this comparison involves calculating the incremental cost per erlang of carrying traffic on the routes of the star network and the cost per junction of providing the direct route. Thus to decide if a direct route should be provided between exchanges A and B* the following costs are needed:—

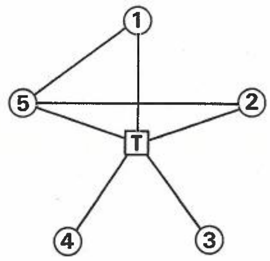


Fig. 4 — Combined Star and Mesh Network.

Cost of one direct trunk from A to B — C (ab)

Cost of carrying one erlang of traffic from A to the tandem. — K (at)

Cost of carrying one erlang of traffic from B to the tandem. — K (tb)

If E (ab) is the traffic from A to B and N (ab) is the number of junctions needed for that traffic then:-

Cost of providing the direct route is (C (ab)). (N (ab)) and savings in tandem network costs by diverting the traffic is {E (ab)} . {K (at) + K (tb) } and the condition to be met to justify the direct route is {C (ab) } . {N (ab) } < {E (ab) } . {K (at) + K (tb) } or

$$\frac{E\ (ab)}{N\ (ab)} > \frac{C\ (ab)}{K\ (at) + K\ (tb)}$$

The quantity C (ab) / {K (at) + K (tb) } is of great importance in network design and is usually designated as H (ab) and is known as a 'cost factor' or as 'marginal occupancy'. Using this symbol the condition can be written as E (ab)/N(ab) > H (ab).

* Say 1 and 5 in Fig. 4.

The left hand side of this inequality is the traffic per junction of the direct route and this must exceed the cost factor. Typical values of H are from 0.1 to 0.6, the lower values being found when the direct route is much shorter than the route via the tandem. If H = 0.5 then a direct route is only justified if the traffic exceeds 10 erlangs, and if H = 0.3 the minimum traffic which justifies a direct route is 3 erlangs.

The innocent looking expressions 'cost of a direct junction' and 'cost of carrying one erlang of traffic' are really extremely elusive when one attempts to define them precisely. One important aspect which frequently arises is that there are some costs which arise immediately it is decided to adopt a more flexible switching discipline and are then independent of further exploitation of that flexibility.

Of the three types of network so far discussed, the star and the mesh networks have identical switching patterns for all exchanges and this allows the numbering scheme to be correlated with the switching plan in such a way that step by step switching can be employed. On the other hand the combination of star and mesh trunking in Fig. 4 requires a different switching pattern for each exchange so that step by step switching cannot be employed unless a different set of dialling codes is used at each exchange. There are some networks, not accessible to the general public where this kind of numbering is employed; for example the New South Wales Railways private system and the 2VF trunk network, but for the reasons outlined earlier this cannot be tolerated in the public system. The combination of a star network with some direct routes therefore usually requires a translation of the directory number into a different routing code at each exchange as is done in the English director system. This is considerably more expensive than a step by step system and it can be seen that before adopting the system of mixed star and mesh trunking it is necessary that the total savings in network costs are greater than the cost of providing the increased flexibility. This is an important consideration in the design of all types of network, for it is no use to plan a trunk network which saves $100,000 by some elegant technique if the cost of the switching equipment must be increased by $200,000 to do it.

Hierarchical Networks

For very large networks two further extensions of the preceding techniques are needed. The first is the principle of a hierarchy of switching centres. If a small group of exchanges forming part of a larger network is treated as a star network for the traffic between them then it is possible also to switch all the traffic between this group and the rest of the network via the tandem. So far as the rest of the network is concerned this group of exchanges is now a single traffic source and destination as is shown in Fig. 5. The same thing can be done with other groups of exchanges and after the traffic with-

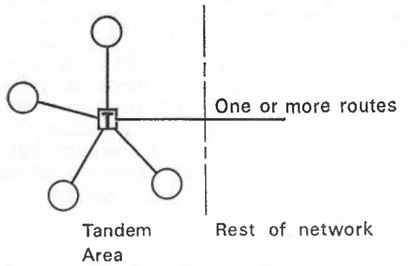


Fig. 5 — Tandem Serving Part of a Network.

in each star is handled within its own system there remains only the inter-star traffic between the tandems. It is now necessary to design a network to link these tandems, which are less numerous than the original exchanges. The traffic between any pair of tandems is likely to be large and a mesh network is likely to be the more economical but a star or mixed star and mesh can be employed if desirable. Fig. 6 shows a group of 20 exchanges interconnected via a single tandem, while Fig. 7 shows the same exchanges trunked as 4 star networks with the star points interconnected by a mesh network. The third alternative of a full

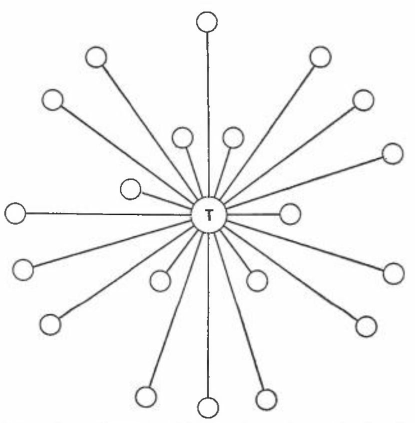


Fig. 6 — Twenty Exchanges Switched via One Tandem.

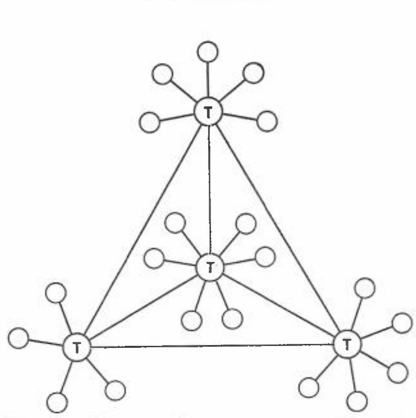


Fig. 7 — Twenty Exchanges Switched via Four Tandems.

mesh has not been drawn but would involve 190 separate junction routes. It is clear that the network with four tandems provides more direct routing than the star network for much of the traffic, while the number of separate junction routes is still small, and they are all likely to carry a reasonably large traffic.

The same principle can be extended to several levels of tandem switching points. For example, a network of 64 exchanges could be interconnected in groups of 4 via 16 tandem points, while these tandems could again be connected in groups of 4 via 4 higher level tandems, as is shown schematically in Fig. 8. Of course, in a real system each tandem is unlikely to serve precisely the same number of exchanges, and Fig. 8 is meant only to illustrate the principle. A system with more than one level of tandem switching is called hierarchical.

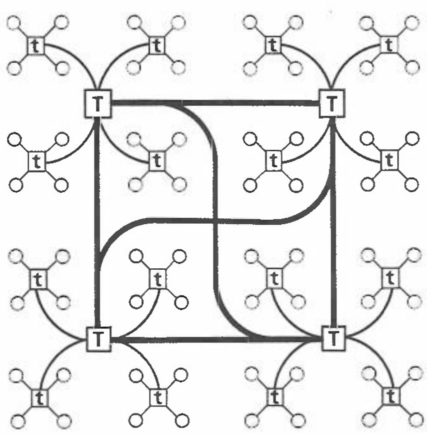


Fig. 8 — Network with Two Levels of Tandems.

The particular network of Fig. 7 is of considerable importance since it represents the most complex network which can be built without register control, and has been used in all the Australian city networks. It has further been extended by the use of switches such as DSR's which give the facility of adding some direct routes to the basic star and mesh network to give a remarkably powerful system.

The other technique is the use of alternative routing, which involves the provision of direct routes with the ability to direct the call via the tandem points if there is no free trunk on the direct route. Referring back to Fig. 4, which was a simple star network with superimposed direct routes, the direct route could only be justified if the traffic per junction exceeded the cost factor. Thus if a possible direct route has a cost factor H = 0.3, and the offered traffic is 2.0E, the direct route would require 7 junctions and carry 0.28E per junction so that it would not be justified. However, if only 3 circuits were provided, and traffic allowed to overflow via the tandem when they were all busy, these three circuits would carry 1.58E or 0.52E per junction leaving 0.42E to be carried via the tandem. The direct routes act like the first choice outlets of a grading, in carrying a large amount of traffic, while the route via the tandem is similiar to the late choice commons which carry the traffic passed on from several groups.

Alternative routing thus combines the best features of both star and mesh trunking, by using the routes via the tandem to carry the overflow traffic from the direct routes, and allows the direct routes to operate at a higher efficiency. An alternative routing network is characterised by a large number of direct routes, frequently as small as 2 or 3 junctions. In a hierarchical network these direct routes may be between terminal exchanges, from a terminal exchange to a tandem other than its parent, or between tandem centres. The problem of determining whether a direct junction route is justified, and if so how many junctions should be provided, is rather complex and is the subject of a voluminous literature.

Nomenclature

There is a large variety of systems employed by different administrations to identify the various switching centres in a hierarchical network. The CCITT nomenclature gives to the lowest level of switching centre, which provides a star point only for terminal exchanges, the name of primary centre. The second level provides a star point for primary centres and is called a secondary centre, while the higher levels are called tertiary, quaternary, etc.

The Australian Post Office designations for the same centres are Minor, Secondary, Primary and Main Trunk Switching Centres.

As in the case of simple star networks, it is usual for one building to accommodate both a terminal exchange and switching centre of more than one category, and for the relevant switching plant to be partly common to both functions.

The basis of a hierarchical system is, of course, the pattern of interconnections which form the final routing, and the process of determining this pattern is known as 'network design' and is usually regarded as a separate problem from 'network dimensioning' which is the process of deciding how many trunks will be provided on each high usage and final route of the system.

NETWORK DESIGN PRINCIPLES

In network design a number of different network configurations must be compared and the most economical of them selected. While this could, in principle, be done by dimensioning and costing each alternative, the labour involved is prohibitive as there may be hundreds of alternatives for even a small network, and it is therefore necessary to find some simpler, if less accurate, approach. One method, used in the 'COMET' study of the Sydney network, is to cost a simplified model of the real system and with the increasing size and speed of computers it may eventually be possible to take account of all significant factors in such a study. However, for a multiple level hierarchy the network design problem has not yet been reduced to a manageable mathematical model, and there is therefore still a considerable amount of subjective assessment involved in any large network design. This can be aided by mathematical studies of simplified models which at least define some boundaries within which the optimum solution should be found.

The object of a network design is, of course, to develop a minimum cost network capable of carrying the offered telephone calls, and the basis of the design must therefore be the telephone traffic. The traffic will show patterns which reflect the commercial and social structure of the community, and it is to be expected that the telephone network will likewise have features which correspond to this structure. At the same time, switching and trunk line equipment considerations have a large effect, and the usual process of network design involves simultaneous consideration of traffic flow and equipment problems. It is usual to break down the analysis of equipment factors into a number of more or less independent items, of which only one or two may be dominating in considering a particular part of the design. It is often possible to concentrate attention on one switching centre and its trunk routes.

The traffic routes associated with any one switching centre may be divided into internal routes to points within the area served by the switching centre, and external routes to points outside the area. Any call set up through the centre will either link two internal routes, in which case it may be called an internal call, or one internal and one external route, which will be designated an external call. This is a somewhat artificial sub-division which has been found convenient mainly because the costs of switching internal traffic are relatively easily estimated, while costing the external traffic presents very difficult problems.

For internal traffic the switching centre and its associated links form a star network with a good grade of service, which, depending on the provision of high usage links within the area, will carry all or part of internal traffic.

For external traffic the switching centre performs two functions. Firstly, it provides a means whereby the external traffic to and from all points within its area (except that which is direct switched past the centre) is combined to be handled as a single block of traffic, thus concentrating several relatively small volumes into a larger unit which can be more efficiently carried. If this is then directed over a single route to a higher order centre this provides concentration as a means of improving efficiency.

In addition, however, this addition of several small volumes of traffic will usually mean that there is sufficient traffic to and from specific foreign switching centres to justify high usage routes to them. The switching centre can therefore also perform a function of dispersing, or direct switching of traffic. This is not incompatible with the concentration function as the direct routes on a high usage basis do not greatly reduce the average traffic loading of the trunks from the switching centre. (Breaking one fully provided route into four fully provided routes may require 10-15 extra trunks, but a system of three high usage routes and one fully provided route will require only 1-2 extra trunks).

A switching centre thus can be regarded as a point which collects all the residual traffic from an area, deals to finality with the internal component, and, after directly switching as much external traffic as economically justified passes the remainder (a residue of the residues) to another centre more competent to deal with it. This process, of course, involves a concept of a graded series of switching centres with the thought that the more levels we provide, the higher the overall efficiency will be. There are, however, certain limitations to the number of levels which are desirable in a network.

One of these is that the cost of providing two trunk links of a given total length with an intermediate switching centre is greater than that of a single link of the same total length by an amount which is sometimes very large. This is particularly true for links between switching centres, which must be 4 wire and are usually provided by carrier systems. Over a broad band route the bearer costs are a relatively small part of the total, and even if switching costs are neglected, two carrier channels, each of 100 miles, are 50% dearer than a single carrier channel of 200 miles. Comparisons based on 'channel miles' as a unit of cost can therefore be very misleading. One effect of this is that 'concentration' in itself is an unimportant function of a switching centre of higher status than minor centres. The situation at a minor centre is slightly different, as the link from minor centre to terminal is allowed to have a moderate attenuation (6dB in Aust.) and may frequently be 2 wire. The extra cost due to breaking trunks at a minor centre will be relatively small if the terminals can all be served 2 wire from the minor centre, and there is no other potential switching centre to which the exchanges could be connected by 2 wire circuits.

SWITCHING EQUIPMENT COSTS

For purposes of network design three properties of the switching equipment can have a significant effect on the optimum design. These are establishment cost, relative costs of minor and higher order switching centres, and the centralisation of common facilities in switching centres.

It is well recognized that the cost of any switching equipment is relatively higher if it is provided in small units, mainly because it is necessary to provide certain facilities, such as batteries, rectifiers, racks, common tones and pulse supplies, and alarms, in relatively large increments, and also because installation and maintenance can be more efficiently organised for a small number of large installations than for a large number of small installations. It has been found that a satisfactory allowance for all this can be made by assuming the cost of an installation is of the form $C = A + Bn$, where n is the number of (say) inlets, and A & B are constants. A is then called the 'establishment' or 'first in' cost.

As a minor switching centre need not have 4 wire switching, it is less expensive than a secondary or higher order centre when 4 wire switching is essential. It is, moreover, possible to more closely integrate a minor centre with a terminal exchange on the same site, in which case the 'first in' costs are relatively small, as most of the first in charges would have to be met in any case for the terminal exchange. The degree of integration possible, and the effect on first in costs is of course quite variable, depending on the type of switching system employed, and can have a great influence on the network design.

There are many facilities which cannot economically be provided at every terminal exchange and are therefore centralised, almost invariably at a switching centre. This is becoming progressively more important as the range of facilities offered to the subscriber is increased, and as common control systems become more sophisticated. Where this is a matter of centralising control devices, such as registers, it means that the cost of a register link is increased, and that moving the switching centre will alter the register link cost. In other instances, such as where charging or manual trunk handling are centralised, all calls which need the facility concerned must be routed through the centre where the facility is provided. This may require calls to be switched through a particular centre purely in order that, for example, the charge rate can be determined, or for an operator to confirm that a particular person has been obtained at the called telephone. It may also require calls from A to B to be switched differently to calls from B to A.

THE N.S.W. TRUNK NETWORK

The N.S.W. trunk network is at present being reviewed as a result of a realisation that the previous design included a number of switching centres which could not be justified economically because 'first in' costs of switching centres were higher than had been expected, the previous design having been prepared about 1955 on the basis of step by step switching, before any accurate crossbar costs were available. Some aspects of this review illustrate the way in which the various factors listed above influence network design.

The telephone traffic pattern for N.S.W. has been established by analysis of a large number of dockets for manually connected trunk calls which, on the macroscopic scale, show that traffic decreases rapidly at larger distances and that in 1960 approximately 95% of all calls (trunk and local) terminated within 30 miles. There is also evidence that the growth rate of long distance traffic is higher than short distance traffic, but not sufficiently to produce a marked change.

When the details of the traffic are analysed a fairly clear pattern emerges in the rural areas (which comprise 50% of the population and 95% of the area). In these areas there are large towns of populations of 5,000 to 25,000, spaced at intervals of about 60 miles. Many of these originated as overnight stops on coach routes, and have developed into the commercial and marketing centres for the surrounding districts. A large amount of traffic is present between any one of these towns and the surrounding area, and this accounts for the bulk of short distance traffic. The pattern is often distorted by competition between adjacent towns and there are also a number of smaller towns which prospered in the days of horse transport, but whose trade is generally being captured by the larger towns.

The longer distance traffic is dominated by calls to and from Sydney, and to a smaller extent by the larger country cities which act as regional centres for a large area. However, Sydney offers so many facilities in manufacturing and service industries that only Newcastle and Canberra appear able to challenge its supremacy over any significant area. It is illuminating in this respect to peruse the pink pages of any country telephone directory.

The above comments apply particularly to the daytime peak which is largely business traffic. Night time traffic includes more social calls and tends to be more diffuse, and, although night traffic is lower in total volume and usually ignored in network design, it is possible that a system designed to carry the daytime traffic may be overloaded in some places by night traffic, particularly if the design is very closely tailored to suit the daytime dispersion.

An important feature of the traffic dispersion was that most exchanges either did not justify any high usage routes or required only one or two direct routes to adjacent exchanges and nearly all of those which justified more direct routes were likely to be switching centres. Consequently most minor areas (including the minor areas associated with secondary and higher centres) directed all their external traffic via the minor centre, and therefore, once the minor centres and their areas were determined the network could be simplified by treating each minor area as a single point.

The problem of determining the best switching network was therefore divided into two problems. Firstly, to decide which locations justified the establishment of a switching centre to perform at least the function of a minor centre for surrounding terminals, and secondly, to design a network linking these minor centres, a process which involved raising some of the centres to a higher status. The problems interacted on each other to a limited extent, and on determining the structure of the higher level network, it was necessary to review the minor centres, particularly the cases where reducing one or two marginally justified minor centres to terminal status allowed the secondary centre on which they were based to be then reduced to a minor centre.

MINOR CENTRES

The nature of the equipment proposed for the A.P.O. trunk network, and the traffic and geographical considerations, were such that the economic factors determining the location of minor centres were dominated by first in costs of the switching equipment. The A.P.O. has standardised two types of crossbar terminal exchanges, for small and large exchanges respectively.

The main features of the ARK type of exchange which is intended for small installations are that it is capable of economic extension in units of 50 or 100 lines to a maximum capacity of 1000 lines, is small enough to be installed in a transportable building, and is normally controlled by registers located at a switching centre. Consequently, its first in cost is lower than other crossbar equipment but the cost per line is higher than the larger ARF type exchange.

The ARF exchange is intended for larger installations, and has no effective upper limit in size. Subscribers' equipment is provided in modules of 1000 lines and although there is the possibility of installation in 200 line blocks, it is necessary to provide the full complement of common equipment for a partially equipped module. Other items, such as group selectors, are also provided in large modules, and the first in cost is considerably greater than for an ARK exchange.

There are likewise two types of switching centres. The less versatile is an ARF minor centre which is made up of ARF terminal exchange group selectors with special registers and line relay sets. It is usually closely integrated with an ARF terminal exchange and shares common facilities with it. Being a 2 wire switching device, the use of ARF switching equipment is confined to minor centres.

For secondary and higher order centres, where 4 wire switching is needed, an ARM exchange is necessary. This is almost completely independent of any ARF which may be sharing the same building and ARM equipment has a high first in cost and cost per line is substantial.

For the purpose of deciding whether to establish a point as a minor switching centre, it is sufficient to determine whether there are nett savings elsewhere greater than the first in cost of an ARF minor centre.

There are two possible values for the first in cost, depending on whether or not an ARF terminal exchange is required at the same location. If the terminal exchange requirements can only be met by ARF equipment, then the first in cost of the minor centre is comparatively small and consists of only those additional items which are needed to convert a terminal exchange to a minor centre.

The savings resulting from the establishment of a minor centre are mainly in carrier channels and as an indication of the order of magnitude of savings required, the first in cost of providing an ARF minor centre at an exchange which would be ARF in any case is equivalent to about 10 carrier channels, while the cost of establishing an ARF terminal exchange and minor centre at an exchange which would otherwise have required only an ARK exchange is equivalent to the cost of about 40 carrier channels.

In preparing the switching plan for N.S.W. it was assumed that ARF would be provided wherever the initial installation exceeded 600 lines or the 20 year requirement exceeded 1000 lines. It must be emphasised that this is not a planning rule, but merely a convenient method of identifying the most probable ARF exchange locations. It was discovered that in every case where ARF was justified on the above basis (except those in suburban areas of large cities) savings in trunk provision would justify establishment of a minor centre, while, at nearly every location which did not justify an ARF terminal, it was not possible to achieve savings sufficient to justify establishing a minor centre.

It was never found necessary to accurately cost the savings for a particular case, but a procedure had been devised to do so if it proved necessary, and this is described in Appendix I.

The end result of the first stage was the determination of about 130 locations in N.S.W. where the establishment of at least a minor centre was justified, and these centres all possessed in greater or lesser degree the following properties:—

(i) They were located in relatively large country towns ranging in size from a population of about 2,500 upwards.

(ii) The minor centre served an area of from 20 to 50 miles radius, within which it was the largest town and usually significantly larger than any other town in the area.

(iii) There is a large proportion of internal traffic.

(iv) External traffic is sufficient to justify trunk provision using systems based on 12 channel group ends.

(v) Trunk provision from minor centres to terminals is mainly by open wire. physical cables, and rural carrier systems.

It is fortuitous that the switching centre locations are compatible with the need for provision of ARF terminal exchanges and also located at an interface between two types of trunk provision. It may be expected, because this has occurred that the switching centre locations will remain stable for some time. The only factor which can be foreseen that may alter this is that provision of VF trunk cables is creating a new interface between the end of the cable and rural carrier systems. It is possible that demands will arise either for a very economical switching centre of limited capabilities for such locations, or for a new carrier system which can be extended in single channel increments, like rural carrier, and capable of operating over long lengths of cables (implying the need for repeaters).

Secondary and Higher Centres

Having produced, as the first stage of the network design, a list of about 130 locations each justifying the establishment of at least a minor centre, it was next necessary to define the network which will link these centres, which will involve the upgrading of some centres to a higher status. Some of the requirements of this network are described below.

Centralisation of Manual Assistance: It has been estimated that with full S.T.D. provision, the trunk operating load at most minor centres will be too small to permit an efficient manual assistance installation, and the smaller centres will obtain manual services from a nearby larger centre. These centres will therefore require 4 wire switching and were at first envisaged as cordless switchboards which would have required an ARM exchange which could be extended to become a secondary centre for automatic trunk switching. However, it was soon realised that automatic trunk switching needed only a very small number of secondary and higher centres and that the only justification for ARM exchanges was to control the cordless switchboards. In view of this, the A.P.O. developed a cord type 4 wire switchboard which does not need an ARM and this will be installed at some locations. This has eliminated the previous need to co-ordinate manual assistance centres and secondary centres.

Centralisation of Charging: The relatively high first in cost of ARM exchanges has already been mentioned, and this factor initiated the development of ARF minor centre equipment. It was originally intended that these centres would rely on their ARM secondary centre for charging on all traffic which could not be carried on fixed fee direct routes and this would have forced some traffic to be routed via the ARM purely because it had to be charged there. However, it was found to be more economical to carry out all charging at the ARF minor centre and this restriction no longer applies.

Centralisation of Echo Suppressors: Echo suppressors are needed on calls over about 2400 miles, and must be located within 1200 miles of each end of the connection. They must be at ARM exchanges, and it is desirable to limit the number of ARM exchanges at which they are provided.

The above three factors are merely cases of centralising facilities in similar form to the centralisation of many facilities at minor centres. They must be allowed for, but do not greatly complicate the problem of the network design. Of much greater importance is the fact that the network will be a multi-level hierarchy and the traffic pattern is such that there is no possibility of treating each level independently, as was done for the determination of minor centres. This makes the design much more difficult due to the much greater variety of possible alternative routes. Fig. 9 shows the possibilities, if the minor centres are grouped into secondary areas, all parented on a Main Trunk Centre in Sydney. Between minor centres 1 and 5 there are 8 different routings possible, if all high usage routes are provided, and precise dimensioning of such a network is a complex problem. It would be a major undertaking, even with a computer to dimension and cost a large number of different networks giving proper consideration to the cost of carrying out traffic over the different routes. However, by means of some less precise methods it is possible to establish some useful criteria, and it is believed that the difference in cost between various alternatives can be satisfactorily assessed in this way.

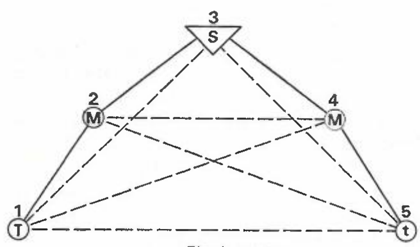


Fig. 9 — Routing Possibilities in Two Level Hierarchy.

Early attempts to analyse the problem showed that there were three factors which had a dominating influence. These were the high first in cost of ARM exchanges, the location of manual assistance points, the low value of the bearer component of trunk costs, and the high proportion of traffic directed to and from Sydney.

The first in cost of ARM exchanges has already been mentioned, and as these are necessary at any secondary or higher centre, the influence on costs is obvious.

The costs of a trunk channel can be subdivided into a distance dependent component (or bearer cost) made up of its share of external plant and of amplifiers and other line equipment, and a constant component comprising the channelling equipment at the ends, the associated relays and switching equipment at the trunk exchanges. The last few years has seen the provision in N.S.W. of many coaxial cables and large capacity radio bearers, and for these the bearer cost is much lower than for open wire and carrier cable routes. The incremental bearer cost may, in fact, be nil, since provision is made in increments which may last for 10 years or more, but even if a reasonable allowance is made for the need ultimately to increase the bearer capacity, it is still small. For example, for a 200 mile trunk on a particular typical broadband route, the distance dependent component is about 20% of the total cost. In the past the use of total channel miles, as a basis of approximate comparison of different schemes, has been frequently used, but it can be seen that total cost is probably better correlated with total channels under present conditions.

The fact that a large proportion of the traffic from most minor centres is directed to Sydney means that they will nearly all have a high usage route to Sydney of reasonable size. It will be shown later that this has quite an influence on the network design.

When presented with a problem too complex for full analysis the most common approach is to analyse one or more simpler problems derived from it, and use these results as a guide. For the case now being considered, a considerable simplification is obtained by neglecting the need to centralise manual operating, so that there are no equipment constraints on the routing of traffic. Again, since trunk costs are largely independent of distance it is possible to assume that for minor-minor routes the H factor for dimensioning will be about 0.4. This will permit the delineation of a number of routes which must exist, and indicate their sizes if they are high usage. Some of these routes will be final routes in the completed design and will then carry more traffic. The traffic remaining after offering to the justified minor centre-minor centre routes will also be known, and it is this traffic which must be switched via either the final route or some other high usage route.

One rule which can be used to select a preliminary design which is likely to need little alteration to achieve an optimum network is to choose the highest traffic route from each originating point as its final route. Applying this to the minor centres produced the result that nearly every minor centre had the route to Sydney as its final route. In other words, Sydney had over 100 centres parented on it, most of which were minors while a few were secondaries with up to three dependent minors. Further examination showed that these secondaries could all be eliminated, and the extra trunk costs would be far less than the saving by avoiding the first in cost of an ARM.

Another rule which can be used is to select as a first route that which gives the lowest cost of:—

(a) carrying the overflow traffic to the nominated parent,
(b) carrying the overflow traffic from the nominated parent to its final destination.

This rule also gave a similar solution with a few secondary centres, none of which could survive a closer examination.

However, if all minor centres are parented on Sydney the result is a vulnerable network in which a major disaster to the one central trunk exchange would fragment the trunk system into a number of isolated pockets. To overcome this vulnerabality it is necessary to choose a more expensive network, and probably to take special action in the dimensioning process to direct certain traffic on non-optimum routings. A number of centres were therefore nominated as secondary centres.

There will not be a complete mesh of links between these secondary centres, but at least there is a substantial increase in the areas which can switch clear of Sydney. This system, however, may suffer from a greater sensitivity to overload. The minor centres will still have high usage routes to Sydney, and these may carry several times as much traffic as the final routes to their secondaries. Consequently, any sharp rise in Sydney traffic may well cause severe overload of the final route. Overflow can be prohibited from the Sydney route to avoid this but it would be necessary to fully dimension two routes instead of one, and the cost increase would be excessive. One solution is the provision of a high usage route from the minor centre to its parent secondary, with both this, the Sydney route, and any other high usage routes sharing a common overflow.

Another problem is that with this network Sydney will rob traffic from the secondary centres unless positive action is taken in the design, and in the routing instructions built into the switching equipment, because very often the routing minor-Main-Minor will be more economical than Minor-Sec-Sec-Minor.

In the network finally proposed for N.S.W. all ARM exchanges in country areas were given the status of secondary centres and parented on Sydney, with a few exceptional cases parented on Brisbane or Melbourne. Manual assistance centres were provided at every ARM location, and a number of other centres. The problems which may arise due to disturbances of the ARM exchanges caused by overflows of Sydney traffic will be carefully watched as the network grows.

Another alternative was investigated of establishing a trunk centre, carrying only traffic between country centres, and acting as the Main Trunk centre for all of N.S.W. outside Sydney. In this way sufficient traffic would be accumulated to justify final routes from this centre to all secondaries, or even minor centres in the State. This system again would be expensive if it involved separate final routes from each centre to both Sydney and the proposed main centre, and would be subject to instability problems if Sydney traffic were allowed to overflow.

The above comments show that for the traffic pattern applying in N.S.W. the trunk centre at Sydney has an overwhelming superiority which makes it impossible for other centres to compete with it economically, and, moreover, that its traffic can disrupt any attempt to favour some other centre artificially. In some degree this is because no other centre outside Sydney has a network of direct routes which is outstandingly more versatile than the average.

This leads to the speculation that perhaps an essential condition for the efficient operation of a hierarchy is that any high order switching centre must be significantly different in scale and in richness of inter-connection from the centres subordinate to it. This is only a hypothesis which cannot be verified in any precise manner, nor can it be used as more than a guide for design purposes. The larger scale and greater degree of inter-connection may sometimes be achieved by the summation of the overflow of a large enough group of similar switching centres, but this did not prove successful in the present case.

NETWORKS IN OTHER COUNTRIES

Any comparison of the networks of different administrations reveals very wide differences in approach. As each of these has been optimised for the local conditions, an analysis of the circumstances leading to these varying networks could undoubtedly give much valuable information.

In examining the switching plans for U.S.A., Great Britain, Germany, Sweden and Australia one is immediately impressed by the wide variations in the areas served by the first level switching centre.

TABLE 1

Country	Area (Sq. Miles)	No. of Switching Centres	Area per Switching Centre (Sq. Miles)
U.S.A.	2,997,000	2,500	1,200
U.K.	88,000	420	200
Germany (Federal Republic)	96,000	455	200
Sweden	173,426	350	500
N.S.W.	310,000	130	2,500

It can be seen from Table 1 that the networks fall into two classes with an order of magnitude difference in the area served by one switching centre. As might be expected, these differences in scale are associated with other differences in structure, and Table 2 lists the general characteristics of networks with large and small minor switching areas.

TABLE 2

Large Minor Area	Small Minor Area
Calls within the area may be trunk rates.	All calls within area are unit fee.
Minor centre frequently has manual assistance.	Minor centre seldom has manual assistance.
Minor centre to terminal links frequently amplified with a significant amount of carrier.	Minor centre to terminal links usually passive, sometimes 2 wire amplified, hardly ever carrier.
Minor centre has elaborate common control equipment.	Minor centre usually equipped with step by step, or relatively simple common control system.

There is a very strong suggestion here that the two types of network represent a local optimum. That is, a small change in the parameters of either would lead to more expensive networks, and in particular, networks with minor areas intermediate in size between the two types are probably less economical.

It is, moreover, rather obvious that the various networks have developed a need within each country for equipment which is compatible with the network design. Consequently, where a country is large enough to support its own telecommunications industry, there is a strong tendency for a network plan, once it has been implemented, to exercise an influence on later equipment designs, which are tailored for economical application to that network.

The result is that network designs tend to be self perpetuating due both to the existing investment, and the way they encourage equipment designs compatible with them. It requires a very large change in technology, sufficient to completely shatter the economic basis of the system, before changes can be justified in a well established network.

Such a change takes place when a manual network is mechanised, particularly as a manual network is seldom well defined, and is subject to continual change as the operators, exchange supervisors, and planners attempt to optimise the routing pattern.

It is doubtful if any other change can be far-reaching enough to disturb a well established system. For example, it appears that the introduction of electronic switching in the United Kingdom will not greatly disturb the network, but rather that the network will force the electronic exchange to conform to its requirements.

If a network is largely frozen at the time it is mechanised, two conclusions may be drawn. The network will reflect the conditions applying at that time in regard to telephone calling habits, equipment costs, etc. Great changes have taken place in recent years in the relative costs of various types of switching equipment and trunk provision and the resulting trend has been described as using cheap carrier channels to allow switching points to be by-passed. On this ground it would be expected that countries which were early in the trunk mechanisation field would have networks with relatively small minor switching areas. This agrees roughly with the preceding table, as trunk mechanisation in Europe commenced earlier than in U.S.A., because national boundaries split Europe into small, almost self-contained areas, for which suitable equipment was available before 1940. U.S.A., which had no such self-contained areas, had to wait longer before suitable techniques were developed, and by this time short distance carrier systems and more economical 2 wire amplifiers were available.

The second conclusion is that once a network is established changes in technology must generally conform to the constraints inherent in that network, and it may not be possible to extract the full benefits of new technological developments. This is an inescapable fact which cannot be bypassed. However, if it is acknowledged, there are two evasive actions which will minimise its impact. First of all, it may be possible to predict trends, and design a network on the basis of expected costs a few years ahead. This will cost money now which will be wasted if the designer makes an error of judgement, so it can only be done on a limited scale. Secondly, it can be recognised that any design based on a delicate balance of various factors is more likely to become rapidly non-optimum, and that a less sophisticated approach may be more economical in the long run, if it is at the same time more tolerant of changes in parameters. Thirdly, a design with greater freedom of choice for subsequent action may be possible. For example, if the same equipment with changes in strapping can operate in a variety of switching disciplines there is more possibility of adaptation to changing circumstances.

CONCLUSION

The basic problem of network design is to determine the location and method of inter-connection of switching centres which will give the minimum network cost. The complexities of the problem have so far precluded detailed mathematical analysis, and considerable reliance must be placed on subjective assessments. Moreover, because opportunities for major revision of network designs occur very infrequently, the design is usually carried out by Engineers with very little previous experience in the field, even though their work will have a degree of permanence which is unusual in telecommunications engineering. For example the original automatic network design for Sydney, developed between 1913 and 1915, was still clearly recognisable 40 years later, and even the new crossbar tandem network design was subject to constraints arising from the earlier work.

A network design group, therefore, has an unusually responsible task and cannot make decisions lightly. It is prudent, therefore, to explore as many different methods as possible and to compare one man's views with another's. In developing the Sydney network plan and the N.S.W. trunk network, many Engineers in N.S.W. and Headquarters made contributions and the final result was one which enjoyed a consensus of support. The author was merely one of the participants in this process, while this paper contains ideas contributed by many others.

APPENDIX I

Minor Centre Costs

In the review of the N.S.W. trunk switching plan it was found that a frequent problem was to decide if a particular small minor centre was justified, or whether it was more economical to switch the exchanges concerned as terminals of a larger centre some 10 to 50 miles away. This larger centre would be the parent of the minor centre if it were established, so the two alternatives are as shown in Figs. 10 and 11.

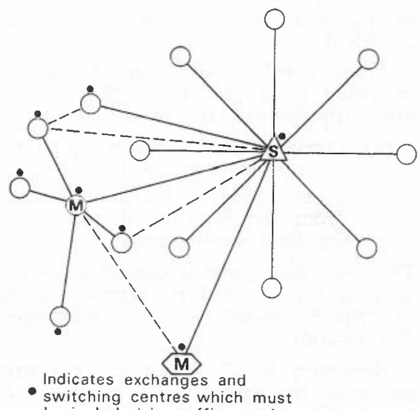


Fig. 10 — Switching Scheme with Minor Centre.

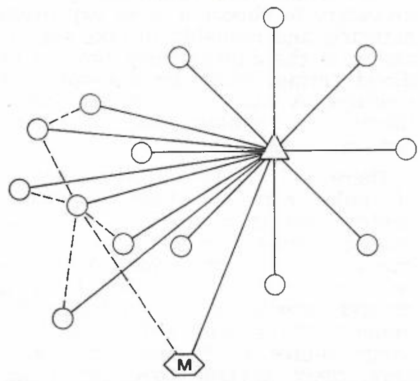


Fig. 11 — Switching Scheme without Minor Centre.

The following conditions generally applied to the traffic of the minor area under study:

(i) There was a community of interest between the minor centre and the terminal exchanges in its area.

(ii) There was also a community of interest of a similar order of magnitude between these exchanges and the secondary centres.

(iii) Very few, if any, high usage routes could be justified from the minor centre or its dependent exchanges to locations outside the secondary area.

A general method of calculating the relative costs of the two alternatives was developed and could easily be put in the form of a computer program. However, in no case was it necessary to make more than an approximate estimate, and manual calculation was more than adequate.

A traffic matrix is prepared giving traffic between all exchanges in the minor area and every exchange or switching centre to which a direct route may be justified from at least one exchange in the minor centre.

In this matrix local traffic within an exchange is omitted, and traffic to locations not listed is added to one of the other entries, usually that for traffic to the secondary centre, unless a particular high usage destination carries traffic to other locations.

Every element of the matrix can be treated as point to point traffic, as the cases where several destinations are combined are those where the traffic is handled as a single block up to the boundary of the portion of the network under study. Given the cost per circuit of all permissible links, it is now possible to dimension the network in a conventional manner for the two alternative switching schemes and compare the total costs. For the minor to be justified the savings shown by this analysis would have to exceed the 'first in' costs. However, a departure from normal techniques is desirable in two respects. Firstly, it is necessary to dimension final routes to fractional numbers of trunks to avoid an accidental advantage being given to one alternative or the other if the actual traffic levels used lead to a number of final routes which barely justify the last trunk.

Secondly, it is informative to have the costs analysed so that the cost of carrying the traffic between any pair of exchanges can be compared. For any two exchanges the total cost of carrying the traffic is the cost of the direct circuits plus a proportion of the cost of the final routes and is given by:—

$$C = \{N(d) + U/H\}\ Cd$$

Where C = Total cost.
N(d) = No. of direct circuits.
U = Traffic overflow from direct circuits.
H = Cost factor.
Cd = Cost of a direct circuit.

$\{N(d) + U/H\}$ is implicitly a function of offered traffic and H, and it was found possible in the 'Comet' study to approximate it by a sub-routine which did not actually calculate either N or U.

It is possible to calculate a reference cost assuming the highest conceivable value of H, for comparison with the costs of the two alternatives. Also, a comparison between the costs of the scheme without the minor centre and this reference network would indicate if there was any possibility of finding a minor centre that could pay for its first in costs.

MR. G. W. LARSSON M.B.E.

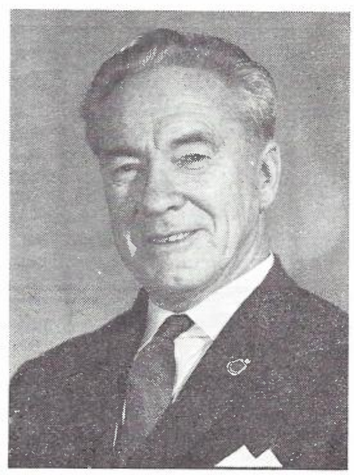
Mr. G. W. Larsson, M.B.E., E.D., A.M.I.E. Aust., M.I.R.E.E. Aust., J.P., retired from the position of Assistant Director, Engineering, Tasmania, on 20th October, 1967, after a career that began in 1923 when he joined the Department at Hobart as a Junior Mechanic. After acting as an Engineer between 1936 and 1939 and following service with the A.I.F. in which he gained the rank of Major R.A.E., he subsequently qualified for appointment as Engineer in 1947. As an Engineer he worked mainly on transmission equipment and was promoted as Divisional Engineer in 1950 and Supervising Engineer in 1954. He rose to the position of Assistant Director, Engineering, in 1955 and in this responsible role controlled engineering activities in Tasmania, until his retirement, through a period of intense development and great technological change.

Mr. Larsson's interest in Engineering and Communications was not confined only to his Departmental responsibilities. He was Chairman, Institution of Engineers, Australia, Tasmania Division 1964-65; Chairman, Institute of Radio and Electronics Engineers, Australia, Tasmania Division 1963-64; Member of Engineering Faculty, University of Tasmania 1962-67, and he was a member of the Tasmanian State Advisory Council for Engineering Education for a number of years.

Mr. Larsson was a foundation member of the Telecommunication Society in Tasmania and served as Chairman of the Tasmania Division in 1961-63. Mr. Larsson's long and enthusiatic support for the Society was recognised in 1967 when Life Membership was conferred upon him.

His activities in other fields in Tasmania included terms as Secretary and President of the Professional Officers' Association, Vice Chairman, Royal Institute of Public Administration, Trustee of Australian Postal Institute and Treasurer, Justices of Peace Association.

Mr. Larsson's splendid and generous service to the Community in so many spheres has been acknowledged in every walk of life and in 1965 Her Majesty the Queen made him a member of the Order of the British Empire.



MR. G. W. LARSSON, M.B.E.

MODERN METHODS OF MEETING THE INCREASING DEMAND FOR TELEPHONE TRUNK CIRCUITS

A. KELLOCK, B.Sc., A.M.I.E. Aust., and A. TRAILL, B.E., A.M.I.E. Aust.***

Editorial Note: This paper was presented at the Institution of Engineers, Australia, Annual Conference, 1967, in Hobart. It is published with the kind permission of the Institution.

INTRODUCTION

Composition of the Australian Trunk Network

The Australian telephone trunk network comprised 37,700 circuits and over 2,300,000 circuit-miles at June, 1966. Fig. 1 shows the proportion of this circuit-mileage which consists of physical lines (open wire or V.F. cable) and carrier. The distribution of circuits over 15 miles long into different radial distance categories is indicated in the following Table I.

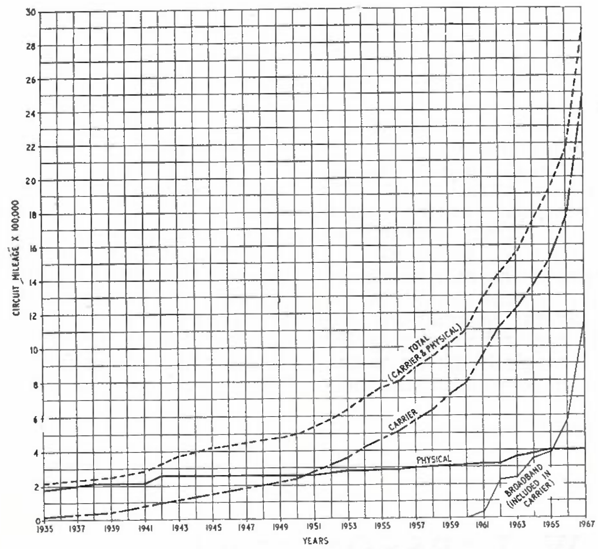


Fig. 1. — Trunk Line Circuit — Miles in Service in Australia.

TABLE I

Circuit Length (Radial)	Proportion of Circuits
16- 50 miles	62.4%
50-120 miles	21.6%
120-200 miles	7.1%
200-400 miles	3.4%
400-600 miles	4.0%
600-1000 miles	0.9%
over 1000 miles	0.6%

From this it can be seen that a large proportion of trunk circuits are less than 200 miles in length and a majority are less than 50 miles. Meeting circuit requirements over these distances is the normal task of trunk planning and installation. The provision of the relatively small proportion of requirements over long distances, which are often called for in large circuit blocks, however, represents a special problem and can be unduly difficult and expensive to resolve unless the appropriate medium is used.

Growth Rates

It can also be seen from Fig. 1 that the number of trunk circuits in service is increasing rapidly. In fact, as indicated in Fig. 2, the annual rate of increase has itself been increasing. There is an element of catching up with past deficiencies in this, but it is estimated that the total circuit requirements are likely to increase each year by at least 12 per cent over the next five years. Growth rates on main routes tend to be greater; for example, the Sydney-Melbourne trunk route has experienced an annual growth rate of about 15 per cent in recent years and Adelaide-Perth over 20 per cent. Growth rates on routes serving lesser centres tend to be less.

This tendency to increasing growth rates in the trunk network has been a common feature of the telephone systems of the more developed countries in the past decade. In Britain, for example, the annual growth rate of trunk traffic had risen to over 17 per cent by 1965 (Ref. 2) and, as an extreme case, Japan has provided circuit-miles at annual rates of over 30 per cent since 1960 (Refs. 3, 4).

The question of meeting a trunk circuit growth rate of 12 per cent, which is higher than the growth rate for subscribers (approximately 6 per cent), is partly a capital problem. Despite the decreasing cost per circuit-mile of providing trunks, this development rate is reflected in the increasing proportion of that part of the annual telecommunications capital works expenditure of the Australian Post Office (A.P.O.) which is devoted to trunk works. This has risen from 17.8 per cent in 1963/1964 to an estimated 24.6 per cent in 1966/67 and is expected to rise further.

There is also a problem of system capacity, particularly on the main routes. A 15 per cent growth rate results in the number of circuits required being multiplied by 4 in 10 years and by over 16 in 20 years. Since new systems are normally provided to cater for at least 20-year requirements, it is apparent that on the major routes, only a broadband system (which may be described as having a bandwidth of a megacycle/sec. or more and in the A.P.O. is normally accepted as having capacity of 300 cir-

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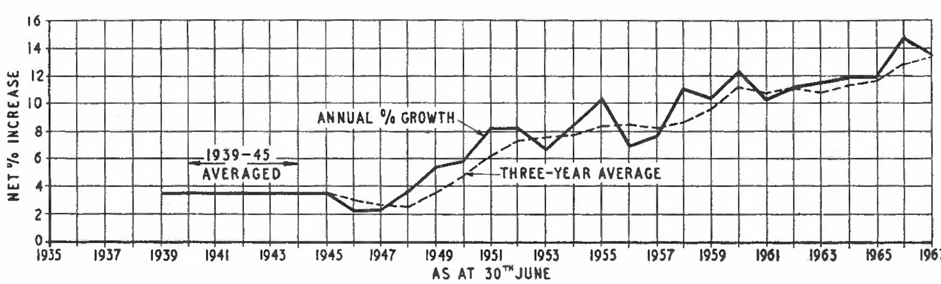

Fig. 2. — Percentage Net Increase in Trunk Circuits in Service in Australia.

cuits or more) will have adequate capacity. There are enough routes of this type for the planning emphasis to have changed recently from the problems of a single link to the overall integration of a broadband network. The planning of the Australian broadband network will be described later.

The most extreme example of rapid development on a main route leading to heavy demands on system capacity has been the Sydney-Melbourne route. Fig. 3 shows provision at various periods of the total number of through circuits on this route terminating at Sydney, Melbourne or other capital cities (e.g., between Melbourne and Brisbane). The provision which will be made over the next two years is shown dotted.

Fortunately, the necessary techniques had advanced sufficiently for both microwave-radio and coaxial-cable broadband systems to be adequately engineered by the time the capacities of the main aerial routes in Australia, notably Sydney-Melbourne, were being severely strained. The first broadband system to be installed in this country was a 600-channel microwave-radio system working in the 4-gigacycles/second (Gc/s) band between Melbourne and Bendigo which was completed in December, 1959. (1 Gc/s is 1,000 Mc/s.) Fig. 1 shows the rapid advance in broadband installations since that date as reflected in the total circuit-miles provided by this means.

The progress from open-wire and cable-carrier systems of 12- and 24-channel capacity to broadband systems with 960 or more channels, represented a discontinuity in the development of system capacity and the gap is now being filled. The fact that a route with 40-65 existing circuits and with a growth rate of 8 per cent would require 200-300 circuit capacity in the planning period, shows that economic systems of medium capacity could have been employed for some time past. More recently, however, the large-scale installation of broadband systems has heavily underlined a requirement for capacities up to the order of 300 circuits as spur routes from drop-out stations. A generation of economic, medium capacity systems has recently come forward and other systems promising even cheaper solutions to this problem are being examined.

The Effect of Subscriber Trunk Dialling

The importance of meeting trunk circuit requirements of the order discussed has assumed a different dimension with the introduction of Subscriber Trunk Dialling (S.T.D.) which is now beginning to be introduced on a wide scale throughout the network to meet the objective of having 66 per cent of all trunk calls dialled by the subscriber by 1975 (Ref. 5).

Under manual operation it has been possible to operate trunk routes with less than the required number of circuits in cases where resource limitations have resulted in under-provision. Manual telephonists can smooth peaks in originated trunk traffic by reverting a call to an originating subscriber when a circuit becomes free. With S.T.D. working, traffic peaks must be met on demand with a reasonable grade of service (a normal standard of one lost call in 100 from circuit unavailability) otherwise exchange congestion becomes severe as repeated calls begin to busy common equipment in trunk switching centres. Calls encountering congestion are offered alternate routes and there is a tendency for the congestion to spread throughout the network.

With the opening of S.T.D. on a route it is essential to provide adequate trunk-circuit capacity on that route to cope with unexpected increases in demand. The forward planning of these routes is thus a vital factor in the implementation of the S.T.D. policy. On long open-wire routes, it is very difficult to add circuits quickly in response to unexpected traffic increases. Broadband systems, however, offer not only the ultimate circuit capacity required on main routes but also the opportunity to add relatively large blocks of circuits at short notice by addition of terminal equipment. For this reason broadband systems are an important adjunct to the introduction of S.T.D. and will find extensive application between major trunk switching centres.

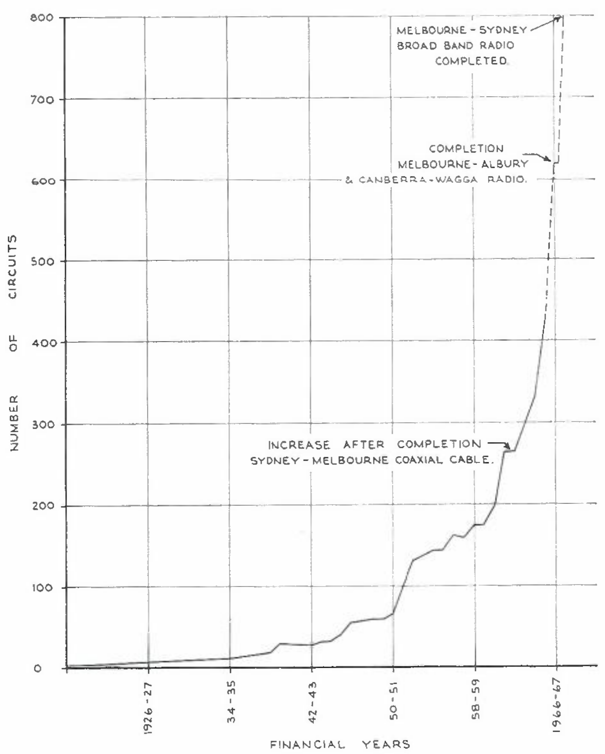

Fig. 3. — Through-Circuit Provision on Sydney-Melbourne Route.

SMALL TO MEDIUM CAPACITY SYSTEMS

Available Systems

A large proportion of the trunk routes in this country are not expected to require more than the order of 400 circuits in the normal 20-year planning period and there are a variety of low- and medium-capacity systems available to meet this type of development (Ref. 6).

Open-Wire Systems: Open-wire trunk routes are expensive to maintain and relatively limited in circuit capacity, even with the addition of carrier systems. Over the past decade improved methods of construction and maintenance have reduced costs, but the number of new routes being constructed in Australia has declined sharply. Exploitation of the capacity of existing routes by addition of carrier systems, however, has been general. All existing open-wire systems operate on a frequency-segregated basis on two wires, i.e., separate frequency bands are used in the "go" and "return" directions of transmission.

Three-channel systems occupy the 6-30 kilocycles/second band, sending 6-17 kc/s in one direction and 19-30 kc/s in the other. Repeaters are required every 200 miles approximately, depending on the gauge of wire and other factors. Three-channel systems are installed in declining numbers now and are mostly applied over 50-150 miles.

Twelve-channel systems extend the number of circuits on a pair of wires by utilising the adjacent frequency band (36-143 kc/s) (Ref. 7). Repeaters are required every 70 miles approximately, and normally necessitate a building and power supply equipment. In the immediate post-war years this was the most commonly exploited method of gaining trunk circuits, particularly over the longer distances. This type of carrier system is also now of less importance and nearly all are being installed over distances which do not call for an intermediate repeater; the majority are being applied to links under 50 miles in length.

Limited use has been made of "high frequency" 12-channel systems in the next higher band (162-300 kc/s). The noise and crosstalk suffered at these frequencies on normal open wires dictates the use of compandors which give an advantage in this respect, at the cost of some deterioration in quality. The application of these systems has been limited to distances of less than 200-300 miles to date.

Less expensive, rural-carrier systems (14-172 kc/s) providing up to 10 circuits each have also been used on open-wire terminal links to country exchanges since 1958 (Ref. 8). Equipment arrangements permit channels to be dropped along the route at low cost. Unlike the other open-wire carrier systems which are of the suppressed-carrier, single-sideband type, rural-carrier systems transmit the channel carrier frequency and both sidebands. This results in 8-kc/s separation between the channels in each direction instead of the 4 kc/s for most single-sideband systems. Compandors are also used in these systems, the noise advantages permitting their use on open wires which have the simpler and cheaper transposition patterns. The effect of the special technical arrangements in these systems is to allow rural carriers to be strong contenders with voice-frequency cables to provide circuits over short distances. This is particularly valid in the case of existing open-wire routes and they have wide application in country areas.

Each of these types of carrier system now includes transistors in place of valves and power requirements are accordingly less. However, the circuit capacity of open-wire routes fully equipped with carrier systems is generally limited to about 100-120 circuits, and in many cases this is inadequate. On the main routes, open-wire routes are being superseded by broadband systems.

Voice-Frequency Cables: Voice-frequency cables are frequently used for the provision of shorter distance trunk circuits. The circuit can either be two-wire type using negative-impedance repeaters to reduce circuit losses, or four-wire using separate pairs of a cable quad for "go" and "return", losses being reduced by conventional V.F. amplifiers. Their advantage for short distances lies in the relatively cheap terminal equipment.

Balanced-Pair Cable Carrier: The most formidable problem of pair cables for carrier working is the characteristic of increasing crosstalk with increasing frequency which eventually becomes very difficult to neutralise by capacity balancing. Each quad in specially designed carrier cables receives a separate lay to minimise crosstalk and this in practice limits their size to 12 quads (24 pairs). Voice-frequency cables can also be used for cable-carrier systems but, in this case, crosstalk limits their use to a few specially selected pairs.

During the 1940's a number of carrier cables were installed on the heavier routes out of capital cities over distances of up to 150 miles. They were operated four-wire using separate "go" and "return" cables to avoid near-end directional crosstalk problems. Carrier systems have been installed with capacities ranging from 9 to 48 channels. The larger capacities were made possible by the fact that the upper frequency required in a 4-wire system is approximately half that needed for a segregated-frequency system of the same capacity. However, with twice the pair requirement for a system, the total capacity of the pairs in two cables is the same. The additional costs attributable to separate cable sheaths limited the economic field of the two-cable carrier system which has not been installed in recent years.

The pair-cable carrier system in general use today is the Z12N system which provides 12 circuits on a single pair, transmitting 6-54 kc/s in one direction and 60-108 kc/s in the other (Ref. 11). It is finding extensive use for extending the life of existing V.F. cables by installation on selected pairs. Its economic range has been widened by development of transistorised repeaters suitable for installing in a small above-ground cabinet, and by power-feeding along the cable. This avoids the need for a building and power-supply equipment at the repeaters. Repeater spacing in 20-lb. V.F. cable is approximately 7 miles, but with the power-fed system it will be 4½ miles. The first system of this type will be installed later this year.

A special type of balanced-pair cable-carrier system is under consideration in the A.P.O. An inexpensive nylon-sheathed copper-shielded single quad (2 pairs of 40-lb. conductors) cable has been designed for the purpose of transmitting frequencies up to the range of 550 kc/s, taking advantage of the limited problem of crosstalk coupling in such a cable. A number of possible systems are being considered to provide approximately 240 circuits capacity using two cables (Ref. 9). These include two-wire 60-channel systems (the second cable could be deferred in this case until more than 120 circuits are required), four-wire 120-channel systems (two systems for ultimate capacity) and four-wire 240-300 channel systems. Costs of suitable equipment are not yet available, but on the basis of extrapolations made from coaxial-cable equipment, the single-quad cable system promises to be a useful addition to the range of medium-capacity systems. The initial investment in the bearer system is not large and the possibility of through-connection of supergroups 1 and 2 (without further demodulation) at broadband supergroup dropout points, invites its application as a spur route to coaxial-cable or microwave systems. In the case of low initial requirements, up to two Z12N systems could be installed initially to be replaced by the larger capacity system when more than 24 circuits are required.

The Selection of a System

The selection of the most appropriate of these systems for any application depends primarily on the comparative costs involved, although factors of system capacity may be relevant.

It is difficult to generalise as to the most economic trunk system for a particular route. There are many variables which could differ substantially in each application, e.g.—

(a) The need to consider wayside circuit requirements along the route.
(b) The suitability of the terrain for cable laying or for radio site development.
(c) The order of accuracy which would be expected of the estimated circuit requirements.
(d) Whether existing facilities can be shared by the new systems.
(e) Whether through-group connection is possible.

In practice, therefore, a separate study is generally necessary in each case to determine the appropriate choice of a system.

A generalised economic comparison of the total costs associated with each of the numerous trunk line systems in meeting a low and medium trunk development over distances up to 70 miles does, however, enable each system to be placed in its approximate perspective. In this context a study has been made of the relationship between the present value of annual charges, including maintenance, associated with a particular trunk system under "average" conditions for three typical discrete levels of trunk development between two centres and with varying distance between them.

The various additions to plant are assumed to be made only when required to meet development. Sinking fund charges take account of different plant lives. Details of the maintenance rates, estimated plant lives, etc., used in the generalised economic comparison are given in Appendix I.

Three orders of growth, typical of many trunk routes, were used in the calculation and the results are shown respectively in Graphs A, B and C of Fig. 4:

(A) 20 circuits initially growing to 60 circuits in 20 years.
(B) 60 circuits initially growing to 240 in 20 years.
(C) 100 circuits initially growing to 400 in 20 years.

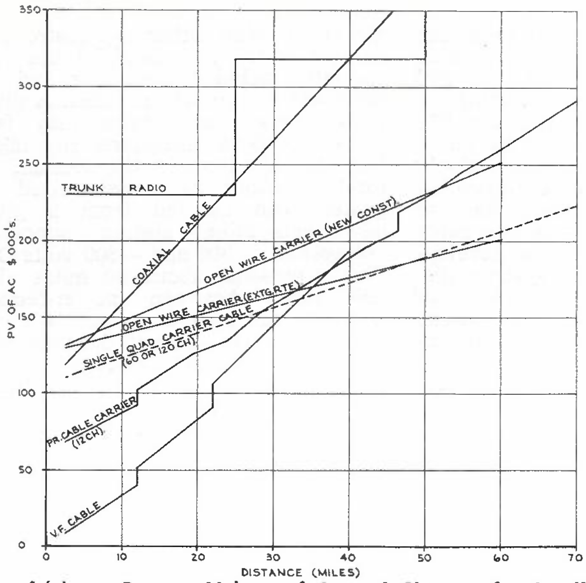

Fig. 4 (a). — **Present Values of Annual Charges for Small to Medium-Capacity Systems. (Graph A—Rate of Trunk Development, 20 circuits initially, 60 in 20 years).**

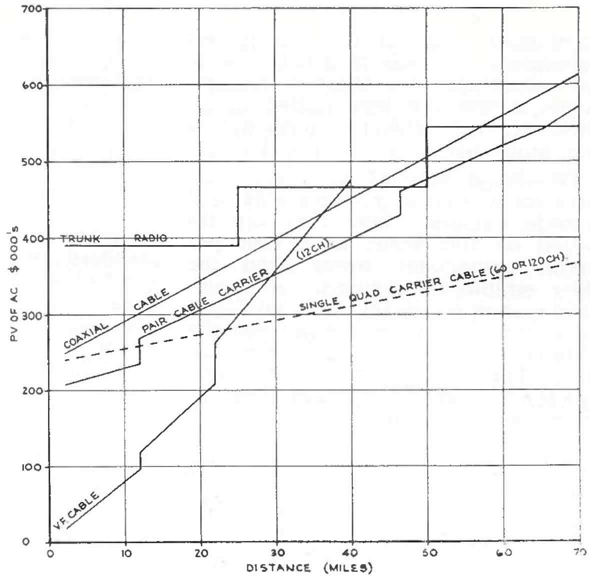

Fig. 4 (b). — **Present Values of Annual Charges for Small to Medium-Capacity Systems. (Graph B—Rate of Trunk Development, 60 circuits initially, 240 in 20 years).**

Except for the existing open-wire route in Graph A, all systems are assumed to have no installed component existing at the time of the study.

It is emphasised that the results can be taken only as approximate because of the particular factors associated with every requirement and because of the variation of relative costs with time. For particular applications there is a case for investigation of every system which the generalised graphs show to be in the same cost vicinity.

It can be seen, however, that V.F. cables have a definite application for low to medium development, over shorter distances up to a distance of the order of 30 miles, dropping slightly in range if the development level is higher.

Beyond this range a number of systems are possible at present. Open-wire carrier on an existing route merits examination if development is low, pair-cable carrier if it is higher. However, in this latter case it is marginal in cost compared with medium-capacity coaxial-cable and microwave-radio system costs and in many cases they would be preferred because of their greater capacity. For the upper level of development there is little doubt that the broadband systems would normally be preferred.

If, however, costs of the single-quad cable systems are of the order expected, they are likely to have wide application beyond the distance range of V.F. cable particularly for the higher development levels.

BROADBAND SYSTEMS

The Economics of Broadband Systems

Broadband systems include two basic types: coaxial cable and microwave radio (Ref. 12). These media provide the bearers to which channelling equipment can be added in order to derive circuits.

The choice between microwave radio and coaxial cable mainly depends on comparative costs. Coaxial cables tend to be capable of serving substantial wayside circuit requirements more economically. Noise requirements restrict the number of demodulation points on long-haul microwave routes. Most Australian microwave routes are designed for long-distance traffic in accordance with the C.C.I.R. hypothetical reference circuit (Ref. 24, p. 58) in which the standard average length between demodulating repeaters or terminals is 175 miles. This inhibits the ability of a microwave system to serve wayside towns which must be connected to the nearest demodulating repeater by a minor trunk cable, an open-wire route or an auxiliary radio system, and this is provided at a cost penalty.

Capital cost factors tend to favour microwave radio but on the basis of present value of all charges the situation is more marginal. The recent development of the "buried" transistorised, coaxial-cable repeater has tended to favour coaxial cable on a present value basis on routes with

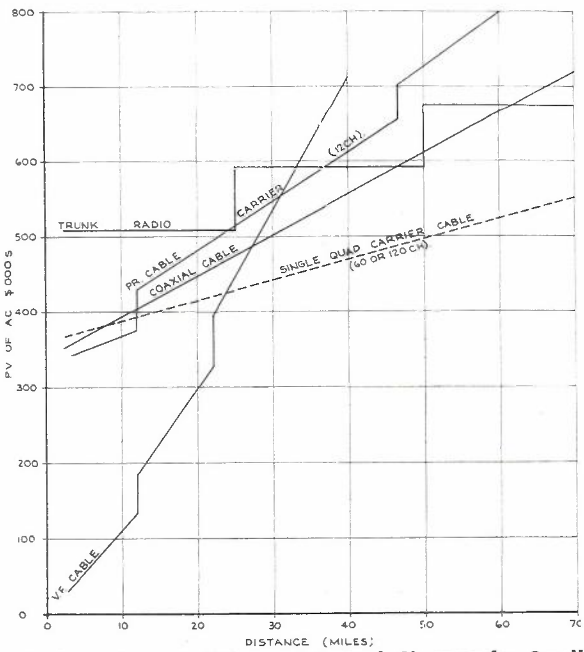

Fig. 4 (c). — **Present Values of Annual Charges for Small to Medium-Capacity Systems. (Graph C—Rate of Trunk Development, 100 circuits initially, 400 in 20 years).**

substantial intermediate circuit requirements, whereas microwave radio has advantages for through requirements across the less settled areas. However, each project requires individual study before a selection is made.

Broadband systems not only meet large-scale circuit requirements but provide circuits, where they are required on this scale, at a cost per circuit appreciably lower than the older established systems. A broadband system reasonably fully equipped for circuit derivation can provide circuits for the order of $15 per circuit mile, whereas the corresponding average for low-capacity systems is of the order of $150. (Broadband systems from which few circuits are derived would, of course, yield a much higher figure because of the high order of basic cost.) This is reflected in the fact that the average cost per trunk circuit, adjusted to a common value of 1965/66 prices, has dropped from over $9,500 in 1957/58 to $6,000 in 1965/66. Circuit costs derived from lower-capacity systems have also dropped in this period.

Coaxial-Cable System

Although the first broadband system to be installed in Australia was a microwave-radio system, the first commercial broadband systems developed were coaxial-cable systems. The conductor pairs in these cables consist essentially of an inner conductor of copper wire surrounded by an outer copper tube.

The particular advantage of coaxial cables resides in the decreasing crosstalk between coaxial tubes as the frequency increases. The attenuation at high frequencies is moderate (about 7.5 db/mile at 4 megacycles/second and about 13.5 db/mile at 12 Mc/s for 0.375-in. cable). In addition, the variation of attenuation and impedance across the frequency band is relatively limited so that matching to a particular transmitted frequency results in good return-loss values. These factors make coaxial cable a very suitable medium for transmitting frequency bands of several megacycles/second. The favourable crosstalk characteristic makes it possible to include several tubes under a single sheath, a pair of tubes being used normally on a "go" and "return" basis to provide a single telephony bearer.

All cables installed in Australia have tubes of 0.375 in. internal diameter (or the approximate metric equivalent) commencing with the 4-tube cable, which was put into service between Melbourne and Morwell (Ref. 13) in 1961, and the Sydney-Melbourne 6-tube cable opened for service in 1962 (Ref. 14).

The coaxial cables installed in this country as at June, 1966, comprised approximately 1,500 sheath miles.

Small-diameter coaxial cables with tubes of 0.174 in. outer diameter have been used fairly extensively in other countries. It has been common experience that small-diameter cable can be an economic method of providing 120 circuits (on a single tube) or 300 circuits (on two tubes operating up to 1.3 Mc/s), or more recently 960 circuits on two tubes operating up to 4 Mc/s). However, the relatively limited market available to Australian coaxial-cable manufacturers has so far made the introduction of two cable standards impracticable. The development of single-quad cable systems discussed above promises to provide an economic alternative for applications requiring relatively few circuits initially, particularly where the foreseen requirements are of the order of 100-200 circuits.

The earlier coaxial systems installed in this country were equipped with repeaters operating up to a frequency of 6 Mc/s. This standard was adopted because of the need to relay 625-line television signals which have a bandwidth of 5 Mc/s. When relayed over coaxial cable using vestigial-sideband transmission, line frequencies up to 6.056 Mc/s are required. The 6-Mc/s repeaters provide capacity for 960 telephone circuits which occupy the band up to 4 Mc/s. A mastergroup of 300 circuits operating in the upper band can be added above this, extending the capacity to 1260 circuits and the frequency band to about 5.5 Mc/s. A mastergroup has been installed on the Sydney-Melbourne coaxial cable between Melbourne and Wangaratta and another will shortly be installed between Sydney and Wagga.

As the majority of 0.375in. coaxial-cable systems used overseas employ 4-Mc/s repeaters, the choice of 6-Mc/s systems for the Australian network has led to limitations in the choice of the systems being offered by manufacturers and the prospect of higher prices because of additional developmental costs. However, when 12-Mc/s systems were introduced an alternative method of relaying television programmes over coaxial cables was developed which employs the upper portion of the 12-Mc/s spectrum. As a further possible alternative, the repeaters of some new transistorised systems with only a 4-Mc/s effective bandwidth for telephony purposes are able to accommodate a C.C.I.T.T. standard television relay because of the limited energy content of the video signal in the portion of the band from 4 Mc/s to 6 Mc/s. With the advent of transistorised 4-Mc/s and 12-Mc/s line equipment therefore, the A.P.O. adopted this standard rather than continuing to use specially designed 6-Mc/s equipment. All projects installed from 1966/1967 onwards will use solid-state line equipment of bandwidth 4 Mc/s and 12 Mc/s.

A significant feature of these transistorised systems is the development of the "buried" repeater enabling the cost of buildings at each non-regulating repeater, to be eliminated (Refs. 15, 16). As with earlier systems, power for these repeaters is fed over the cable using either the centre conductors of the two coaxial tubes or a specially included conductor and the outer conductors of the tubes. A given power generating station may feed power in both directions for about half the repeaters in the section. A total of about 21 transistorised repeaters can be fed from a given power-generating station supplying voltages of + 300 and —300 volts D.C. This represents about 60 miles (i.e., 120 miles between power-feeding stations) for 4-Mc/s systems with repeater spacings of about 5.8 miles and about 60 miles for 12-Mc/s with repeater spacings of about 2.9 miles. Even greater distances can be obtained using voltages of + 600 and — 600 volts D.C.

The development of the transistorised 12-Mc/s repeater has been fairly recent. This system accommodates 2,700 circuits on a pair of tubes and represents a notable advance in system circuit capacity for which a requirement can now be seen on the main interstate routes. This development will be incorporated in several projects to commence shortly including sections of the coaxial cable on the alternative main route system between Sydney and Brisbane.

As an alternative to 2,700 telephony circuits it is possible, as mentioned, to use the spectrum of a 12-Mc/s system for approximately 1,200 telephone circuits together with a C.C.I.T.T. standard television relay in the upper part of the band by means of terminal multiplex equipment. It is planned to use this technique on a coaxial cable to be laid from Perth to Carnarvon by 1969.

In the United States, a coaxial-cable system with a line system designated L4 with capacity for 3,600 circuits per pair of tubes has been developed for very heavy trunk routes, because of the saturation of the radio spectrum on these routes (Ref. 18). The repeaters at 2-mile spacing will pass a band of 16 Mc/s width. It is intended to use a 20-tube cable which would yield a total capacity equivalent to 32,400 telephone circuits.

The development of even wider band systems using 0.375in. coaxial cable is being actively pursued in several countries and it is expected that systems working up to 40-60 Mc/s may become available commercially within 5-10 years (Ref. 19, 20, 21). Circuit capacities of the order of 10,000 on a pair of tubes, which these systems would offer, are not envisaged for wide application in Australia, but they can be seen as having a possible future application on some main interstate routes, notably Sydney-Melbourne.

Apart from the Sydney-Melbourne cable, most coaxial cables consist of 4 tubes. Some 2-tube cables are to be installed in special cases of spur routes with limited requirements. (Larger cables with up to 12 tubes are also used where necessary as tails joining trunkline equipment centres to microwave-radio terminals.)

It follows from the foregoing that a 4-tube cable has capacity, with existing techniques, for 5,400 circuits. Within the foreseeable future, such cables will have capacity for approximately 20,000 circuits. However, it will be difficult to change repeaters on one pair of tubes to provide greater capacity unless there is capacity to accommodate all working circuits on the other tubes, and the substitution must be planned in time for this changeover.

Microwave-Radio System

Microwave-radio systems providing broadband communication bearers operate in the U.H.F. and S.H.F. bands and require repeaters on a line-of-sight basis which in practice has meant an average spacing of 30 miles. The route mileage of installed systems in Australia at June, 1966, was approximately 3,900.

Microwave systems installed in Australia generally have a capacity of 960 circuits per bearer. Some of the early systems had capacities of 600 circuits but most of these have been upgraded to 960-circuit capacity. Some recently installed systems, however, have nominal capacities of 1,200 per bearer, while long-haul equipment with a nominal capacity of 1,800 circuits and short-haul equipment of 300-circuit capacity are planned for installation shortly. Microwave systems operating in the 4-Gc/s band can accommodate 5 broadband bearers plus one standby or protection bearer while those operating at 6 Gc/s allow for ultimate installation of 6 working bearers and 2 standby bearers, or 7 working bearers and one standby bearer. A fully equipped 6-Gc/s radio system with 1,800-circuit bearers would have a capacity of over 10,000 circuits.

Although a typical microwave equipment nominally provides 960 circuits to C.C.I.R. noise performance standards on conventional routes, it may not be possible to achieve this. In some circumstances, a route may be exceptionally difficult or may require unusually good performance, in which case, it is possible to meet these requirements by a reduction in circuit capacity. For example, the Melbourne-Launceston system employs equipment designed for 960-circuit capacity. However, with the long over-water paths involved (one of 99 miles and one of 69 miles), the probable capacity is limited to about 600 circuits. In some special cases, system capacity has been limited by special noise requirements. The supergroup provided between Sydney and Cairns as an extension of the SEACOM cable to Madang, Guam, Hong Kong, Jesselton and Singapore, has a specified circuit noise of no worse than 1 pW/km over the major part of the route (Refs. 22, 23). This has effectively limited the capacity of the nominal 1,200 channel bearer between Brisbane and Maryborough to 600 circuits and between Maryborough and Cairns to 300 circuits.

A wide range of solid-state microwave equipment is now commercially available with maximum transmitter powers varying from about 300mW at 7Gc/s to about 2 watts at 2 Gc/s, or from about 2.5 watts at 7 Gc/s to about 20 watts at 2 Gc/c if a final travelling-wave-tube (T.W.T.) output stage is employed. Since about 50 per cent of the total power requirement for the equipment is consumed by the travelling-wave tube, the elimination of this component is very desirable for long routes with repeater stations in remote locations. At the present stage of equipment development, if the T.W.T. stage is eliminated it is very difficult to achieve 3 pW/km for bearer capacities in excess of 600 circuits using equipment which would otherwise carry 960 circuits. However, new developments such as lower receiver noise factors due to improved mixer designs, and the increasing transmitter output available from solid state devices, will probably remove this limitation in the near future.

Large though the capacities of many microwave systems are, the usual spectrum limitations of a radio medium eventually apply even in the microwave field. The C.C.I.R. recommendations provide for the allocation of frequencies in the 2, 4, 6, upper 6, 7, 8, and 11-Gc/s bands, for broadband radio-relay systems (Ref. 24). In Great Britain it is estimated that the limitation in the number of systems which can be operated in the currently-used 2, 4, and 6-Gc/s bands will be exhausted on the heavy traffic routes in 10 years, although 11-Gc/s systems under development could extend this to 15 years (Ref. 25). The congestion on some routes in the United States has been mentioned earlier.

In Australia, most of the installed systems have operated in the 4- and 6-Gc/s bands, although some use has been made of 2 Gc/s which is shared with other services. Most of the 7-Gc/s systems available have been short-haul types mainly used for television relay spurs (Ref. 26). Equipment in the 11-Gc/s band has not yet been used in Australia and, because it suffers from marked rain absorption problems, it requires closely spaced repeaters. The limitations of available frequencies are unlikely to be as severe as in Great Britain but difficulties may be experienced in areas where there are a large number of closely sited routes, particularly around Sydney and Melbourne. The use of 4 Gc/s and 6 Gc/s for operation between communication satellites and earth stations can cause interference to land-based systems and vice versa unless the earth stations are carefully sited. The normal frequency patterns operated in the 4- and 6-Gc/s band in accordance with C.C.I.R. recommendations are shown in Fig. 5 (Ref. 24, pp. 32-37). Each R.F. channel represents a broadband bearer. There are also interleaved patterns, offset by the order of 15 Mc/s which are used in a four-frequency plan when interference problems arise.

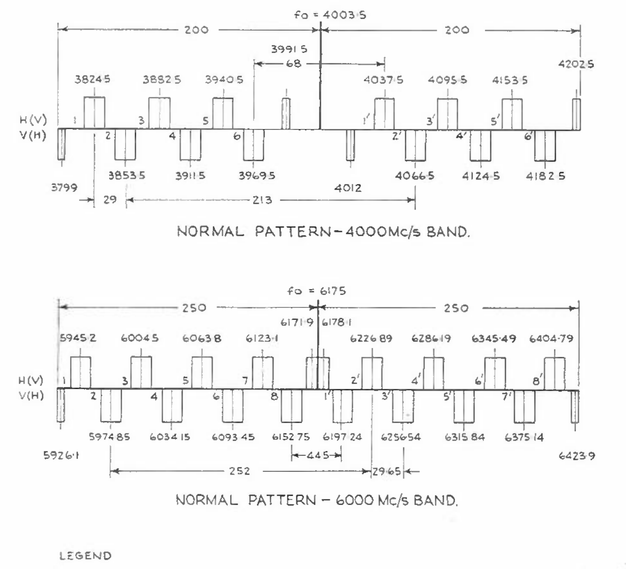

Fig. 5. — C.C.I.R. Radio Frequency Channel Arrangements for Radio-Relay Systems operating in the 4-Gc/s and 6-Gc/s Bands.

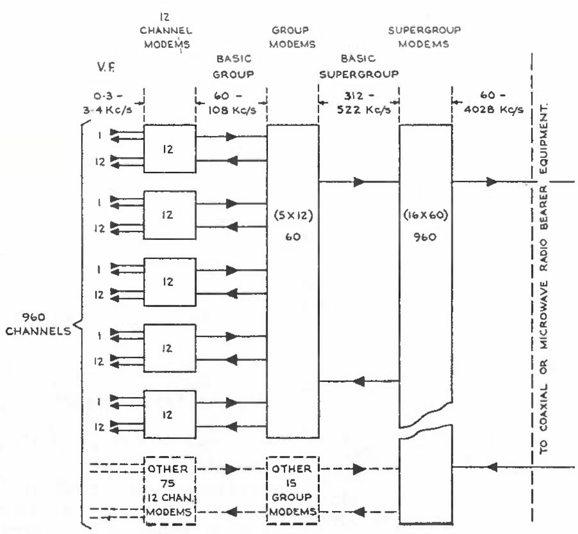

Fig. 6. — Simplified Block Diagram of a Broadband System Terminal for Channel Derivation.

Channel-Deriving Equipment

The terminal equipment for deriving channels from the broadband systems has been electrically standardised so that it can be applied flexibly to either a coaxial-cable or a microwave system. Fig. 6 represents a typical 960-circuit broadband terminal which assembles voice-frequency channels (effectively transmitting 0.3-3.4 kc/s) at 4-kc/s spacing into a frequency band 60-4028 kc/s.

The translation stages involved are:

(i) the modulation of 12 voice channels into the basic group frequency range of 60-108 kc/s;

(ii) the modulation of 5 groups (i.e., 60 channels) into the basic supergroup frequency of 312-552 kc/s;

(iii) the translation of each of the 16 supergroups (except supergroup 2 which remains at basic supergroup frequency) into its position in the 60-4028 kc/s band. The reverse processes occur at demodulation. The voice channels in both the "go" and "return" directions are combined, if necessary, at each end through a hybrid coil to provide a circuit between 2-wire terminating points.

In the case of 12-Mc/s coaxial-cable systems there are several alternative methods of assembling the 2,700 channels (Fig. 7) (Ref. 27). The first method (A) uses supergroups 2 to 16 in the band from 312 to 4028 kc/s and six basic mastergroups of 300 channels each (consisting of supergroups 4 to 8 occupying the frequency band from 812 to 2044 kc/s) in the band from 4332 to 12,388 kc/s. The second method (B) consists of 9 mastergroups occupying a band from 316 to 12,338 kc/s while the third method (C) consists of three supermastergroups each comprising three basic mastergroups occupying the frequency band from 316 to 12,388 kc/s.

An additional method recently recommended by the C.C.I.T.T. allows for the direct assembly of 15 supergroups (2-16) into a frequency band 312-4,028 kc/s. Three such assemblies are then transmitted to line occupying the frequency bands 312-4,028, 4,404-8,120 and 8,620-12,336 kc/s, respectively.

At repeater points along coaxial cables it is possible by means of branching and translating equipment to drop any supergroup and use some or all of the 60 circuits without replenishment, i.e., the channel frequency allocation cannot be used between two other locations on the route. The use of band-stop filters as well as translating equipment provides the facility to drop supergroup 1 (where it exists) and 2 at any point with replenishment. It is also possible to drop and replenish supergroups 1-5 to 7-16 as a block at any point but filtering arrangements may result in the loss of supergroup 6 from the system. The alternative method of obtaining large blocks of circuits at a point in the 60-4028 kc/s range, without losing a supergroup, is to provide back-to-back terminals bringing all circuits down to basic supergroups, stopping the supergroups required, and connecting the remaining supergroups through. There is a penalty in the form of additional noise and cost for this arrangement.

To drop and replenish from a microwave system it is normally necessary to have a demodulating repeater which brings the signal frequencies to "baseband", i.e., the frequency band of the assembled supergroups with which the radio frequency is modulated at the terminal. The arrangements are then similar to those used at coaxial repeater points. However, as mentioned above, there are limitations on the number of demodulating microwave repeaters due to the additional noise introduced by this process, being even more marked than when this method is used in the case of a coaxial-cable system.

Microwave equipment is now available which permits a number of supergroups to be dropped at a repeater

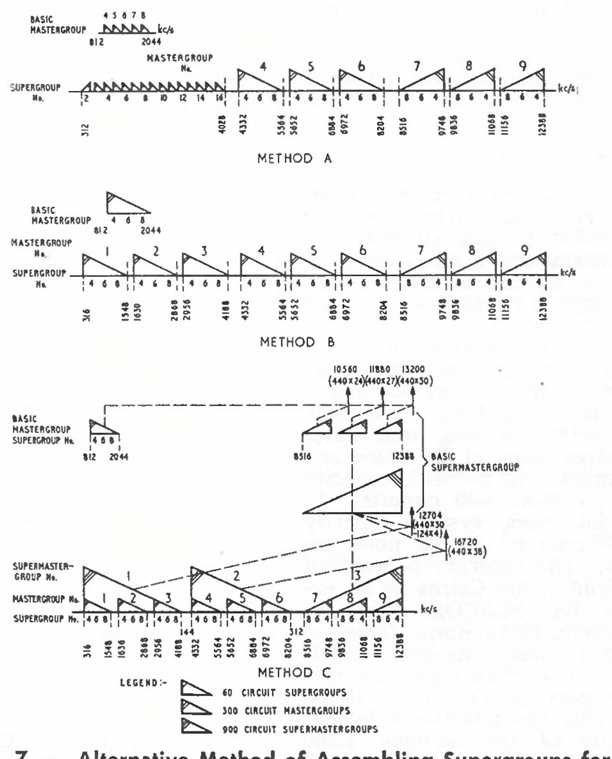

Fig. 7. — Alternative Method of Assembling Supergroups for 12 Mc/s Coaxial Cable System.

without demodulation of the through traffic. These supergroups are not available for replenishment. This process will be used first in Australia on the Hobart-Launceston system where a supergroup will be dropped out at the Cleveland repeater to provide circuits between Launceston and Campbell Town.

The Long-term Development of an Australian Broadband Network

The individual broadband systems installed in Australia by the end of 1966 have begun to form a network. By 1969 the Western Australian systems will be linked to the main Commonwealth network by the installation of the Adelaide-to-Perth microwave-radio system.

To assist the development of individual projects into a broadband network meeting national objectives, a long-term broadband plan has been prepared (Fig. 8). In the light of probable local requirements developing at different stages, an attempt has been made to indicate the likely shape of the network at three different periods terminating at 1970, 1985 and 2000. These periods are intended to represent respectively:—

- (a) Systems already installed, under installation or firmly planned.
- (b) Systems which are likely to be installed within the range of a 20-year planning period.
- (c) Systems which may be required as far ahead as useful prediction can be made.

The main objectives which the plan aims to meet are:

- (i) At least one alternate broadband route should be available between all capital cities. In all cases this should be provided by 1985.
- (ii) A broadband connection should be provided within the 20-year period to most major centres.
- (iii) Within the 20-year period it should be possible to by-pass each of the capital cities in the case of emergency. Within the long-term period, it should be possible to by-pass all major cities.

FUTURE TRENDS

Submarine Cables

A number of submarine cables have been used in the Australian network for telephony circuits between centres separated by the sea. Many of these, however, are multi-pair cables over short distances and may be described as "underwater" cables to distinguish them from the single pair (in coaxial form) submarine cable normally used for longer distances. The most notable coaxial-type submarine cable still used for this purpose in Australia is the Apollo Bay-Stanley cable carrying 15 telephone circuits between Tasmania and the mainland (Ref. 28). The first long-distance multichannel submarine cable with underwater power-fed repeaters was laid between Scotland and Newfoundland in 1956 with 36 circuits. Time-assignment speech-inter-

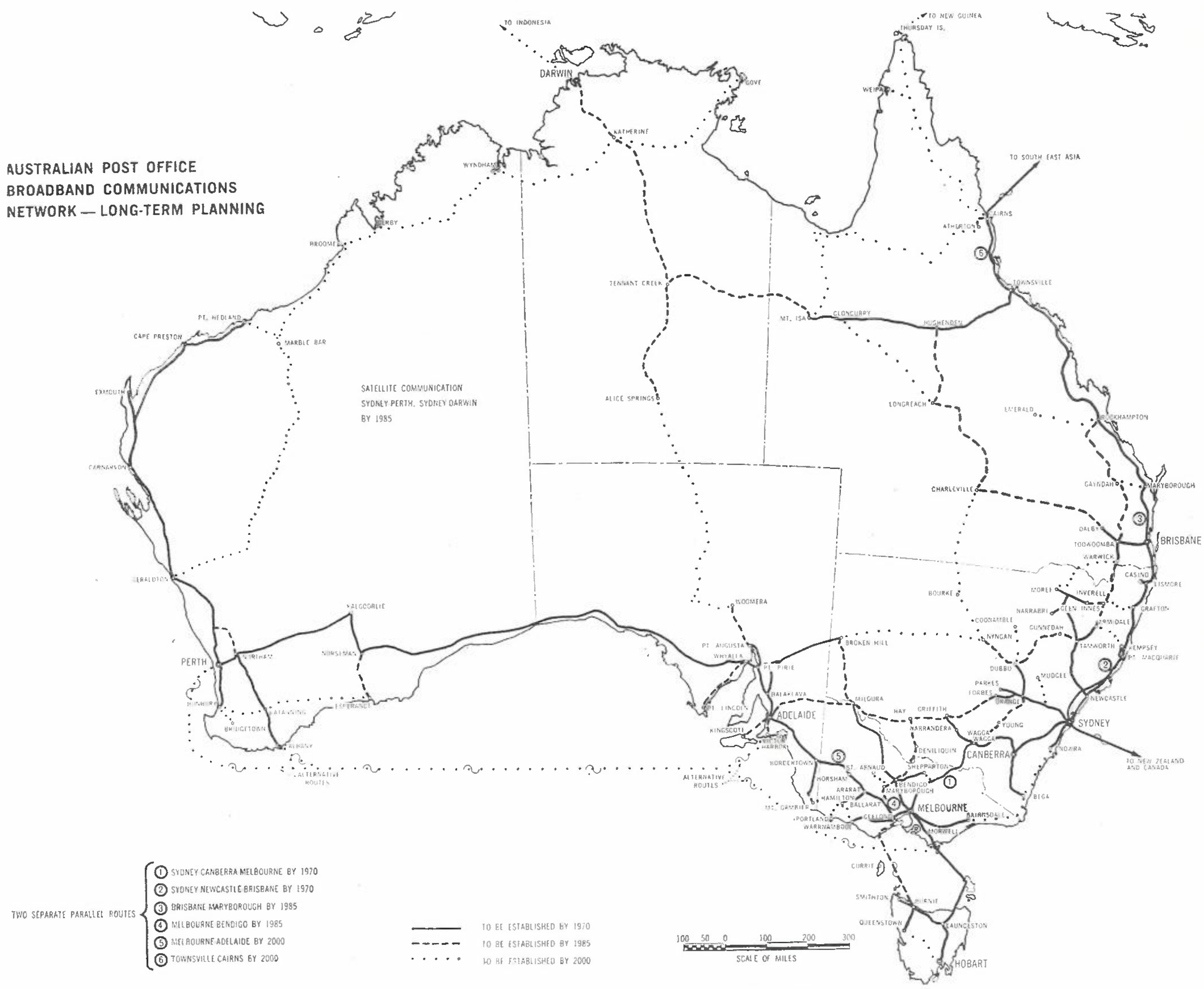

Fig. 8. — Long-term Broadband Plan for the Australian Network.

polation (T.A.S.I.) equipment was later applied to this cable to make additional use of the circuits during gaps in conversation, so that the effective number of conversations which could be applied to the cable could be doubled at times of 100 per cent. T.A.S.I. activity. The frequency spacing of circuits in most of the recent submarine cables have been 3 kc/s instead of the normal 4 kc/s in order to increase the circuit capacity. The transmitted band for each channel under this arrangement is 0.250-3.050 kc/s.

In 1963 the COMPAC cable across the Pacific from Sydney to Auckland and Vancouver was opened with eighty 3-kc/s circuits (Ref. 29), and the SEACOM cable from Cairns to Madang, Guam, Hong Kong, Jesselton and Singapore with capacity for one hundred and sixty 3-kc/s circuits between Cairns and Guam is due to be finally commissioned in April 1967. A number of other long-distance cables have also been laid between the United States and Europe and the United States and Asia.

The use of this type of submarine cable for intercontinental telephony was justified by the fact that there was no alternative other than unsatisfactory high-frequency radio links until the advent of satellite communications. However, the costs per circuit-mile for this type of system have compared unfavourably with other systems, so far, for linking centres on the Australian coastline. In addition, circuit capacity of even short cables has to date been limited to about 480 circuits of nominal 3-kc/s spacing. This number can be increased by the addition of T.A.S.I.

However, the capacity of these systems is steadily increasing and the American Telephone and Telegraph Company has recently announced its intention of laying a 1,250-mile cable with transistorised repeaters to carry 720 voice circuits. As the circuit capacity increases the cost per circuit tends to decrease and the development of this type of system must be watched to ensure its application at such a time as it may become competitive with other systems. It is in the hopeful prospect of this eventuality that the alternative broadband systems to Perth and to Tasmania shown on the long-term broadband plan (Fig. 8) have been indicated as submarine cables. It is, of course, possible that the development of satellite systems may make circuits provided by this means more attractive than submarine cable circuits to Perth, while another radio system may be preferred as an alternative link to Tasmania.

Satellite Links

The rapid development of communication satellites has brought within reach the means of providing large blocks of international circuits previously not available from the limited capacity of submarine cables (Ref. 31). A satellite of the "Early Bird" type was successfully launched in January, 1967, for communication in the Pacific area. It is one of a group known as INTELSAT 2. The timing has resulted from a requirement by the National Aeronautics and Space Administration (N.A.S.A.) of the United States for additional communication facilities for their world-wide network established to support the Apollo "man-on-the-moon" project. To meet N.A.S.A.'s needs the Overseas Telecommunications Commission has established an earth station near Carnarvon which employs a 42ft. aperture antenna.

The commercial capacity of INTELSAT 2 will be exploited by an earth station being installed in the Moree area for operation at the beginning of 1968. This earth station will also be used in conjunction with a provision of a "global satellite system" known as INTELSAT 3 some time in 1968. This system will have a satellite above the Pacific Ocean, the latter calling for an Australian earth station west of Adelaide.

The allocation of frequencies in the 4-Gc/s (satellite-to-earth-station) and the 6-Gc/s (earth-station-to-satellite) bands has been mentioned, and the system basically operates as a very long-hop, line-of-sight microwave system using these frequencies. A capacity of the order of 1,200 circuits is to be provided by the INTELSAT 3 satellite but problems of multiple access, giving simultaneous access to the full range of these circuits at various earth stations has yet to be solved. In addition, a station with a smaller antenna can derive only a smaller number of circuits than those with large antennas for the same noise figures. Thus a station with a 42ft. antenna uses approximately 8 times as much satellite capacity for a circuit as a station with an 85ft. antenna or equivalent. For a 30ft. antenna the figure relative to an 85ft. antenna is of the order of 27. However, the INTELSAT charges are based on the effective satellite capacity required by an earth station and the relative costs are likely to make it cheaper for a country to install an 85ft. antenna or equivalent, thus ensuring that a maximum number of circuits can actually be obtained.

Satellites appear likely to have a future application to long internal circuits and an examination has been made of the feasibility of satisfying major long-distance trunk and television relay requirements within Australia in the immediate future by this means. The study was designed to indicate whether the present planning for broadband terrestrial links between widely separated centres should be abandoned in favour of satellite communications. It was assumed that the satellite system could be operating by 1970 and, with a currently assumed satellite life of 5 years, would meet requirements to 1975. Currently quoted costs for earth-station installations and space-sector rentals were also assumed. An alternative was examined which assumed that the A.P.O. could purchase a satellite and have it launched at the same unit costs as are available to INTELSAT (the 49-nation International Communication Satellite Consortium). In the case of an Australian-owned satellite it was considered possible to use smaller antennas at some stations requiring only a few circuits since the total circuit requirements would not use the whole satellite capacity. Since the cost of the earth stations predominate, circuit requirements are grouped at a reasonably small number of centres. Fig. 9 shows the centres and circuit numbers considered.

These costs were compared with the costs of extending the broadband system to serve requirements at the same centres to 1975 in accordance with current planning. Another series of comparisons was made on the basis of relaying television to the centres indicated on Fig. 9 as well as meeting the telephony requirements of the first comparison. In the case of the satellite it was assumed that a single programme would serve all centres,

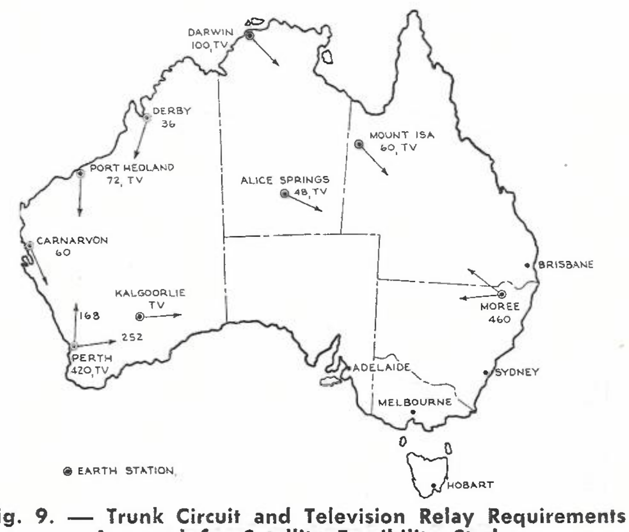

Fig. 9. — Trunk Circuit and Television Relay Requirements Assumed for Satellite Feasibility Study.

whereas in the terrestrial system a programme from the nearest capital city studio was assumed.

The study showed clearly that, on the basis of total annual charges, until the costs of earth stations and satellites are reduced considerably from those currently quoted, planning for national communications should proceed on the basis of conventional terrestrial systems. This applied also to limited use of satellite communications on links which would appear to be most favourable to satellite communication (for example, Eastern States to Darwin and Perth only).

The probability of satellite launching success has been quoted at 0.9 and if the initial satellite launch fails there would be an increase in the capital cost of a satellite system of the order of 30 per cent and in annual charges of the order of 40 per cent.

In addition, there are possibilities of conversation difficulties over synchronous satellite links with a round-trip delay of 520 milli-seconds in addition to that arising from the land extensions. This may be less tolerable to subscribers used to present standards on internal trunk calls than in the case of international calls. The A.P.O. standard multi-frequency signalling system employs a compelled-sequence principle which is not suitable for satellite links with delays of this order, and special arrangements would be needed over these links.

However, the techniques and costs of satellites and earth stations are changing rapidly and the future prospects appear so promising, that constant revaluation of the position will be necessary.

Tropospheric-Scatter System

Tropospheric-scatter communication systems depend on the scattering of radio signals from turbulences in the troposphere which is that portion of the atmosphere extending to a height of about six miles above the earth.

By means of high-power transmitters and narrow-beam, high-gain antennas a strong radio signal is fed into the troposphere. A portion of this signal, scattered from a common "scatter volume" formed by the intersection of the beams of the transmitting and receiving antennas, is detected by a highly sensitive receiver. By this means over-the-horizon communication is possible for distances extending up to several hundred miles. This facility can be very useful for working over routes where repeaters cannot be installed or are difficult of access.

Systems installed throughout the world provide up to about 300 voice channels using equipment operating in frequency bands from about 400 Mc/s to 4 Gc/s with transmitted powers from about 1 kW to 100 kW using antennas of diameters from about 30 feet to 120 feet. Protection against fading is provided by means of space diversity, frequency diversity or polarization diversity, or by a combination of all three.

A typical system with a substantially clear view to the horizon, operating over a distance of 280 miles, using a frequency of 900 Mc/s with 10kW transmitters, tunnel-diode pre-amplifiers, 60ft. diameter antennas and quadruple diversity, might provide 60 circuits at a signal-to-noise figure of better than 47 db for about 95 per cent of the time.

A variation of the tropospheric scatter system exists and has been used with success in a number of installations. If it is possible to arrange that a large obstacle appears near the centre of a path, the microwave signal may be propagated over the horizon by diffraction from the edge of the obstacle rather than by scattering from atmospheric turbulence. Diffraction paths are rather more efficient than scatter paths and hence can provide more channels and use less power. They are most commonly found as long over-water hops with an island as the obstacle.

Tropospheric scatter systems have not been utilised to date in the Australian network except for a four-channel system carrying N.A.S.A. circuits from Geraldton to Carnarvon in W.A. Circuit capacity, initial cost, klystron replacement cost, and power consumption factors, have militated against the adoption of troposcatter systems, but all these problems are becoming less difficult and may shortly reach the point where a major system could be employed. These systems may have a particular application in the North or North-West of Australia where short-notice requirements are beginning to be encountered for 12-60 circuits over 150-300 miles, with very little intermediate settlement. Power requirements, however, loom large in these situations.

Pulse-Code Modulation (P.C.M.) Systems

The analysis of trunk circuit lengths in the Australian network in Table 1 shows the predominant requirement to be for the shorter distance circuit. An economic solution beginning to emerge in this field is the application of pulse-code modulation (P.C.M.) for circuit multiplexing, and already this is beginning to be widely employed by some overseas administrations.

The P.C.M. technique essentially involves sampling, quantizing, and coding. The continuous input signal is first replaced by regularly spaced pulses, equal to the signal amplitude at the sampling instants. It may be shown that at a sufficiently fast sampling rate, the continuous input sample can be recovered without distortion. Typical sampling rate for telephone speed is 8,000 per second. The samples are then quantized into one of a number of predetermined levels (commonly 128), and the recognised level is then coded into a set of binary pulses. A set of 7 is required for 128 levels with an eighth normally added for signalling. Several channels, commonly about 24, are time-multiplexed by consecutively transmitting the 8-bit sets of several channels in each sampling interval of 1/8000 sec. A typical bit rate of the multiplexed signal is thus $8000 \times 8 \times 24 = 1,536,000$ bits/sec.

P.C.M. is a digital form of modulation. Received binary pulses, even if heavily distorted, can be regenerated correctly as long as they are not distorted beyong recognition by noise or transmission defects of the transmission medium. Noise and crosstalk therefore has no cumulative effect, and if it remains below a certain threshold, typically if a signal-to-noise figure of 10 db can be maintained, line noise does not appear in the recovered speech.

This form of multiplexing P.C.M. has therefore the advantage, compared to the frequency-division multiplexing normally employed in carrier telephony, of relative immunity to noise, crosstalk and certain forms of distortion. Wrongly received bits lead to errors in the reconstitution of the speech signal and what is known as "error noise". As line noise approaches a threshold value, the error noise of a P.C.M. circuit deteriorates rapidly.

The process of quantizing, however, involves "quantizing noise", heard during speech due to the fact that only discrete voice-frequency amplitude levels can be accurately reproduced. The difference between the actual and the quantized samples may be thought of as a random train of rectangular pulses, superimposed on the recovered speech signal, and giving rise to the quantizing noise.

P.C.M. systems tend to be less affected by level fluctuations in the transmission path and this characteristic makes them suitable for application to bearers of less than the highest quality. In principle the signal can be regenerated during transmission any number of times, so that transmission over any distance is possible with no impairment other than quantizing noise. In practice, however, there is difficulty in maintaining accurate regenerator (repeater) timing. In addition, the connection of P.C.M. circuits in tandem tends to give rise to increasing noise deterioration from tandem quantizing.

The evolution of solid-state devices and improved circuitry has provided the opportunity to realise the potential economies of this technique and P.C.M. has taken large steps forward recently after many years of development. The fact that gain regulation is not required in either terminals or repeaters assists in minimizing system costs, and it is claimed that the low cost of terminals in particular, invites their application to short-haul circuits previously below the economic range of carrier. However, it is relevant to the Australian situation that the potential economies of this equipment appear to depend on high-volume production.

The initial P.C.M. system installations throughout the world are of the junction-carrier type which can also be used for short-haul trunks. The relative noise immunity is useful in this application because of inter-bearer crosstalk normally present in junction cable. The noise difficulties from tandem connection may make it necessary, at least initially, to confine P.C.M. systems to terminal links (i.e., links to the terminal exchange) to ensure that no more than two are connected in tandem.

The most obvious immediate application of P.C.M. systems is to increase the capacity of existing voice-frequency cables. Cost studies in Great Britain and Japan indicate that on typical routes there, P.C.M. should be cheaper than new cables for lengths exceeding 15 miles. Where no existing duct space is available the break-even length should be considerably less. Japanese studies indicate that P.C.M. can be economically applied to lengths as short as 10 km (Ref. 34). Selected pairs in existing junction cables are prepared for P.C.M. multiplexing by removing the loading and inserting regenerators at the loading points. With 2,000 yards repeater spacing, compatible with the usual loading-coil position, a 24-channel system with a digital rate of 1.6 Megabits/second can be operated successfully on each selected pair (Ref. 35).

The Research Laboratories of the A.P.O. are currently evaluating a 24-channel P.C.M. junction-carrier system. The system purchased for trial provides 24 two-way voice-frequency channels of bandwidth 0.3 to 3.4 kc/s. The P.C.M. line signal consists of rectangular bipolar pulses of 4 V peak amplitude at a frequency of 1.6 Megabits/second. The evaluation will assist in determining the application to the Australian network of P.C.M. equipment involving new principles. Field trials involving a number of 24-channel P.C.M. systems on existing junction and minor trunk cables in the Australian network are expected to take place in 1969.

Consideration is also being given to the introduction of micro-wave radio systems using P.C.M. techniques into the network. The price of these systems is attractive and they could find application as trunk system to terminal exchanges and as back-up systems in emergency situations since, due to their compact size and integral channel deriving equipment they can be easily transported and quickly installed. It is also probable that eventually P.C.M. will be used on cables specially installed for the purpose, as well as on microwave systems.

When P.C.M. systems have become established in the network as individual transmission systems, a further stage of development envisages the integration of such systems with electronic exchanges based on time division. In such a system, a telephone channel would be converted to a P.C.M. channel at the first exchange or line concentrator, remaining in digital time-division-multiplex form through intermediate switching centres until reaching the remote exchange. Long-term studies of an Integrated Switching and Transmission System, as this is known, are in hand in the A.P.O.

Finally, looking further ahead, P.C.M. is likely to have application to the very wide-band systems under development. The advantages of P.C.M. with regard to crosstalk and certain forms of distortion make it suitable for application to the waveguide systems discussed later, even though it calls for a higher working bandwidth for a given number of circuits than amplitude or frequency modulation.

Waveguides

For many years considerable attention has been given in the United States, Europe and Japan to the development of waveguides as a long-distance transmission medium for a very wide frequency band. Normal waveguides have attenuation characteristics which are unsuitable for this application and development has been concentrated on "over-moded" waveguides which are characterised by cross-section dimensions many times the wavelength of the transmitted signal.

In particular the overmoded circular waveguide using the H_{01} mode (also referred to as TE_{01}) promises the transmission of extremely high frequencies with relatively low attenuation. The attenuation of the wave modes Hon, which have transverse components of electric field, decrease with frequency and of these the H_{01} mode has the lowest attenuation which is of the order of 1 db/mile at 70 Gc/s in a 2in. pipe. If, however, an H_{01} mode is launched into a circular waveguide of these dimensions, numerous other modes are generated by irergularities, bends or ovality in the waveguide. Generation of unwanted modes causes loss to the wanted mode but, although undesirable, this is not significant. Once generated, however, it is important that they be attenuated, since modes with longitudinal components of electric field have different propagation velocities to the transverse modes and result in multi-path interference.

The unwanted modes can be heavily attenuated by treatment of the inside of the tube. One of the most favoured methods is to wind a wire helix, around which a plastic tube is formed. The wire helix presents substantial impedance to the longitudinal modes only. Another treatment is to line the inside of the metal tube with a plastic dielectric film such as polythene or polypropylene (Refs. 36, 37).

In an effort to reduce the cost of the wire helix waveguide, some attention has been given to using a straight steel tube with a thin internal coating of copper for a major section of the route. The dimensional tolerances for roundness and straightness are extremely close however. Various methods have been proposed to cope with bends, including dielectric loading, but it is likely that sharper bends will be negotiated either by flexible, corrugated, circular copper tube lined internally with polypropylene or by temporary conversion to a waveguide that is not over-moded. Helical sections would probably be required also in the regions of bends to attenuate unwanted modes.

It is estimated that a circular waveguide about 2in. in diameter could provide an effective transmission medium for frequencies between about 30 and 100 Gc/s, possibly omitting frequencies in the region of 50 Gc/s which is subject to absorption by water vapour. P.C.M. multiplexing is assumed. Delay distortion puts definite limits to the bandwidth which can be satisfactorily transmitted by each carrier frequency, and the available bandwidth would be shared by parallel modulators operating on different frequencies each transmitting a number of P.C.M. channels.

The use of two pipes on a "go" and "return" basis would provide capacity for more than 100,000 channels with repeater spacing variously estimated at 10 to 20 miles. Not only would such a system provide capacity which cannot be conveniently provided by any other existing system, but a British study suggests that it would also be economic for over about 50,000 circuits (see Fig. 10 and Ref. 25). Below this point the advantage appears to lie with multi-tube coaxial cable.

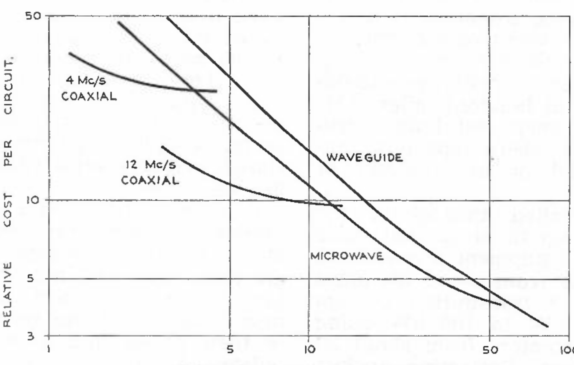

Fig. 10. — British Post Office Study of Probable Relative Costs of Providing Large Circuit Quantities. (By Courtesy of Post Office Telecommunications Journal).

The number of routes in the world where this order of capacity would be required in the foreseeable future is limited, although on certain routes the problem invites solution. The mechanical problems of maintaining adequately close dimensional tolerances in the tubes, during fabrication and particularly during installation, have so far been serious obstacles to the development of an over-moded waveguide system.

Lasers

The possibilities of using lasers for communication purposes have been the subject of a great amount of development effort but despite considerable progress it is still at a relatively early stage. The potential use of the laser as a communication generator arises from its properties as a source of coherent frequency in the optical spectrum, but its success in this field will depend among other things on the degree of coherence, the attenuation of the transmission medium, and economic achievement of modulation and demodulation techniques.

The achievement of more effective modulation methods is making rapid advances, and bandwidths of over 1 Gc/s have already been achieved by frequency and phase modulation methods (Ref. 38). Although this is only a small proportion of the theoretical bandwidth potential which is of the order of 10^5 Gc/s, it still represents an impressive circuit capacity. A more difficult problem, yet to be solved however, is the question of finding a suitable transmission path. The earth's atmosphere presents many problems to transmission in the range of optical frequencies, whereas it does not seriously trouble microwaves. Many attempts are being made to develop covered transmission paths such as fibre optics and tubes with polished internal surfaces or regularly spaced internal lenses (Ref. 39). Unless the problem of a satisfactory transmission path is solved the main application of lasers may be to communications in space.

CONCLUSION

Australia, in common with the larger telephone administrations in other parts of the world, is experiencing heavy increases in demand for the provision of trunk circuits. To meet this requirement over the next decade and beyond will present problems in both resource allocation and technique to provide adequate economic circuit capacity.

The most common need at present is for low-to-medium capacity systems operating over relatively short distances, and a variety of systems are available for this purpose. The selection of the most economic system for each application is vital to ensure that available resources will meet the demands which will be placed on them. With present costs and techniques, any particular combination of expected development and distance appears, from generalised studies, to justify economically the application of a particular system. However, almost every application needs an individual study.

The joint pressures of adequate ultimate capacity on a route, ready response to unexpected demand under S.T.D. operation and reduction of costs per circuit-mile will call for an increasing number of broadband systems. At present the choice between the two major alternatives, coaxial cable and microwave radio, depends principally on the economic factors of each application. In a future period, satellite systems and, possibly submarine cables, may provide an alternative for national trunk circuits. It is necessary to ensure that the individual additions to broadband network, now emerging, are integrated to meet long-term aims for the security of the national network.

The heavy demand for trunk circuits on some routes in North America and Europe is stimulating intensive research into media such as waveguides and optical wavelength systems suitable as very wide-band bearers. Although there are some promising contenders, there are formidable problems still to be solved. The smaller, although significant, Australian requirements on even the major trunk routes are likely to be satisfied by the intermediate development of coaxial systems with bandwidths of the order of 50 Mc/s until the period when commercial very wide-band systems may become available.

ACKNOWLEDGMENTS

The authors wish to thank the Director-General, Postmaster-General's Department, for permission to publish this paper. Acknowledgment is made of the assistance provided by colleagues at Headquarters and in the State Administrations of the Postmaster-General's Department during the preparation of the paper.

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APPENDIX I.

Economic Comparison Details

1. Economic Comparison:

(i) Period: 20 years.
(ii) Interest rate: 5%.
(iii) Where a system or cable capacity is insufficient to meet the development within the costing period, multiple installations have been assumed.

2. Cable Provision:

(i) Life of cable: 35 years.
(ii) Residual value: Nil.
(iii) Maintenance: 0.40% of capital.
(iv) V.F. cable sizes have been determined as follows:— 20-year cable increments for 200-pair cables and smaller 8-year cable increments where 20-year cable provision would exceed 200-pair cable sizes.
(v) Z12N-type cable-carrier installations use 14-pair 20-lb. conductor, carrier-quad cable or 24-pair 20-lb. conductor, carrier-quad cable.
(vi) Two-tube 0.375-in. diameter coaxial cable costs have been used in the comparison, in view of the limited capacities required.

3. Voice Frequency (V.F.) Amplifier Cable Provision.

The economics of V.F. cable provision are based on the following amplifier provisions:—

(i) 0-8 miles: Unamplified circuits on 10 lb./mile cable.
(ii) 8-12 miles: Circuits on 10-lb./mile cables amplified with negative-impedance repeaters (N.I.R.'s).
(iii) 12-22 miles: Circuits on 20-lb./mile cables amplified with negative-impedance repeaters (N.I.R.'s).
(iv) 22-40: Circuits on 10-lb./mile cables with 4-wire V.F. amplifiers.

4. Carrier Equipment Provision:

(i) Life of equipment: 25 years.
(ii) Residual value: Nil.
(iii) Maintenance: 5% of capital for open-wire systems: 3½% of capital for all other equipment.
(iv) Coaxial-cable costs have been based on 4-Mc/s fully solid-state equipment with buried repeaters.
(v) Single-quad cable-carrier equipment assumed to be 120 channel, four-wide systems.
(vi) Channelling costs based on high-density equipment (120 channel modems per rack side).

5. Radio System Provision:

(i) Life of equipment: 25 years.
(ii) Residual value: Nil.
(iii) Maintenance: 3½% of capital for fully solid-state equipment.
(iv) Repeater spacing: 25 miles.
(v) Cable link from carrier to radio terminal: 3 miles of 4-tube coaxial cable.
(vi) Building and access road for each microwave-radio terminal or repeater: $15,000.
(vii) Tower cost: $4,000.
(viii) Power to radio equipment: $3,000.
(ix) 120-, 300- and 600-channel radio system costs used for growth rates A, B and C, respectively.

6. Open-Wire System Provision.

(i) An existing open-wire route assumed to consist of 8 open-wire pairs.
(ii) Open-wire bearers assumed to be added as required within the 20-year period in the computation of charges associated with new open-wire routes.
(iii) Pole route annual charges comprise interest on capital (applying to new construction only) and a combined maintenance-plus-sinking-fund charge.

C.C.I.T.T. SYSTEM No. 6 — A COMMON CHANNEL SIGNALLING SCHEME

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INTRODUCTION

General

In recent years the increasing use of satellite links for international telephony has accentuated a problem that has always existed in parts of the international telephone network — that of signalling delays. These delays are caused not only by the long propagation times experienced but also by the nature of the signalling schemes themselves, many of which are pulse systems in which the recognition times of individual line signals are one or more hundreds of milliseconds.

Modern developments in telephone switching and transmission facilities have made possible an elegant solution to this problem which also meets the demand for greater information capacity in signalling systems. A new signalling scheme, known as System No. 6 as it is the sixth system to be adopted for international telephony, has been developed by the International Telegraph and Telephone Consultative Committee (C.C.I.T.T.), and is to be field tested over the next few years.

Although primarily developed for the international network, System No. 6 is of considerable interest to the Australian Post Office for use in the national telephone network, because of its high speed and information capacity. The A.P.O. is co-operating with the Overseas Telecommunication Commission (Australia) in the field trial of System No. 6, to assess its value in the developing national network as well as in the international network.

This paper describes the new signalling scheme as it has been specified for the field trial. It is likely that minor changes will be made to the specification as a result of experience gained during the field trial, but it is very unlikely that the essential features of the system will be altered in any way.

Glossary

The following terms and abbreviations are used in this paper:

SU — Signal Unit; consisting of 28 bits.

LSU — Lone Signal Unit; a message contained in one signal unit.

MUM — Multi-Unit Message; a message contained in a number of consecutive signal units.

ISU — Initial Signal Unit; the first signal unit of a MUM.

SSU — Subsequent Signal Unit; the signal units following the ISU in a MUM.

IAM — Initial Address Message: the first message sent to establish a call.

SAM — Subsequent Address Message; messages containing address information (digits) for the establishment of a call, following the IAM.

Block — A sequence of 12 signal units the last one of which is an ACU.

ACU — Acknowledgment Signal Unit; the last signal unit of a block, which contains SU acknowledgment and block numbering information.

SYU — Synchronisation Signal Unit; a signal unit containing a fixed 16-bit pattern used for synchronisation purposes.

SCU — System Control Unit; a signal unit used for control of the signalling link, such as the instruction "changeover to an alternative signalling link".

BASIC REQUIREMENTS

System No. 6 is a common channel signalling scheme. All the telephone signals between two exchanges are passed over a single link between the exchanges and not over the individual speech circuits concerned, as illustrated in Fig. 1. A brief review of conventional in-channel signalling schemes is of value in appreciating the requirements of a common channel system.

Telephone signals may be subdivided into two classifications, information signals and line signals. Information signals are used to establish connections in the network and require a high rate of information flow for a short period. Line signals are used to supervise the connection, and are used infrequently during the progress of a normal call.

The early Strowger switching systems used decadic pulsing for information signalling; although quite slow and inflexible, this was satisfactory for the control techniques then available. The advent of common control switching systems demanded more flexibility and speed in signalling, and multi-frequency systems were developed which utilised the available circuit bandwidth much more efficiently during the setting up period of the call. Common control techniques themselves made this economically possible by time-sharing the expensive code sending and receiving equipment between a large number of circuits.

Equipment for the generation and reception of line signals is contained in the line relay sets of electromechanical switching systems. Although line signals do not occur frequently, equipment must always be available to detect such signals for the proper supervision of connections, and time-sharing of these often expensive devices is not practicable with the switching speeds available from electromechanical components.

As in the case of information signalling, the introduction of electronic control of switching centres, usually in the form of a central processor, is making possible the concentration of line signalling logic for a large number of circuits, with a consequent reduction in the cost of the individual line relay sets. However, unless care is taken, an exchange processor may be given an excessive load in merely scanning circuits to detect line signals with a consequent loss of capacity for other switching functions. It is also necessary for the processor or suitable interface equipment to translate the various signals into the digital language of the processor, and vice versa. A much more efficient way of transferring information between processor controlled exchanges is to provide a bi-directional data link between the two processors over which they can exchange signals in digital form. A group of speech circuits thus share a common signalling link.

In conventional signalling schemes the signals are passed over the transmission circuits which are also used for carrying the speech between the two subscribers. When a common signalling link is used it becomes necessary to include with each signal sent the identity of the speech circuit to which the signal belongs. A number of 'bits', or units of information, contained in the signal must be allocated to label the signal, the number de-

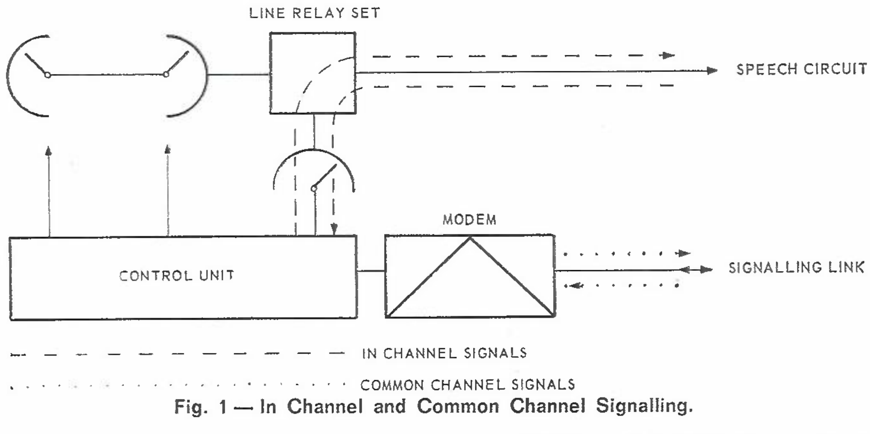

Fig. 1 — In Channel and Common Channel Signalling.

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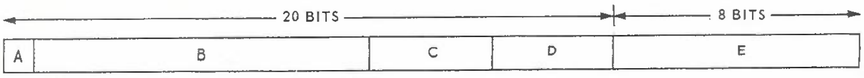

A- LABEL INDICATOR, 1 BIT
B- LABEL, 11 BITS
C- HEADING FIELD, 4 BITS
D- INFORMATION FIELD, 4 BITS
E- CHECKING FIELD, 8 BITS

Fig. 2 — Lone Signal Unit.

pending on the number of individual speech circuits to be identified. This depends on the capacity of the signalling link to transfer telephone signals which in turn depends on the transmitted bit rate and the size of each individual signal. Provision must also be made to identify the telephone signal being transmitted and to control errors which may occur during transmission. These factors are considered fully in the following sections.

THE SIGNAL UNIT

A data transmission rate of 2400 bits per second (bps) has been selected for use with System No. 6, this being the maximum rate for transmission over a phase-equalised speech-band channel for which modems were commercially available at the time of the selection. At this data rate it has been estimated that one signalling link can carry all the signals required by 1500 to 2000 speech circuits without introducing excessive delays of individual signals. In order to distinguish 2000 circuits a label of eleven bits is required as $2^{11} = 2048$. These 11 bits are referred to as the 'label field', as shown in Fig. 2.

A number of bits within each signal unit must be allocated to distinguish the specific telephone signal being transmitted and eight have been reserved for this purpose, divided into two fields of four bits each, a heading field and an information field. This is shown in Fig. 2. The two fields allow for ease of administration of the signals, an individual heading being allocated to a class of signals such as address signals or backward line signals, and individual signals within each class being distinguished by the information field. The two fields more than cover existing signalling requirements and leave capacity for new signals as may from time to time be required, and even for new classes of signals. An example of the latter is network management signals which may be used in future networks to change routing strategies to cater for dynamic traffic patterns. As System No. 6 has been specifically designed for international telephony, two heading fields have been reserved for the use of administrations wishing to use the system in a national network. Thus signals not required by international calls may be incorporated into the system when required.

It has been found necessary to add a special field of one bit, known as the 'label indicator', to the signal unit. This is used to identify subsequent units of multiple units messages and is discussed in the next section.

For ease of synchronisation (discussed in more detail in a later section) all signal units are of the same length, and the fields described so far give a total requirement of 20 bits. Unlike conventional analogue signalling schemes, which are protected by a degree of redundancy, the signal unit being described is very vulnerable to errors. Each signal is sent only once, and if an error occurs due to noise or a momentary line fault the signal may be lost completely, causing lost calls, false metering and other service problems. Accordingly some redundancy is added in each signal unit in the form of eight error detecting bits. The function of these bits and the method used to recover information lost due to errors is described in the section headed Error Control.

A complete signal unit, called a Lone Signal Unit (LSU), consists of 28 bits, as shown in Fig. 2. A typical signal may be represented by a series of ones and zeros divided into the various fields by oblique strokes as follows:

1/11100101101/0011/1011/11001011

At 2400 bps each signal unit has an emission time of approx. 11.7 ms. The information field can be used to carry one digit of a subscriber's number in binary coded decimal (BCD) form, so this signalling system allows the emission of one digit in 11.7 ms., or 85 digits per second which is much faster than any of the signalling systems currently in use. The four bits of the information field allow the formation of 16 signals, which correspond to the 10 digits and 5 special codes (11 to 15) of the m.f.c. scheme used in crossbar exchanges, and one extra.

MULTIPLE UNIT MESSAGES

As has been stated in the previous section, System No. 6 can transmit address information at 85 digits per second. A nine digit national number, as in the Australian national network, could be transmitted in 105 ms., using nine successive signal units, but even at this speed it is obviously inefficient to use 11 bits of every unit to repeat the circuit label each time. To further speed up the signalling rate, provision is made to build up a multiple unit message (MUM) which contains the label only once in a number of units. The format of an MUM is shown in Fig. 3. It consists of one 'initial' unit and a number of 'subsequent' units.

The formation of the initial unit is much the same as for a normal signal unit, except that the information field identifies the MUM by using the 16th code pattern not found in the m.f.c. scheme, 0000. The subsequent units do not contain labels and this fact is identified by the use of a zero (0) in the initial bit position, the label indicator, whereas all units containing a label have a one (1) in this position.

The second, third and fourth bits of subsequent units contain a record of the total number of subsequent units in the message — 000 indicating one subsequent unit, 001 indicating two subsequent units, and so on. This is necessary to allow the receiving exchange to recognise the end of the MUM. This identification also performs an important function under fault conditions, as if one or more of the subsequent units is mutilated it is possible to identify whether the next correctly received subsequent unit belongs to the original message or not. It is seen that a maximum of eight subsequent units is possible, limiting the total number of units in a message to nine. It is currently considered unlikely that address messages will use more than five units in a multi-unit message.

Four bits of each subsequent unit are used for identification purposes, leaving 16 bits to carry information. Each subsequent unit can thus contain four digits in BCD form. In the international system the first two such digit fields of the first, or initial, address message (IAM) are used to carry special information required in the setting up of connections. The allocation is as follows:—

(a) 5th bit — terminal or transit seizure. This informs the receiving exchange whether it is

BIT POSITION

1.	2.	3.	4.	5. 6. 7. 8.	9. 10. 11. 12.	13. 14. 15. 16.	17. 18. 19. 20.
1	LABEL					1 0 0 0	0 0 0 0
0	0	1	1		CATEGORY	DIGIT 1	DIGIT 2
0	0	1	1	DIGIT 3	DIGIT 4	DIGIT 5	DIGIT 6
0	0	1	1	DIGIT 7	DIGIT 8	DIGIT 9	DIGIT 10
0	0	1	1	DIGIT 11	DIGIT 12	DIGIT 13	ST

NOTE: 8 CHECK BITS NOT SHOWN

Fig. 3 — Multi-Unit Address Message.
Note: ST is an 'end of address' signal.

to be the last international exchange in the connection or a transit point.

(b) 6th bit — nature-of-circuit indicator. In particular this bit records if a satellite link has been used, as it is undesirable to have more than one such link in a single connection.

(c) 7th bit — echo suppressor control, whether an echo suppressor is required or not.

(d) 8th bit — spare.

(e) bits 9-12 — calling party's category, such as 'operator', 'normal subscriber' or 'data service'.

In subsequent address messages (SAM) these 8 bits are used to convey two digits.

It can be seen that by using a multi-unit message, a 9-digit national number requires 4 units, thus having an emission time of 47 ms.

It is interesting to note that a special 'seize-forward' signal is not required in System No. 6 as the initial address message performs this function. It can also be seen that to convey the necessary special information in addition to some digits of the called subscriber's number more than one unit is necessary and the initial address message on any call is always a multiple unit message.

In addition to address messages, MUMs may be used in the future for network management signals or to convey other types of information between exchanges.

ERROR CONTROL

As has already been mentioned, provision is made in every signal unit to detect errors due to noise or link faults causing a mutilation of bits. Eight check bits are generated in the form of a cyclic code.

The principles of this technique are described in Ref. 1. The generator polynomial selected to generate the check bit pattern will provide maximum protection for short noise bursts affecting up to four consecutive bits. To detect longer noise bursts a carrier fail detector is also employed. This detects failure of the data carrier or an excessive noise level relative to carrier level, and takes effect after a delay of about 5 ms.

Having detected an error, the signal unit concerned must be disregarded, and the information contained in the unit must be retransmitted. We thus need two things; a method of acknowledging signals and requesting retransmission, and a means of identifying signal units. The latter is achieved by transmitting units in blocks and allocating identifying numbers to the blocks. Individual units can then be identified by a block number and a position number within the block. Blocks are of fixed length, 12 units, comprising 11 signal units and a special block signal called an acknowledgement signal unit (ACU) which carries the number of the block. A block is illustrated in Fig. 4. Three

Fig. 4 — Block Formation.

bits in the ACU identify the block number, providing for a count of 8.

The ACU also provides the signal acknowledgement mechanism. Eleven bits are allocated to identify the signal units of blocks received in the reverse direction on the signalling link, on a one to one basis, and a zero (0) or one (1) is written in the ACU depending on whether the corresponding unit was received correctly or in error. A further three bits identify the block being acknowledged. An ACU format is shown in Fig. 5. The first three bits are given the identifying pattern 011.

It will be noted that in each ACU block acknowledgement field, the received ACU is not itself acknowledged. If an ACU, identified by its 12th position in the block, is received in error all signal units of the next block waiting to be acknowledged are assumed to have been received in error and the telephone signals within that block are retransmitted. This means that on occasions the same telephone signal may be received twice and the exchange design must ensure that such events do not cause service faults.

The selected method of error control introduces a further problem, that of ensuring the correct sequence of signals. Due to a signal unit being mutilated and retransmitted, it is possible for the successive digits of a subscriber's number to be received out of sequence and, to prevent wrong numbers, the digits must be rearranged in their correct sequence. To achieve this, three bits of the heading field of address messages are allocated to provide a message count relating to each connection. The first bit of the heading field is a one (1) denoting the fact of an address message, and the last three bits increase from 000,001 to 111 for each successive address message. Thus the third address message for a particular call, containing digit 9, would take the form

1/10111011001/1010/1001/11100101

if it were a single unit message.

Some line signals also must retain their correct sequence. For example assume that on answer of a call, the B-party 'flashes' his switch-hook thus sending a rapid sequence of 'answer' and 'clear-back' signals. If one of the 'clear back' signals is mutilated and retransmitted, or if an ACU is mutilated resulting in the unnecessary retransmission of of the 'clear back' signal, that signal could arrive at the originating exchange last, thus marking the B-party's condition incorrectly. This could result in false time-out or other service faults. Again this difficulty is overcome by allocating a sequence count to these signals for each call, in this case by defining three 'clear-back' signals, numbers 1, 2 and 3, and three re-answer signals.

Some line signals are exchanged on a compelled sequence basis and overcome difficulties caused by retransmissions in this way. For example, a clear-forward signal always elicits a release-guard when the distant end is cleared, and until the release-guard is received, follow-on calls cannot use that particular circuit. This prevents problems caused by the clear forward signal being delayed due to errors and subsequent re-transmission. Another line signal using this technique is the 'blocking' signal, which results in another 'blocking' signal being returned from the receiving exchange. This has the additional advantage, from a service point of view, that a bothway circuit cannot be arbitrarily blocked to incoming traffic at one exchange and used exclusively for outgoing traffic unless a special management signal is sent between the two exchanges concerned. Blocked circuits are cleared by the use of unblocking signals exchanged on a compelled sequence basis.

Finally it should be noted that if any unit of an MUM is mutilated, the complete MUM is retransmitted to avoid associating subsequent units with the incorrect initial unit.

PRIORITY

When a large group of circuits has only one link for signalling purposes it is inevitable that on occasions more than one signal will require transmission and delays will occur due to the need to form such signals in a queue. In such circumstances important sig-

A- FIXED CODE 011, 3 BITS

B- ACKNOWLEDGEMENT FIELD, 11 BITS

C- NUMBER OF BLOCK BEING ACKNOWLEDGED, 3 BITS

D- NUMBER OF BLOCK BEING SENT, 3 BITS

NOTE: 8 CHECK BITS NOT SHOWN

Fig. 5—Acknowledgment Signal Unit.

nals can be given priority, to reduce their delay. In the international context the only signal requiring such priority is the 'answer' signal due to its importance for call charging, and suspension of time supervision of the pre-answer period. Thus the answer signal is given priority over all other signals, but even with this priority it cannot break into MUMs. Retransmitted messages are also allocated priority over other 'first attempt' messages in their own priority grouping. When management signals are introduced it is assumed that these will be allocated a lower priority rating than normal telephone signals, so the priority rating of signals will be:—

1. retransmitted answer
2. answer
3. other retransmitted telephone signals
4. other telephone signals
5. retransmitted management signals
6. management signals.

Regardless of the priority of signals waiting for transmission the ACU is always sent to the twelfth unit position of each block, and in a sense can be regarded as having the highest priority of all. An ACU is the only unit that can interrupt an MUM.

SYNCHRONISATION

To enable transmitted information to be correctly received, the receiving terminal must be in synchronism with the transmitting terminal. Three levels of synchronisation are necessary — bit, unit and block synchronisation.

Bit synchronisation is provided by the data modem, which uses a four phase, synchronous, differentially coherent modulation method. The four phases each represent two bits of information (00, 01, 10 or 11), called dibits. The modem then presents a continuous serial bit stream to the signalling equipment which then must identify units and blocks.

On start up of a signalling link, the signalling equipment transmits blocks consisting of eleven special units called synchronisation signal units (SYU), and one ACU. Fig. 6 illustrates a SYU which consists of a 16-bit fixed pattern, a four bit field which identifies the location of the SYU within the block (i.e. first, second . . . or eleventh unit), and the usual eight check bits. The particular 16-bit fixed pattern of the SYU has been chosen because it presents an easily recognisable pattern with a variation at the end to aid in its detection, and because it provides six dibit transitions to aid the attainment of bit synchronisation by the modems.

Even before synchronisation of the received signal is obtained the transmitted ACU contains block acknowledgement (initially all ones (1) until synchronisation occurs) and the transmitted block identity number. Until synchronisation of the incoming signal allows identification of a received ACU the identity of the block being acknowledged cannot be given, so this 3-bit field in the ACU is given the fixed pattern 000. As soon as an incoming SYU is recognised, its position within the block is known and the location of the ACU is determined. The transmitted ACU can then contain acknowledgement of correctly received signals and the identity of the block being acknowledged. In this way both terminals become aware when each is synchronised with the other and the transmission of telephone signals can commence.

The SYU is also used as a 'dummy' signal when there are no telephone signals waiting to be transmitted. It is estimated that, even when the signalling link is serving the maximum number of speech circuits, on the average half of all units sent will be SYU (that is, the signalling link occupancy is 0.5). The inclusion of these units in normal transmission aids the regaining of synchronisation should this be lost due to excessive noise on the link.

Although each demodulator must be synchronised to its respective modulator, it is not proposed to synchronise the two modulators on a signalling link. Although this can be done over frequency-division multiplexed carrier channels, with some difficulty when a satellite link is involved, it is not possible over a time-division multiplexed system such as P.C.M. It is therefore inevitable that small variations in transmitted data rate will occur in the two directions of a signalling link even though the modem clock is stable to 0.005 per cent. Because the System No. 6 uses a block acknowledgement technique this difference in speed will create situations, over a long period of time, wherein the faster terminal has to form an ACU before the next complete block has been received, and the slower terminal accumulates a growing number of blocks to be acknowledged.

This difficulty is overcome by the following strategy. If a terminal has to transmit an ACU without having received a new block, it acknowledges the last received block again. If, on the other hand, a new ACU is formed before the previous one has been transmitted, the old ACU is replaced by the newly formed one. In the former case the distant end will receive two identical ACU's, except for the transmitted block number, and will ignore the second one. In the latter case the distant end will know from the acknowledged block number of the ACU that one block has not been acknowledged and will retransmit that complete block again, just as for the case of a mutilated ACU. In this way differences in the modem data transmission rates do not cause problems.

16 BITS	4 BITS	8 BITS
1 1 1 0 1 1 1 0 1 1 1 0 0 0 1 1	POSITION NO.	CHECKING FIELD

Fig. 6 — Synchronisation Signal Unit.

CONTINUITY CHECK

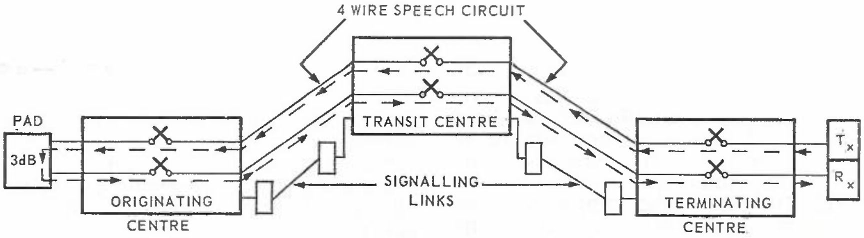

Fig. 7 — Continuity Check.

The use of a common signalling link removes one facility that is inherent in conventional schemes, that of checking the speech path as it is established. If a speech path is faulty, in-channel signals will not be received and the call will not be established. It is considered necessary to provide a similar service with System No. 6, and accordingly provision is made for a speech path continuity check on each call established using common channel signalling.

Fig. 7 illustrates the continuity check method. The last exchange in a connection using System No. 6 signalling connects a tone generator-receiver to the 4-wire speech path. The first exchange in the connection provides a loop, containing a 3 dB stability pad, between the two speech channels. The terminating exchange checks that the tone is passed around the complete connection, and sends a signal over the signalling link when the circuit continuity is confirmed, allowing the circuit to be through-connected at both the first and last exchanges.

If the check fails, the tone not being returned within a time supervision period of two seconds, a 'check fail' signal is returned over the signalling link. This causes each intermediate exchange to clear the connection and check each section as it is cleared in order to locate and remove the faulty section from service. The originating exchange may establish a new connection or return a suitable service tone or announcement to the calling subscriber.

The continuity check is merely a go-no go check of the speech path continuity and is not intended to be a transmission test. The transmitted tone level is — 9 dBmO and the tone receiver acceptance levels are from

—25 dBmO to 0 dBmO. Any number of channel links from two to 12 may be included in a continuity check, and a suggestion has been made that a link-by-link continuity check will prove faster and more efficient than the end-to-end check described above, because checking of earlier links can proceed while signalling continues on the later links. This contention will be tested by experiment before System No. 6 is introduced on a large scale.

It should be noted that to make System No. 6 suitable for signalling in 2-wire networks it would be necessary to change the continuity check to provide a different frequency in each direction of transmission.

SECURITY

With a large number of speech circuits depending on one signalling link for the establishment and supervision of connections, the security of the signalling link must be assured. At least one standby link should be available at all times to carry the signals should the normal link fail or the error rate rise beyond an acceptable level. With conventional signalling schemes calls may be established as long as at least one speech circuit is available, and a similar surety is required in System No. 6.

The standby signalling link may be provided in a number of ways, and it is likely that more than one method will be used to secure each signalling link. The first method is to provide a standby link which is carrying blocks of SYU and is in synchronism, ready to accept signal units at any time. This standby is used exclusively as a back-up link. This technique may be too expensive for small circuit groups, and an alternative is to use the standby link as a last-choice speech circuit when required. This method has the disadvantage that when required for signalling the standby link may be engaged on a call which must then be force released, and the link must be associated with modems at each end and got into synchronism before it can carry signal units. It is also possible that, at an exchange having a large number of System No. 6 signalling links, it will prove too expensive to provide a standby modem for each link, even though an idle standby circuit is provided on each route. In this case a small group of modems will be provided, each of which can be connected to any required signalling link. In this case it is also necessary to attain synchronism before signalling over the standby link.

Another possibility, for very small circuit groups or as a final alternative, is to establish a signalling link between two exchanges by using pre-assigned speech circuits, possibly interconnected at one or more tandem exchanges. A further variation of this method is to establish the signalling connection of 'dialling' a special code, in which case the choice of circuit would not be pre-determined.

Remembering that a network using common channel signalling will be largely processor controlled, another more elegant solution to the problem of security is to send signal units over the signalling link network via other exchanges. This is known as quasi-associated alternative routing of signals. Quasi-associated signalling may in some cases be the normal method of working, as discussed in the next Section.

We have so far considered methods of providing alternative signalling links, but it is also necessary to decide when such standby procedures should be invoked. It is undesirable to delay the switching to a standby link to the extent that signals experience excessive delays, but it is also bad practice to 'jump too soon', particularly as the starting up of the standby link may be a lengthy process. If the fault condition on the normal link is likely to be of short duration it is better to delay action for a reasonable period.

The recorded statistics indicate that spurious breaks on carrier circuits usually do not persist beyond about 300 ms, and that a break lasting longer than 350 ms is likely to persist for some time. It has therefore been decided to delay action for 350 ms in the event of complete loss of the signalling link, that is 100% signal unit failure rate. On the other hand, if the standby link requires some seconds to start up, it is considered desirable to delay the decision to switch to the standby for an even longer period, and for this case 1 second has been selected. These delays take account of the estimated signalling link load and desirable signal delays.

Should the error rate on the signalling link rise without the link failing completely, different criteria are required. The normal signal unit failure rate on a working link is expected to be about 1 in 10^4, but the link should work satisfactorily under a much higher error rate. It has been decided that security measures should be invoked if a unit failure rate of 20% is experienced for 30 seconds. These points give rise to the graph in Fig. 8 which relates error rate to security switching delay.

In some cases only one channel of the signalling link will fail and the receiving terminal must instruct the far end to switch to the standby. In other cases the complete link will fail and both ends must switch to the same standby. It is possible that the standby is also faulty and a pre-determined sequence of alternative links must be tested in turn by each end, following timed periods which ensure that one terminal does not get ahead of the other, which would remove all chance of the two ends regaining contact.

When a terminal observes that the error rate on the signalling link has exceeded an excessive level for the required period of time, a system control signal unit (SCU) is sent to the far end which causes that end to switch to the standby. This signal is called a 'changeover' signal and is sent in a continuous stream except for the acknowledgement signal units. The near end also proceeds to start up the standby if this is necessary. The far end, on receipt of the first 'changeover' signal unit also proceeds to start up the pre-determined standby if necessary and applies a continuous stream of SYU, with appropriate ACU, in the return direction. When the standby link attains synchronism, signal units are propagated over it. The original link continues with SYU propagated in one direction, the faulty direction, and 'changeover' units in the other. As soon as the fault condition is cleared the SYU's allow the receiving terminal to regain synchronism, and the normal link may then be returned to service. If the fault affects both channels of the signalling link and 'changeover' units are propagated in both directions, one of the terminals will be pre-assigned to change transmission to SYU on detection of the incoming 'changeover' units.

NETWORK ASPECTS

The high speed and digital nature of System No. 6 makes it a very suitable signalling technique between processor

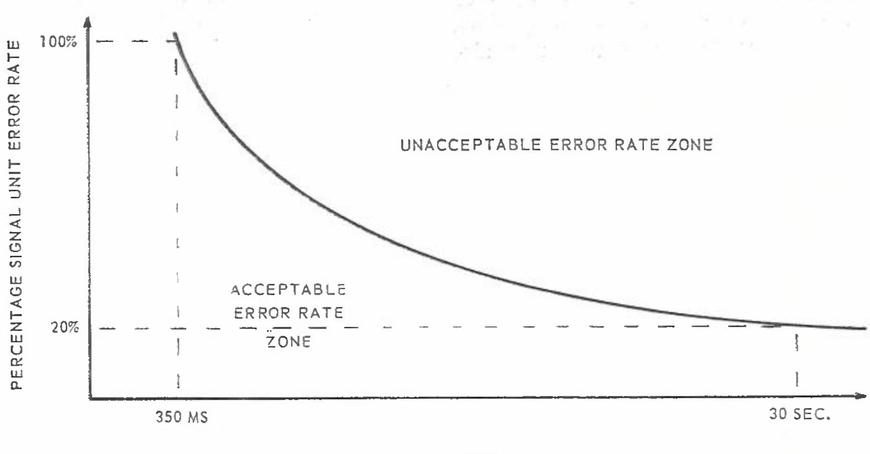

Fig. 8 — Security Switching Delays.

controlled exchanges but not so readily applicable to the present generation of electromechanical exchanges. Its introduction therefore depends on the establishment of a network of electronic exchanges, but new exchanges inevitably have to interwork with the established equipment and must use the analogue signalling systems presently in use. As the number of processor controlled exchanges grows in relation to the number of earlier types, a point will be reached when the necessity of providing the older signalling facilities in the new exchanges will impose severe cost penalties and it will become economic to extend common channel signalling to the electromechanical exchanges, probably by replacing the registers and other control equipment with electronic units. The point at which this changeover becomes economic will depend on the cost of the new equipment, which on present trends can be expected to fall at an appreciable rate for some years. It will depend also on the requirement to extend the greater facilities available with electronic equipment to the older exchange systems.

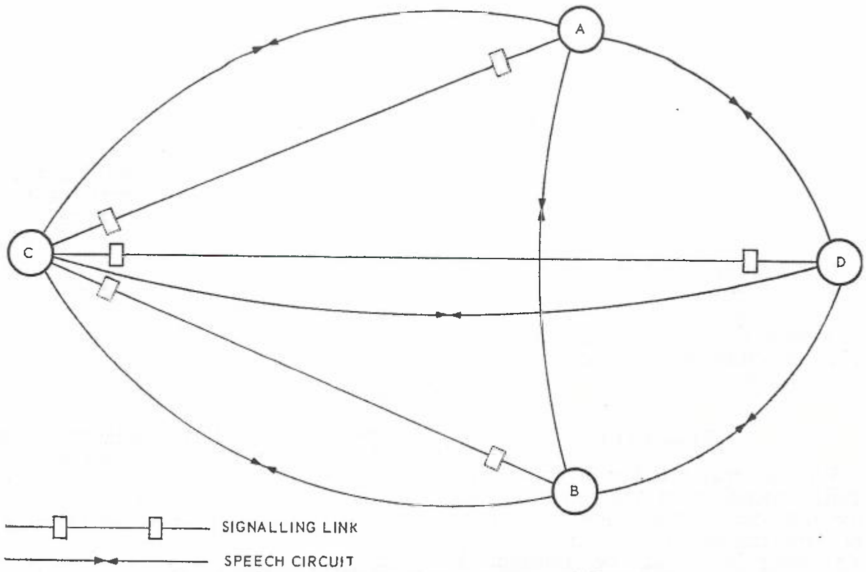

Fig. 9 — Network Using Common Channel Signalling.

The economic implications of a common channel signalling scheme in a hybrid network are difficult to judge at this early stage, but signalling between two processor controlled exchanges should prove cheaper with a common channel scheme than with a conventional in-channel scheme for about 60 circuits or more, on present equipment costs. Exchange networks contain many circuit groups of smaller size than this, but the flexibility of processor control and common channel signalling allows for the efficient inclusion of these small groups in the network. Consider the network of Fig. 9. All four exchanges, A, B, C and D are interconnected by bothway circuits but only AC, BC and CD share signalling links. Signalling beween AB, AD and BD is conducted via C, which identifies signals destined for other exchanges from the label included in each signal unit. This mode of signalling is called quasi-associated, as opposed to the normal associated mode wherein the signalling link and speech circuits have the same terminal points. Exchange C is known as a signal transfer point. Calls from A to B may also be routed via C, in which case C becomes a call and signal transit point. Signals arriving at a transit point not only require switching through to the appropriate signalling link after appropriate label change, but also must be acted upon, if appropriate, by the transit exchange.

Because of the high speed of System No. 6 signalling, the time required by a transit or transfer exchange to accept, process and re-emit a signal may become a limiting factor in the overall network signalling speed. Accordingly permissible cross-office transfer times for signal units have been specified. The average values of these delays vary from 40 ms for a priority single unit (answer) to 120 ms for a multiple unit message. These figures include the queueing delay experienced by signals on entry to the signalling link which is a function of signal traffic.

A further point which will enhance the economic advantages of common channel signalling lies in the fact that such a network can be expected to contain only bothway speech circuits, as the signalling method does not require the provision of expensive bothway line relay sets on all circuits. Dual seizure conditions can be readily handled by the processors, one end ignoring the incoming seizure while the other end re-establishes the call on another circuit.

CONCLUSION

C.C.I.T.T. System No. 6 is one of the most interesting telephone signalling developments in the history of telephony. It is a system being developed for the next generation exchange equipment types rather than an expedient to meet an existing requirement. It is also the first signalling system to be developed by international co-operation between operating authorities, so that it has the potential to become a universal signalling system, for national and international use. The Australian Post Office and the Overseas Telecommunication Commission, of Australia, are actively participating in its development and testing.

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P.C.M. RADIO RELAY SYSTEMS

*K. A. ENDACOTT, B.E., Dip.E.E.**

INTRODUCTION

In the early 1950s, the Australian Post Office installed a number of 23-channel pulse time modulation (P.T.M.) radio relay systems, some of which are still in use. These P.T.M. systems used vacuum tubes and were difficult to align, unreliable, and extravagant in their use of the radio frequency spectrum.

Recently, pulse code modulation (P.C.M.) systems have become practical due to the development of suitable semiconductor devices, and the A.P.O. is at present evaluating a trial two-hop 48-channel P.C.M. radio relay system between Windsor and Kurrajong in N.S.W. Other P.C.M. radio relay equipments capable of carrying up to 300 telephone channels per radio bearer are available, and even larger capacity systems are being developed by several manufacturers.

P.C.M. encoding is carried out by sampling the input waveform at regular intervals and generating a pulse code which represents the signal level at the sampling instant. Pulse signals from a number of channels are then combined in serial form to give a pulse stream that can be transmitted over a suitable bearer. Only the presence or absence of a pulse must be determined at the decoding end to reconstruct the input waveform, and the system can operate satisfactorily in the presence of heavy noise.

When transmitting P.C.M. over radio relay systems, the pulse stream must modulate the radio bearer. Methods in use include amplitude, phase, and frequency modulation and the resultant overall modulation is described as P.C.M.-A.M., P.C.M.-P.M. and P.C.M.-F.M. respectively. By comparison, the existing broadband radio relay systems frequency modulate the radio bearer with a frequency division multiplexed signal (F.D.M.-F.M.).

In this article, equipments of differing capacity and modulation method offered by three manufacturers are described and the general system design aspects of P.C.M. radio relay systems are discussed. Applications to the Australian network, particularly for 'thin line' systems in remote areas, are considered.

P.C.M. FUNDAMENTALS

In the Appendix, a brief outline of P.C.M. principles is given. Fig. 1 shows a pulse stream from a typical 300-channel P.C.M. encoder. The 'marks' are shown as rectangular pulses, but in practice they are usually transmitted as 'raised cosine' pulses to give a minimum bandwidth of about twice the pulse rate for a unipolar pulse stream.

The error rate of P.C.M. radio relay systems is usually insignificant for a large percentage of the time, but when fades occur the error rate can rise to an unacceptable level. Fig. 2 shows the error rate versus signal-to-noise

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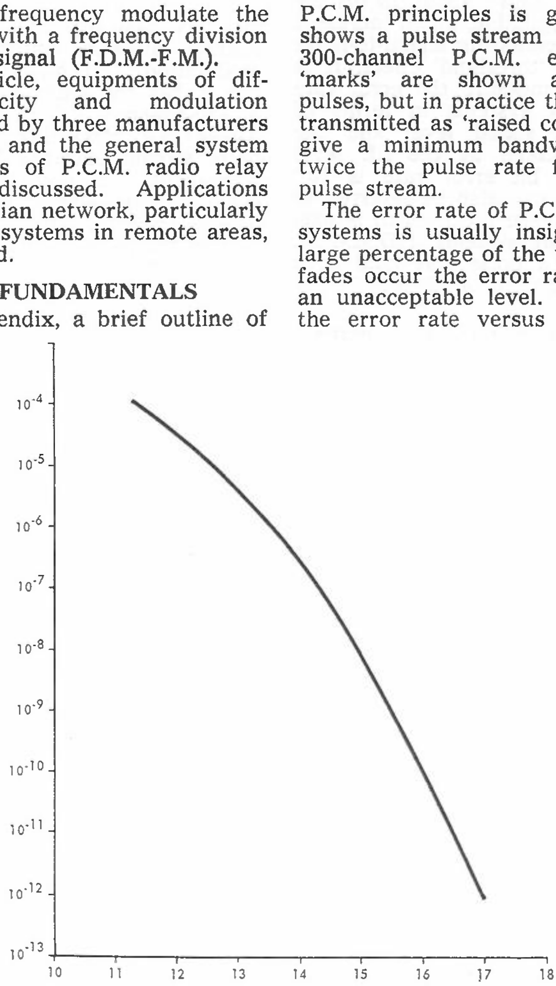

Fig. 2. — Bit Error Rate versus Signal-to-noise Ratio, Assuming Gaussian Noise

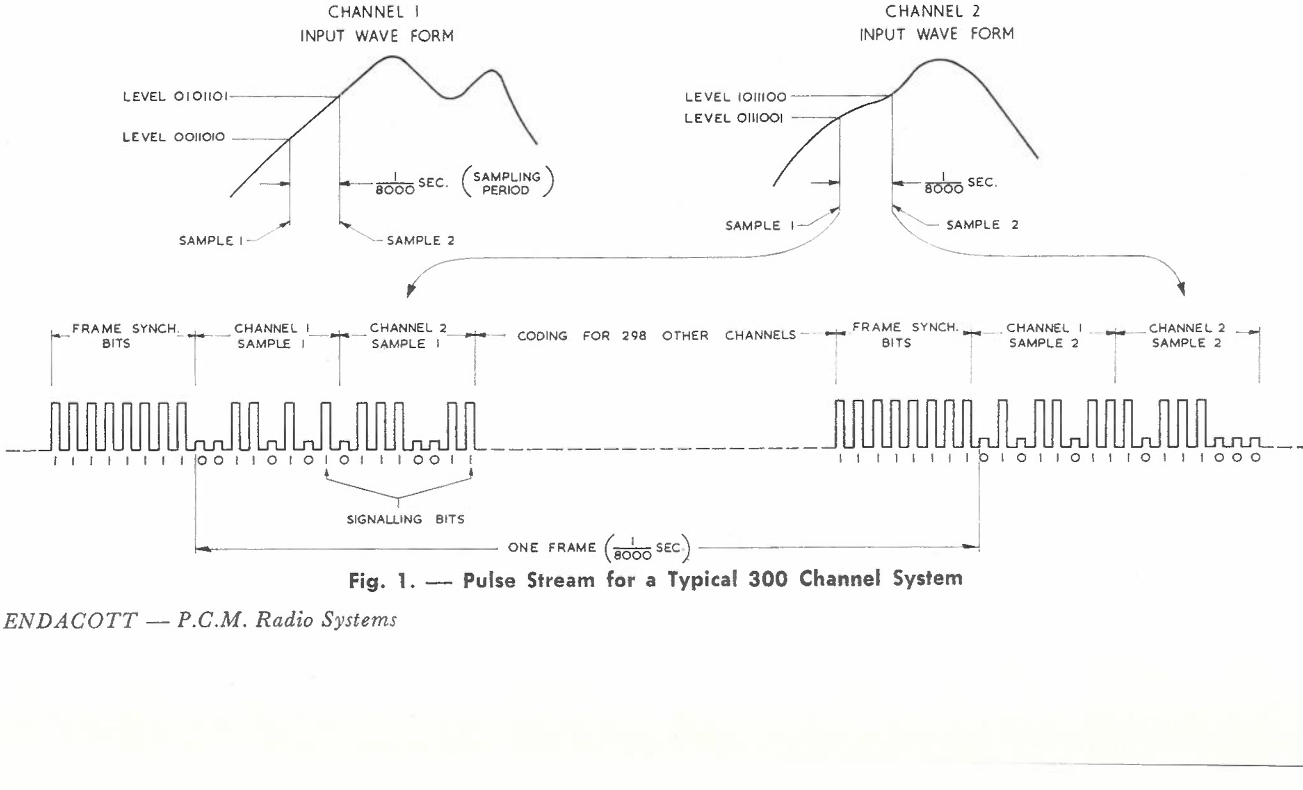

Fig. 1. — Pulse Stream for a Typical 300 Channel System

ratio measured at the P.C.M. decoder for a unipolar pulse stream. For signal-to-noise ratios above about 15 dB the error rate is negligible, but it increases rapidly with decreasing signal-to-noise ratio giving a 'threshold' effect. It is convenient to measure the error rate of radio relay systems in terms of the r.f. input signal level and the threshold is taken as the r.f. level at which the bit error rate is 10^{-6} This threshold can also be referred to the carrier-to-noise ratio which is useful in comparing systems. F.D.M.-F.M. systems have a noise threshold at a carrier-to-noise ratio of 12 dB.

P.C.M. RADIO RELAY EQUIPMENT

N.E.C. 300 and 240 Channel P.C.M.-P.M. Equipment

This equipment uses differential four-phase modulation of the radio bearer to transmit two bits simultaneously and thus halve the bandwidth of the complete pulse stream. The total bit rate is 15.7 Mb/s which is twice the transmitted pulse rate, and the radio bearer bandwidth is about 15 MHz. For the 240-channel equipment the encoding can be carried out in 24 or 120 channel groups with pulse-stuffing equipment available allowing flexibility of arrangement of drop and insert. These groups can be transmitted over compatible cable systems. The 300-channel equipment does not have pulse-stuffing facilities, and the encoding is carried out in 150-channel groups. The 24-channel codecs use diode companders but the 120 and 150 channel codecs use pulse amplitude modulation coding as an intermediate stage and non-uniform coding levels in the P.C.M. converters.

The eighth bit per telephone channel is used for signalling, synchronising and error detection. This bit has an information capability of 8 Kb/s but, as signalling requires a much lower speed, 6 Kb/s of this is allocated to synchronising and error detection.

When several synchronisation pulses in succession are lost (a single lost pulse will not cause loss of synchronisation) the system will re-synchronise. Channel synchronisation is achieved in an average time of about 50 microseconds. Error detection is achieved by monitoring the channel synchronising bits which occur at the rate of about 1.4 Mb/s. This error detection can be used to control protection switching or diversity equipment.

The radio frequency carrier-to-noise ratio for a bit error rate of 10^{-6} is about 15 dB but deterioration of this figure occurs if a supervisory system which frequency modulates the radio bearer is used. Non-demodulating repeaters are used and demodulation and regeneration every 280 km are recommended. N.E.C. claim it is possible to transmit and receive six radio frequency bearers with the one antenna and a total of 12 bearers on two antennas can be used in a 400 MHz frequency band.

Telettra 120-Channel P.C.M.-F.M. System

The Telettra H24 radio relay equipment is basically a 960-channel frequency division multiplex-frequency modulation (F.D.M.-F.M.) equipment but it has the capability of carrying a 120-channel P.C.M. system. An Alternative Mark Inversion (A.M.I.) pulse stream obtained from encoding equipment for the Telettra P.C.M. cable systems, gives a baseband signal of 8 KHz-8MHz which frequency modulates the radio bearer. Demodulation and regeneration is carried out at every repeater. When carrying a 120-channel P.C.M. signal, the radio bearer occupies the same bandwidth as a 960-channel F.D.M. system and, furthermore, the fading margins of the P.C.M. and F.D.M. systems are not significantly different.

S.G.T. & E. 48-Channel P.C.M.-A.M. System

This equipment uses two 24-channel codecs identical with the S.G.T. & E. P.C.M. cable system, with additional equipment to combine into a 48-channel 3.088 Mb/s stream. This pulse stream amplitude modulates the radio bearer in the 7.5GHz band. Demodulation and regeneration is carried out at every repeater and a 24-channel group can be dropped and inserted. The bandwidth of the radio equipment is 6 MHz and the P.C.M. threshold occurs at a carrier-to-noise ratio of 14 dB. It is possible to use radio bearers spaced about 7 MHz apart on the one route and thus use all 14 channels in the 7.5 GHz band.

The advantages of this equipment are simplicity and moderate cost.

SYSTEM DESIGN

Performance Objectives

Although there is at present no C.C.I.R. recommendation on the performance objectives of P.C.M. radio relay systems, the Japanese (Ref. 1) propose an error rate exceeding 10^{-6} for not more than 0.01% of any month for a C.C.I.R. reference circuit of length 2500 Km. This proposed standard is similar to the C.C.I.R. recommendation for F.D.M.-F.M. systems, of telephone channel noise exceeding 10^6 pW for not more than 0.01% of any month for the 2500 Km reference circuit. These error rate and noise criteria represent the effective thresholds of the P.C.M. and F.D.M.-F.M. systems, and therefore the design fade margins would be the same if the two systems were applied to the same path. Existing P.C.M. systems have a 'threshold' at a carrier-to-noise ratio of greater than 14 dB compared with 12 dB for F.M. systems and, furthermore, the effect of interference and misalignment is to increase the effective P.C.M. system threshold. The net result is that, in order to meet the Japanese proposed objectives, P.C.M. systems must be designed to have higher received signal levels compared with similar capacity F.D.M.-F.M. systems.

Interference

P.C.M. radio relay systems are insensitive to interference provided the interfering signal is less than the wanted signal by a protection ratio which is dependent on the type of interference and the receiver transfer factor. The interfering signal must be less than the threshold signal by the amount of the protection ratio if the fading margin is to be unaffected. For example, paths of length around 25 miles may require fade margins of 40 dB. Assuming an interference protection ratio of 10 dB, the interfering signals must be 50 dB less than the unfaded signal. Antennas for these paths should therefore have front-to-back ratios of greater than 50 dB.

Shorter paths require lower fade margins and would require less interference protection. Systems with short paths can use low-grade antennas, low foreground clearance and relaxed overshoot criteria compared with long path requirements.

Frequency Planning

The bandwidth of a unipolar P.C.M. signal is about 10 times the bandwidth of an F.D.M. signal of the same capacity. However, a typical 300-channel F.D.M.-F.M. equipment has an i.f. bandwidth of between 15 and 20 MHz compared with the P.C.M.-P.M. system i.f. bandwidth of 15 MHz. F.D.M.-F.M. equipment requires the i.f. bandwidth to be in excess of the transmitted bandwidth in order to maintain flat response over the band occupied by the signals, whereas the equalisation requirements of P.C.M. are not as severe and the i.f. bandwidth of practical P.C.M. equipment can be close to the theoretical limit. By comparison, 1800-channel F.D.M.-F.M. systems use an i.f. bandwidth of about 40 MHz, but a hypothetical 1800-channel P.C.M.-P.M. system would require an i.f. bandwidth of 90 MHz.

In general, small and medium capacity (up to 300-channel) P.C.M. radio relay systems utilise the radio frequency spectrum at least as efficiently as F.D.M.-F.M. systems of similar capacity.

Receiver transfer factors for interference between P.C.M. and F.D.M. systems are not known at present, but it is reasonable to assume that any problems that will occur will be due to interference from the P.C.M. system into the F.D.M. system. Careful frequency planning and attention to antenna characteristics should overcome any difficulties.

N.E.C. suggest that interference between P.C.M. bearers can be reduced by using radio channels spaced at a multiple of the bit rate, but this may require a non-standard frequency plan. To reduce interference problems with existing frequency allocations, P.C.M. systems must use compatible frequency plans.

Diversity and Protection Switching

Standby radio bearers were originally intended to protect against equipment failures only, but modern solid state equipment has a high reliability and the standby channels can be used to provide some frequency diversity and thus allow the fading margins on paths to be reduced accordingly. However, space diversity may still be required on individual paths where severe propagation difficulties are encountered. Diversity and protection switching of P.C.M. systems can be operated from error detection, provided the detection is rapid. For example, failure of A.M. signals can be detected within a few bits and, with rapid switching, single errors will occur in only two or three telephone channels but error detection based on frame synchronisation can result in errors in all channels.

P.C.M. RADIO RELAY SYSTEMS IN THE AUSTRALIAN NETWORK

P.C.M. multiplexing equipment is considerably cheaper than F.D.M. equipment of the same capacity. On the other hand, P.C.M. radio bearer costs of presently available equipment tend to be higher than F.D.M.-F.M. bearer costs because of the higher signal levels required to achieve the same fading margin. Therefore, for an isolated radio relay system, P.C.M. would be more economical, particularly for short haul applications, but the interconnection of P.C.M. systems with the F.D.M. broadband network presents problems. Interconnection must be carried out by either demodulating and remodulating individual telephone channels or by pulse code modulating groups of F.D.M. channels. Unfortunately both methods increase multiplexing costs and the latter method gives inefficient use of the bearer and frequency spectrum.

Therefore the full cost advantages of P.C.M. cannot be realised unless the P.C.M. system is interconnected with other P.C.M. systems, as the isolated system rarely exists in practice. The existing F.D.M. broadband network represents a heavy investment and should be expanded to its design capabilities, nevertheless the development of a P.C.M. network may be hastened by the increased demand for data transmission and by further equipment cost reductions with increased use of integrated circuits.

By comparison with F.M. bearers, P.C.M. radio relay systems are less efficient for carrying television signal transmission. At present a large percentage of Australian radio relay systems carry television.

Many new radio relay routes will in future be located in remote areas with connection to the broadband network at only one or two points. Using currently available F.D.M.-F.M. equipment, such systems are expensive because of high installation costs, power supply problems, propagation difficulties and the need for high towers due to the generally flat nature of the country.

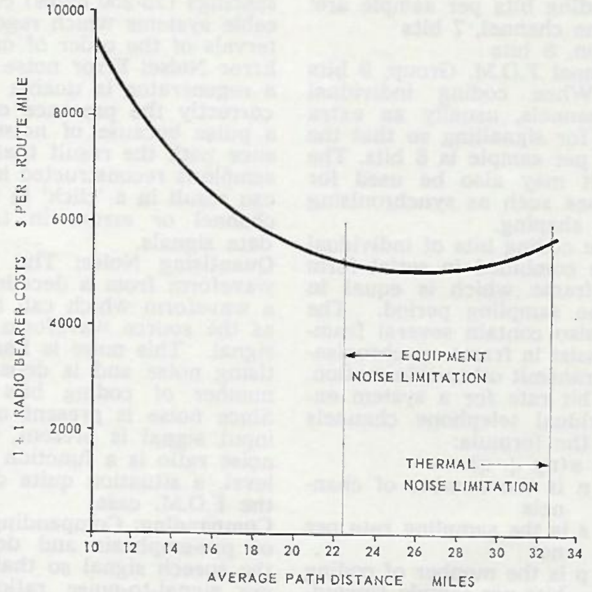

Fig. 3. — Typical 300 Channel FDM-FM Radio Bearer Costs. Assuming Route over Flat Country

Fig. 3 shows typical bearer costs versus average path length for currently available 300-channel F.D.M.-F.M. systems assuming the route is over flat country. The costs shown include radio and power equipment, buildings, towers, antennas and site works. The maximum and minimum average path lengths are limited by thermal and equipment noises respectively. By contrast, P.C.M. systems can give satisfactory performance with short path lengths, and the equipment can be designed for this service giving a different cost curve. Short paths would require low fade margins which would enable the use of low-power consumption equipment, small diameter antennas and low height, lightweight towers. Power supply may still present a problem, although improvements in lifetime and reductions in cost of thermo-electric generators using bottled gas have been made recently.

CONCLUSION

Despite the extra radio equipment cost due to the higher signal levels required, P.C.M. radio relay systems for telephony are less expensive than F.D.M.—F.M. systems because of their low multiplexing costs. However, interconnection with the existing F.D.M. network presents problems and will inhibit the use of P.C.M. P.C.M. systems are very suitable for carrying data transmission but are relatively inefficient for carrying television relays.

For all but a small percentage of the time, P.C.M. radio relay systems give telephone channel noise that is independent of the number of repeaters. P.C.M. may be suitable for systems in remote areas using low-power equipment and short paths.

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APPENDIX

P.C.M. Principles

These notes give an outline of the principles of P.C.M. and define some of the commonly used terms.

Sampling Rate: The sampling rate must be at least twice the maximum analogue frequency to be encoded. Typical sampling rates are:—

Telephone channel, 8K per second
Television signal, 12M per second
600-Channel F.D.M. Group, 6M per second.

Coding Bits per Sample: The number of discrete levels that can be transmitted is 2^p where p is the number of coding bits per sample. Distortion occurs because the input waveform can be encoded only to the nearest coding level and thus the reconstructed waveform is not an exact replica of the input signal. Larger values of p give less distortion but the overall bit rate is increased.

Typical coding bits per sample are:
Telephone channel, 7 bits
Television, 8 bits
600-Channel F.D.M. Group, 9 bits

Signalling: When coding individual telephone channels, usually an extra bit is added for signalling so that the total coding per sample is 8 bits. The signalling bit may also be used for other purposes such as synchronising or spectrum shaping.

Bit Rate: The coding bits of individual encoders are combined in serial form to form a frame which is equal in period to the sampling period. The frame may also contain several framing bits to assist in frame synchronisation and to transmit other information.

The total bit rate for a system encoding individual telephone channels is given by the formula:

bit rate = s(np + q)

where n is the number of channels
s is the sampling rate per nel
p is the number of coding bits per sample (including signalling bit)
q is the number of framing bits per frame

Typical bit rates are:
24 telephone channels, 1.5 Mb/s
300 telephone channels, 15.7 Mb/s

Regeneration: Regeneration is carried out at intervals along the transmission path to ensure that the bearer signal-to-noise ratio does not become small enough to cause large error rates. Regeneration is achieved by sampling the incoming signal to determine the presence or absence of a pulse, and generating a new pulse accordingly. The sampling is controlled by a local clock which is phase locked to the bit rate of the incoming pulse stream.

Jitter: Jitter of a pulse stream takes the form of time displacements of the pulses. When decoded this results in a time displacement of the reconstituted sample which appears as noise similar to thermal noise, although under some circumstances intelligible crosstalk can be produced. Jitter occurs on a regenerated pulse stream because of phase variations of the local clock, noise on the incoming signal, crosstalk from other P.C.M. systems, or from the local clock phase locked to the incoming pulse stream which has random pulse patterns and hence does not have a constant frequency spectrum. This last reason is by far the most important because it results in similar jitter at each regenerator, giving cumulative effects.

Jitter can be reduced by using a narrow bandwidth on the phase control loop of the local oscillator or can be largely removed by a 'dejitterizer' which consists of a memory into which is written the incoming pulse stream. The outgoing pulse stream is then obtained by reading the memory with a 'clean' clock, the frequency of which is arranged to keep the store half-full on the average.

Jitter presents few problems on P.C.M. radio relay systems which regenerate at from one to five repeater spacings (25-250 miles) compared with cable systems which regenerate at intervals of the order of one mile.

Error Noise: Error noise occurs when a regenerator is unable to determine correctly the presence or absence of a pulse because of noise or interference with the result that a particular sample is reconstructed in error. This can result in a 'click' in the telephone channel or errors in telegraph and data signals.

Quantising Noise: The reconstructed waveform from a decoder consists of a waveform which can be considered as the source waveform plus a noise signal. This noise is known as quantising noise and is dependent on the number of coding bits per sample. Since noise is present only when an input signal is present, the signal-to-noise ratio is a function of the signal level, a situation quite different from the F.D.M. case.

Companding: Companding is a process of pre-emphasis and de-emphasis of the speech signal so that the quantising signal-to-noise ratio is approximately independent of signal level over a wide range of input. Companding is often carried out by means of non-linear pre-emphasis and de-emphasis of the analogue signals, followed by linear encoders and decoders, but it may also be achieved by using non-uniform coding levels. Distortion of the signal can occur if the companding curves are not closely matched.

Synchronising: The positions of the frames in the pulse stream and the channel pulses within the frame must be determined so that decoding can be carried out. Special framing pulses determine the start or end of a frame; however, a burst of noise could cause the decoder to lose frame synchronisation and it may take some time (several milliseconds) to recover, during which all channels will be lost. Most radio systems use powerful synchronisation methods to minimise the loss of synchronisation that could occur with fades.

Spectrum Shaping: Satisfactory transmission of a binary pulse train by radio requires that the bearer have a bandwidth from d.c. to about twice the pulse rate. The handling of d.c. presents some difficulties for cable systems and so they usually shape the frequency spectrum by changing the character of the pulse stream. The most common method is by using Alternate Mark Inversion (A.M.I.) with bi-polar pulses. With this method, a zero signal represents a "space" and a positive or negative signal a "mark". Alternate marks are inverted so that the frequency spectrum of the resulting signal is halved and contains no d.c. components. Although the bandwidth is halved, the noise immunity is also halved.

Radio bearers can usually pass the d.c. component of a signal, but in order to reduce the bandwidth requirements, multi-level coding is sometimes used. This method also trades bandwidth for noise immunity.

Drop and Insert: Dropping of channels from a multichannel P.C.M. signal presents little problem and individual or groups of channels can be dropped by selecting relevant pulse groups from within the frame. However, the insertion of channels presents some problems because it is necessary to exactly synchronise the sampling rates of all channels. Three methods of insertion are possible:—

Clock distribution: A central timing clock is distributed to all encoder-decoder (codec) points in the network. This method has obvious disadvantages in setting up a distribution scheme and in maintaining reliability. In addition, changes of phase of the distribution bearers can cause problems.

Stable oscillators: In this method all encoder clocks are made as stable as possible. The pulses to be inserted are written into a holding store from which they are extracted when required for insertion into the pulse stream. Because of the frequency difference between clocks, the store will be periodically exhausted (or storage capacity will be exceeded) and the inserted pulses will be repeated (or lost), thus causing an error. The error rate is dependent on the clock stabilities, the store size and the bit rate. Generally, this method is satisfactory for small capacity systems but gives excessive error rates for large systems.

Pulse staffing: This is used to give insertion where the clocks are not synchronised. The method is similar to the stable clocks method except that the local clock is run slightly slower than the main clock with the result that store becomes periodically empty. When this occurs dummy (or stuffed) pulses are sent, at the same time signalling pulses are sent to the decoder identifying the stuffed pulses. These signalling pulses are usually included amongst the framing pulses. The decoder then removes the stuffed pulses from the pulse train and restores the original clock frequency of the particular channel group.

Television Signals: P.C.M. systems can carry television signals if a sufficiently high bit rate can be transmitted. For coding 525 line colour television, the Bell System use nine coding levels and a sampling rate of 12M per second to give a total bit rate, including signalling and framing bits, of 112 Mb/s. On the other hand, it is possible to satisfactorily transmit 625 line monochrome television with a bit rate of about 60 Mb/s.

Error Detection: Errors can be detected by examining redundant information in the pulse stream. For example, with A.M.I., the reception of two successive positive or negative marks indicates an error. Other methods of detection include the monitoring of synchronising or signalling pulses.

TRUNK CIRCUIT TESTING IN THE S.T.D. NETWORK

*I. G. COOK, B.E., A.M.I.E.E.**

INTRODUCTION

The development of a Subscriber Trunk Dialling network for Australia envisages provision of the trunk switching function mainly by L. M. Ericsson A.R.M. trunk exchanges, line pulse signalling and multi-frequency compelled sequence (M.F.C.) information signalling (Refs. 1, 2 and 3). The design and development of economic and effective methods for supervising the service performance of a rapidly growing S.T.D. network is a challenging task faced by many administrations. In the Australian Post Office, one vital facet is surveillance of the performance, particularly transmission performance, of the trunk and junction circuits in the network.

S.T.D. Network Performance

The methods used or being developed to supervise the performance of the S.T.D. network and to reveal trouble spots are as follows:

(a) Alarm equipment associated with either the trunk line relay sets or the carrier equipment. The trunk relay sets will automatically busy or block themselves to traffic when a fault occurs on the circuit. When a certain pre-determined number of circuits on a route are out of service, an urgent alarm will draw the attention of staff to the fault. Pilot alarms may be provided on twelve channel group equipment. However, with short and medium distance broad band bearers these may not be necessary.

(b) The regular use of traffic route testers (T.R.T.'s) over S.T.D. routes.

(c) Sampling of live traffic at the point of entry into the automatic trunk exchange. The traffic will be sampled at the nearest point possible to the subscriber's line.

(d) The analysis of subscriber and operator trouble reports on S.T.D. by Service Co-ordination Centres.

(e) The analysis of trunk circuit fault reports by computer.

(f) Holding and tracing of calls for special investigation. This has limited use in modern trunk circuit equipment.

(g) Regular checks of the signalling and transmission characteristics of trunk circuits by the use of automatic or manual trunk circuit testers.

Only (a) and (g) give a direct indication of a faulty trunk circuit. Most of the other supervision techniques give a measure of end to end performance, or point to particular types of difficulties without necessarily pin pointing the actual circuit causing the trouble. Indeed a particular service difficulty may be the result of interaction effects due to sub-standard equipments being connected together in a call.

It is difficult to assess the transmission performance of individual trunk circuits or groups of trunk circuits particularly by indirect means, in a complicated, alternately routed telephone network. Hence there is a need for some method of checking the service performance of individual trunk circuits and this article briefly outlines the test access facilities and the various test units under development for this purpose in the A.P.O.

TESTING FACILITIES

The station designated as 'circuit control' is responsible for the end-to-end testing and fault finding on a trunk or junction circuit, which is regarded as commencing at the 'exchange' side of the outgoing line relay set appearance, and finishing at the 'exchange' side of the incoming line relay set appearance. In the case of a uni-directional circuit the 'circuit control' station is usually the one with the outgoing appearance.

For the operator controlled network A.P.O. practice has been to provide a Trunk Test Board access facility between the carrier equipment and the trunk line relay set at both the outgoing and incoming appearance of the circuit. This trunk test board enables the testing officer to effectively 'divide' or 'split' the circuit (both speech and signalling paths) between the exchange and the carrier equipment, but it does not permit end-to-end testing of the complete circuit. However, this latter facility has been provided by various automatic means at many manual trunk switching centres where the operators have fully automatic access to the trunk circuits.

The testing facilities now being developed for the S.T.D. network are summarised as follows (see Fig. 1):

(a) At the outgoing end test access is provided to the exchange side of the line relay set of each trunk circuit having an outgoing appearance. The test access is via special automatic switches and is used by a trunk routiner, and by a Trunk Test Console which is used to conduct initial testing and fault localisation when a fault has been reported or there is reason to believe a fault exists. The trunk test console replaces the former trunk test board.

(b) At smaller stations with less than say 100 trunk circuits, a simple manual access from a remote test position can be provided.

(c) A panel comprising one lamp and one button for each outgoing trunk circuit is provided to facilitate fault supervision and control of individual circuits.

(d) Test jacks are provided on each incoming and outgoing line relay set. These jacks are mounted on the line relay set rack test panel which also has a lamp and button per circuit as in (c) above.

(e) At the incoming end of a trunk circuit there is no remote test access facility as for the outgoing end. Test calls can be directed to the trunk test console or a special test relay set known as the Test Call Answer Relay Set (T.C.A.R.S.) at the exchange where the incoming circuit terminates.

It is envisaged that as far as practicable test calls on trunk circuits, either for routine checking or for checking for specific faults, will be conducted from the trunk test console at the outgoing station without the assistance of a technician at the incoming station. From the trunk test console the testing officer can gain access to the individual trunk circuit,

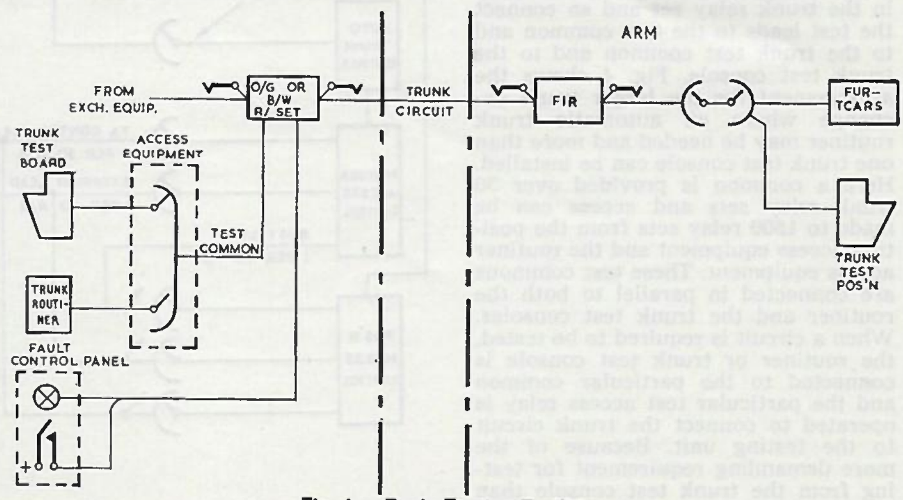

Fig. 1 — Basic Testing Facilities.

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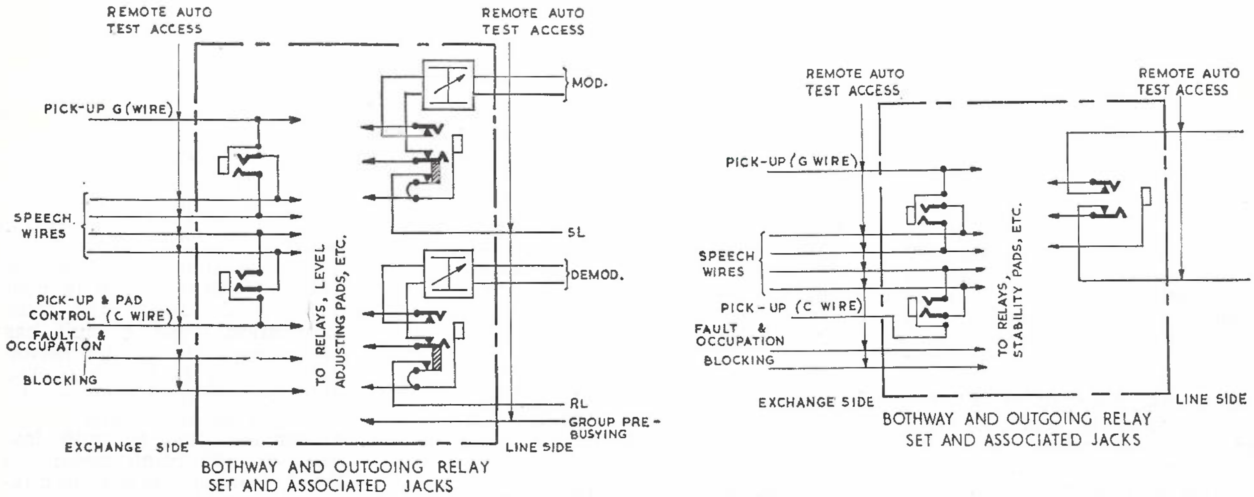

Fig. 2 — Relay Set Test Leads.

set-up a test call and monitor the signals on the SL and RL leads during the setting up. The test call can be directed to either the distant T.C.A.R.S. or the trunk test console, but the technician at the incoming station may be required to do further localisation tests from the line relay set test jacks.

The arrangement proposed is in line with the practice followed by some overseas administrations. With the rapidly expanding volume of trunks to be tested, the trunk test board access becomes unwieldy and to a certain extent ineffective because a major part of the signalling, i.e., the information signalling, is now carried out between registers. The new facilities provide test access from a remote test position so that day to day supervision and fault localisation can as far as possible be undertaken without going into the equipment room. Use will have to be made of the test jack facilities on the trunk line relay sets in some cases to locate a particular fault condition.

Access from the trunk test console to the relay set test leads shown in Fig. 2 can be by either of the arrangements shown in Fig. 3 or 4. In Fig. 3, which is for smaller exchanges, an individual button is provided for each circuit to operate a test access relay in the trunk relay set and so connect the test leads to the test common and to the trunk test common and to the trunk test console. Fig. 4 shows the arrangement for the larger trunk exchange where an automatic trunk routiner may be needed and more than one trunk test console can be installed. Here a common is provided over 30 trunk relay sets and access can be made to 1500 relay sets from the position access equipment and the routiner access equipment. These test commons are connected in parallel to both the routiner and the trunk test consoles. When a circuit is required to be tested, the routiner or trunk test console is connected to the particular common and the particular test access relay is operated to connect the trunk circuit to the testing unit. Because of the more demanding requirement for testing from the trunk test console than from the routiner, priority access is

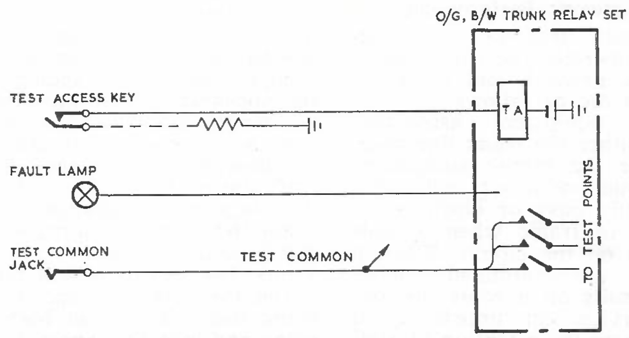

Fig. 3 — Access Arrangements for Small Exchanges.

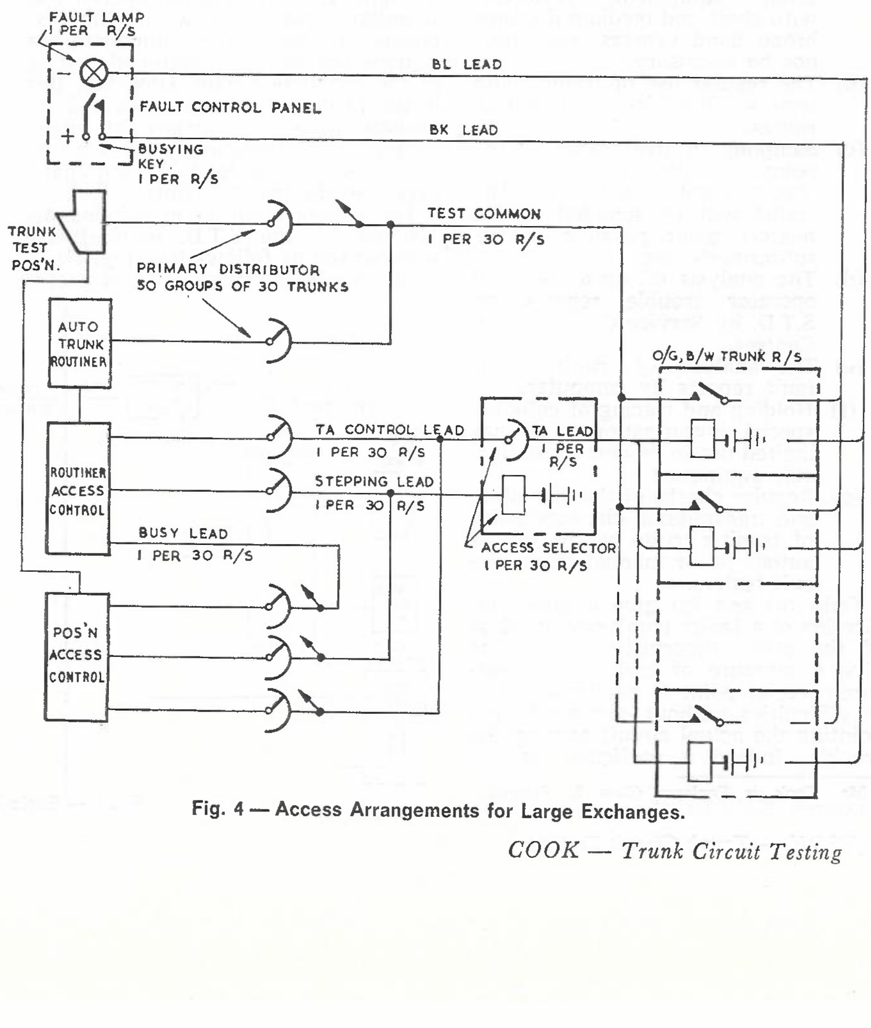

Fig. 4 — Access Arrangements for Large Exchanges.

given to the trunk test console. Thus, if the routiner happens to be testing a circuit and the trunk test console requires access to another circuit which happens to be in the same test access common, the routiner will be thrown off. If, however, another trunk test console has the particular test common in use, a busy signal is given to the calling trunk test console and the access equipment will 'camp on' until the test common is free. Access to the trunk relay set is by dialling a 4 digit code from the trunk test console. In addition, it is possible to step the access switch to select successive relay sets in a common.

The access equipment for the trunk routiner can step to each relay set in order through the exchange or to each relay set in a particular route. On seizure of a relay set a code relay is operated to provide the routiner with the information about the digits needed to be sent on that particular route to call the answering base. Each route to be called will therefore have a code relay provided.

Manual access is provided to all relay sets via test jacks on the rack to allow testing on the relay set from manual test sets. The arrangement of jacks is as shown in Fig. 2 with bridging access on the exchange side of relay sets and break access looking back into the relay set on the line side.

TRUNK CIRCUIT SUPERVISION

For remote control and fault supervision a busying button and a lamp, which gives a half glow when the circuit is busy and a full glow if it is blocked, are provided for each outgoing and bothway circuit. These lamps and keys are provided on a panel near the trunk testing positions in addition to those on the rack. Supervision of the outgoing routes from the exchanges can thus be done visually at any time, and any unusual or unexplained blocking of circuits can be observed immediately. It has been found overseas that at any one time some 5% or more of circuits can be out of service for various reasons. If the number of circuits out of service is not kept in close check, congestion problems can occur on routes that are carrying traffic close to their design limit, particularly in peak periods.

TRUNK TEST CONSOLE

Some of the salient features of the remote trunk test consoles which were developed in New South Wales in conjunction with the Haymarket installation are as follows:

(a) Pick up and signal over any type of outgoing relay set. A special test access register has been developed which can send m.f.c. or decadic signalling under control of instructions from the trunk test console.
(b) Speak 4 wire over the circuit.
(c) Monitoring equipment for the line signalling leads.
(d) When a circuit is connected to the test trunk console the blocking lead is connected, and the fault and occupation lamp appears on the console in place of the lamp on the fault control panel.
(e) Equipment to send tones of 200, 300, 400, 600, 800, 1,600, 2,400, 2,600, 2,700, 3,400, and 3,600 Hz at any required level. The 8dB switchable pad in the relay set can also be switched from the test console.
(f) Equipment to receive VF, tones and measure in the range —50 to +20 dBm. This equipment is able to measure at the same time as tone is being sent forward so that a return loss measurement can be made.
(g) Special access jacks are provided so that tests can be made over the test common from any special test equipment which may be needed to test a circuit.
(h) Order wires are connected as required.
(i) A monitor amplifier and speaker are provided.

AUTOMATIC TRUNK ROUTINER

The trunk routiner which will be provided in ARMs will be able to test large groups of circuits and indicate those in need of attention. The functions of the automatic routiner are as follows:

(a) A programme of calls is made via all circuits in the exchange in order or all circuits on a particular route.
(b) Where a circuit is busy in traffic, the fact is recorded and the access equipment stepped to the next circuit.
(c) A call is set up via the relay set with either m.f.c. or decadic signalling according to the destination, to a T.C.A.R.S. After the answer relay set has been identified by a sequence of B party 'answer' and 'clear' signals and tone pulses, a bothway transmission test is carried out.
(d) For step exchange destinations a separate programme can be run to check the dial pulsing performance of the trunk. This is done by calling a number with an automatic dial pulse checking relay set called a Pulse Length Monitor (P.L.M.) connected to answer the call.
(e) As a fault is detected the information is recorded and the access equipment switches to the next relay set.

TRANSMISSION TESTING

To eliminate the need for a technician at both ends of a trunk circuit to carry out a transmission test, the British Post Office suggested a system, which was developed by the Victorian administration, and only requires a technician at one end of the circuit. (Ref. 4). A test call is directed to a test number which has a T.C.A.R.S. attached. The T.C.A.R.S. answers the call and sends a sequence of 'answer' and 'clear' conditions and tone pulses so that the calling equipment can identify that the T.C.A.R.S. is attached. A level sensitive receiver in the T.C.A.R.S. is then connected to the line, and once a preset level of tone is exceeded, a fixed level test tone is sent back to the testing end and measured to determine the loss in the backward direction.

The transmission testing facility of of the T.C.A.R.S. can be used in two ways, manually or automatically.

Manual: The call is set up to the T.C.A.R.S. and the level of the sending oscillator is gradually increased until the T.C.A.R.S. triggers and sends tone back. The level of the received tone is measured and the level of the tone to be sent to trigger the T.C.A.R.S. noted. Thus the equivalent in each direction is calculated.

Automatic: The call will be set up from the routiner to the T.C.A.R.S., and will be identified by the sequence of 'answers' and 'clears' and tone. The routiner will then send tone at a level too low to normally trigger the T.C.A.R.S. If it is triggered the channel has too much gain in the A-B direction and a fault is indicated. If the receiver is not triggered the routiner will then send tone at a level which will normally trigger T.C.A.R.S. If it is not triggered the channel has not enough gain in the A-B direction and a fault is indicated. To measure the level of tone sent from the T.C.A.R.S. to the routiner the same principle is used, except pads are switched in and out in front of the level sensitive receiver and two levels of tone are not required.

CONCLUSION

Overall supervision of the performance of the S.T.D. network is done by end to end indicators such as T.R.T. programmes, service supervision of live traffic and the various alarms in the ARM equipment. However, these indicators are not sufficient to ensure that the trunk circuit network is performing adequately. Link by link testing is essential to keep the service performance, particularly transmission performance, of the trunk circuits under control.

ACKNOWLEDGMENT

The development of specifications and the design of the wide range of test access and test units mentioned in this article, (and several others not specifically mentioned) is the joint work of engineers and technicians at Headquarters and in New South Wales, Victoria and Queensland. The author acknowledges the contribution, directly and indirectly, by the many people involved in this project.

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SERVICE ASSESSMENT EQUIPMENT — CIRCUIT OPERATION

*V. F. FINDLOW**

INTRODUCTION

This article is the second in a series describing current developments in service assessment facilities in Australia. The present article is concerned with equipment designed to provide local service and subscriber assessment in networks of automatic exchanges in metropolitan and large provincial cities, using physical circuits between the exchanges and the assessment centre. In discussing the facilities required and the operation of the circuits designed to provide them, a full description of all circuit details has not been given. Instead, the emphasis has been placed on the more important problems encountered during development of the circuits, with some reference to the alternatives confronting the designer and the preferred solutions to these problems.

FACILITIES

As described in the first article of this series (Ref. 1) the aim of a local 'service assessment' system is to determine the quality of the service provided to subscribers in general by sampling of live traffic. To achieve this it is necessary to connect the assessing equipment to SR relay sets or first selector equivalents, to observe calls from their commencement. The operator conducting the check must be able to obtain information such as the identity of the originating exchange, the digits dialled, whether the call is successful or otherwise, the nature of a failure if one occurs, metering pulses and tones received, whether transmission is satisfactory and the period of post-dialling delay.

An operator should have simultaneous access to an adequate number of exchanges to ensure that there is no undue waiting for calls to occur. It should also be possible to gain access to all exchanges at any time without the assistance of technical staff at the selected or any intermediate exchange. The assessment equipment should cater for all types of exchange and subscriber equipment in use and, in the case of 'hybrid' exchanges (mixed step-by-step and crossbar equipment), it should be possible for a single circuit to the assessment centre to be used for either section of the exchange at the will of the operator.

In addition to the fundamental facilities briefly outlined above, there are a number of secondary requirements. All information obtained from each call should be clearly displayed to the operator, and it should be possible to carry out traffic selection to some degree, such as observing only calls whose first digit is 'O'. Displayed information should be held under the operator's control as long as it is required, and not automatically cancelled when a call is completed. In larger multi-position installations coupling of positions for some functions such as operator training may be desirable. It should not be possible for two or more operators to obtain access to any one exchange at the same time.

In some cases it is necessary to evaluate the service provided to a particular subscriber ('subscriber assessment'). The information obtained is generally similar to that obtained from service assessment, the main differences being that the exchange number of a line on subscriber assessment is known and it is possible to observe incoming at well as outgoing calls. The equipment is connected to the line circuit in the exchange, instead of the first selectors or SR relay sets. At the centre, arrangements are made for all calls originated or received by that subscriber to appear on a particular position, which is staffed by an operator who has been appropriately briefed. To ensure that no information is lost, only one line in anyone exchange is connected for subscriber assessment and each operator's position is connected to observe only one line. Subscriber assessment calls

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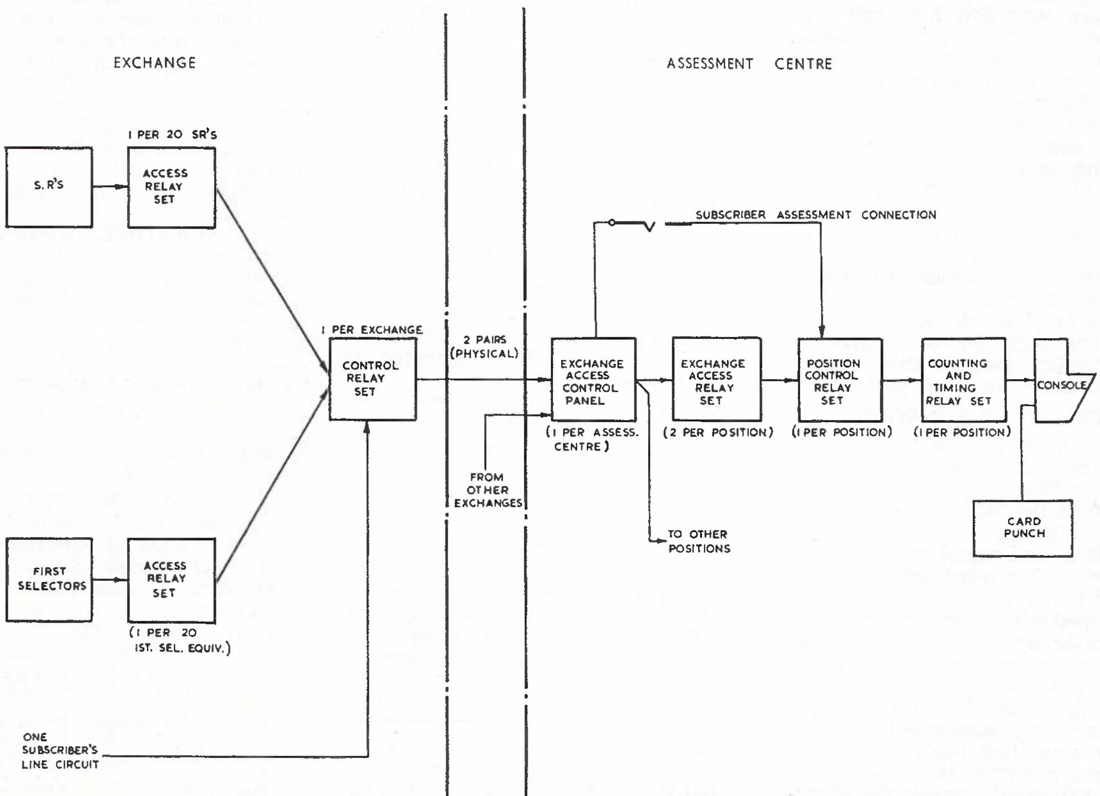

Fig. 1 — Block Schematic of Local Service and Subscriber Assessment.

have complete and automatic preference over service assessment calls, both at exchanges and at the assessment centre, so that the occurrence of a subscriber assessment call will automatically present that call to an operator, irrespective of any service assessment in progress at the time.

OUTLINE OF OPERATING PROCEDURE

Fig. 1 is a block schematic diagram of the equipment and Fig. 2 shows the layout of components on the operator's console. Referring to Fig. 1, it can be seen that a group of positions at the assessment centre have access to a number of exchanges, each of which is provided with a control relay set and one or more SR and first selector access relay sets to suit the type of switching equipment at the exchange. One line circuit may be connected to the control relay set for subscriber assessment. At the centre the access relay sets enable each position to connect to one hundred exchanges, which will be in full multiple to all positions if the network does not exceed this size. Each position may have any one exchange connected to it for subscriber assessment through a special patching arrangement.

The method of operation of the equipment may be briefly described with reference to Fig. 2. The four groups of keys at the right of the diagram (each group consisting of three keys in a vertical line) control the exchange access relay sets. By operating the keys in the centre row the operator may step uniselectors to select up to four exchanges for service assessment, twenty-five being available on each key. When the upper keys are operated to either the 'Connect Crossbar' or 'Connect Step' positions, the exchange equipment is energised and calls will be offered for assessment, only one at a time being accepted by the position. The access circuit which has received the call is shown by one of four groups of lamps at the right-hand end of the upper row of the three lamp fields. Each exchange is allocated a two digit code number, from 00 to 99, and the number of the exchange connected to each of the four connect circuits may be ascertained by operation of the centre row keys to the upper position, the exchange number being displayed on the group of three indicators designated 'Exchange Access Circuit Number'. (The first digit of this number is not at present in use.)

As dialled digits are received, they appear on the top row of lamp indicators, meter pulses are shown at the left on a pair of indicators marked 'Meter Pulse Count', and the time elapsed from the moment when the call was accepted by the position is shown on the group of three designated 'Elapsed Time'. The keys at the left are for common control, providing facilities such as listen, night alarm, speak (on subscriber assessment calls only), etc. The upper lamp field shows common information, such as power

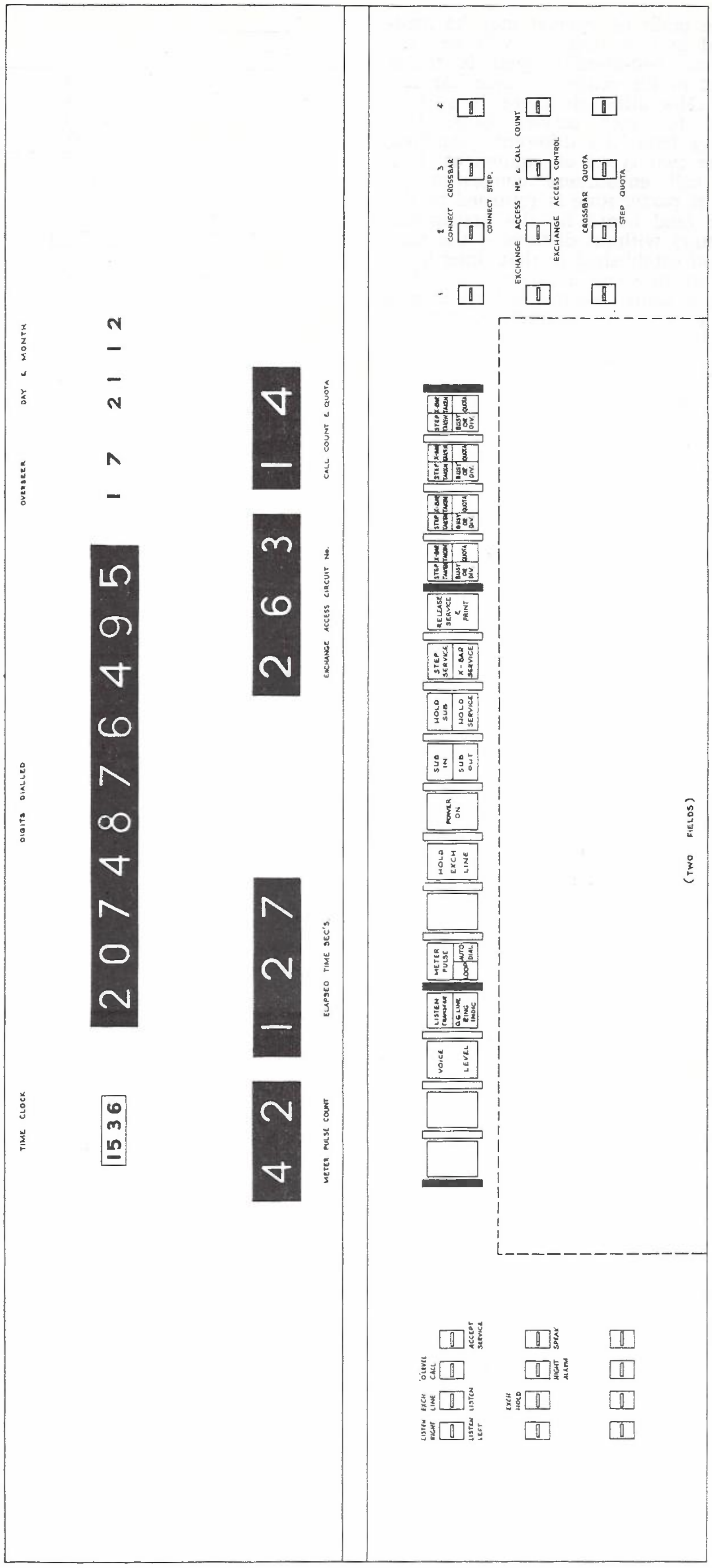

Fig. 2 — Console Layout.

One point of interest may be mentioned at this stage. It will be seen that no end-of-call signal is transmitted to the centre for crossbar service calls although there is such a signal for step service calls. This follows from the different behaviour of the two types of equipment. If a step call encounters congestion or busy B party, tone is returned to the caller (and heard by the assessment operator) without disturbing the connection established to that time; however, in the same situation, a crossbar caller is connected to line-lockout and the equipment is released, so that the assessment operator would not hear the tone, being connected to an SR which is no longer held by the caller. To avoid this it is necessary for the assessment circuit at the exchange to hold the connection back to the calling crossbar subscriber's line circuit, which is done by application of an earth on the 'd' wire of the SR connected for observation of the call. This has no effect on the caller's service, and, in fact, if he clears and calls again, the second call will be observed, although the digit display will be in error as the digits of the new call will be shown following those already on display. The final result is that a step service call releases itself from the assessment position whereas a crossbar call must be released by the operator.

The operational limits of the equipment and the signalling scheme used are closely related. These circuits are designed to work over physical pairs having a loop resistance of up to 3000 ohms, and will tolerate insulation resistance values down to 50,000 ohms. The speech amplifier will compensate for a loss of 17 dB between the exchange and the assessment centre. These figures are approximately equal to the loop resistance and loss for 17 miles of 10 lb loaded cable, so that the equipment is suitable for an area of this radius, or more if heavier gauge circuits are available.

EXCHANGE EQUIPMENT

The equipment provided at the exchange for assessment purposes has a number of functions. It must connect to SR's or first selectors (and in hybrid exchanges to both), for service calls and to crossbar or step subscribers' line circuits. Dialled digits and meter pulses must be detected and repeated to the centre and, in the case of subscriber assessment, outgoing calls must be distinguished from incoming calls. In the development of circuits to perform these functions a number of special problems arise, some of which will now be discussed.

Access to SR's and First Selectors

To ensure that calls are presented to the assessment centre at a satisfactory rate, it is necessary to observe simultaneously a large number of free relay sets or selectors, connecting to the first to become busy. As it is undesirable for this procedure to continue when observation of an exchange is not in progress, the access circuits require to be energised by a signal from the centre. Because some relay sets will be in use when this signal is received, the access control circuit must connect the first relay set to become busy after receipt of the energisation signal, rejecting those already busy and those which become busy while a relay set is connected for observation.

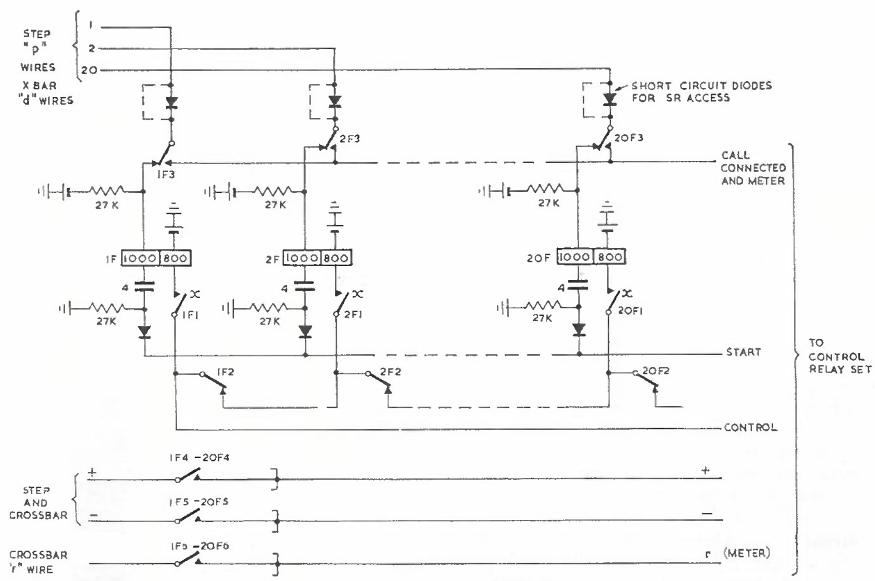

Fig. 3 — SR or First Selector Access.

A variety of methods have been used in the past to perform these functions in step exchanges, including pre-selector uniselectors waiting on free relay sets, relay-type connection circuits, and uniselectors which hunt from a home position on receipt of a start signal generated by a new call. In crossbar exchanges a simple solution is provided by use of the 'Call Reg.' signal which precedes the connection of a caller to an SR. However, a circuit which uses this solution requires additional wiring in the normal exchange equipment and is unsuitable for step exchanges.

The method finally chosen for use in the present circuits requires no extra wiring, uses only one relay for each relay set observed, is suitable for crossbar and step exchanges and can be readily extended to connect more relay sets. The principle is shown in Fig. 3.

When a group of first selectors or SR relay sets is to be observed, earth is applied, under the operator's control, to the 'Start' wire. All selectors (or relay sets) in use at this moment will have earthed 'P' or 'd' wires and the 4 mF capacitors in series with the F relays associated with those selectors will be discharged. Selectors free at this time will have fully charged capacitors. Earth is present on the 'control' wire.

After application of earth to the start wire, the next selector taken into use will connect a full earth to its 'P' or 'd' wire. This causes the discharge of the 4mF capacitor, operating the associated F relay on its 1000 ohm winding. This relay holds to earth on the control wire, opens the locking path to all subsequent relays in the access relay set (releasing all other F relays simultaneously seized) and extends the pos., neg., private (or 'd') and meter wires to the control relay set, which then removes earth from the start wire.

All selectors which are subsequently taken into use will earth their 'P' or 'd' wires without any further effect as the discharge of the 4 mF capacitors will now take place via 27,000 ohms to earth, the resultant current being too low to operate the associated F relay.

False operation of an F relay can occur in step exchanges if the start earth is applied at a time between the seizure of a first selector and the appearance of a meter pulse on its 'P' wire. The meter pulse will operate an F relay by charging the 4 mF capacitor through the 1000 ohm relay winding. This call will be rejected by the control relay set, which tests the 'P' wire for the presence of positive battery as soon as the F relay is operated. If this potential is present, earth is removed from the control wire to release the access relay. A diode in the 'P' wire path (short circuited in relay sets used for access to SR relay sets) ensures that the meter pulse will not be connected to the 'P' wire of any other selector which simultaneously operates its F relay.

These relay sets may be connected in tandem to permit access to any number of SR's or first selectors. In hybrid exchanges two separate groups of relay sets are provided, one for the step equipment and one for the crossbar. When a signal from the operator selects the group required, the control relay set energises those access relays alone. The same system is used in 'pure' exchanges having only one on, service or subscriber call held, subscriber assessment call incoming or outgoing, etc. In some cases these lamps are combined with common control keys so that the function performed by the key is displayed by the inbuilt lamp. Examples of this are the 'Hold Subs/Hold Service' key and lamp, and the key and lamp 'Release Service and Print' which is depressed by the operator to release a service assessment call from the position, simultaneously clearing down the display.

If a subscriber assessment outgoing call appears at a position carrying out a service assessment, the display will be automatically cleared down and prepared for the new call. An incoming call releases the service assessment call but does not clear the display, which is not required for the subscriber call, and which may still contain information of value relating to the service call from which it was derived.

The operator cannot prevent a subscriber call seizing the position, but can release it at any subsequent time to permit further service assessment calls to arrive from other exchanges. Under these conditions, the subscriber call holds the assessment equipment at the exchange until the call is completed. A new subscriber call will re-seize the position in the normal way.

The lower pair of key and lamp fields shown on Fig. 2 are required only for punching of cards as described in the first article (Ref. 1) of this series and will not be further discussed here.

SIGNALLING METHODS

Between each exchange to be observed, and the assessment centre, a group of four wires, designated 'A', 'B', 'C' and 'D', is provided. Table 1 shows the full range of conditions which must be signalled over these wires, together with the circuit methods used, for service assessment, and Table 2 shows the same information for subscriber assessment. All the conditions listed apply to both step-by-step and crossbar calls unless shown otherwise. The differences between the two tables arise mainly from the basic requirement that service calls may be accepted or rejected by the assessment centre, whereas subscriber calls are connected to the position without any such option.

TABLE 1: SIGNALLING METHODS — SERVICE ASSESSMENT

Condition	Signal sent from Exchange	Signal sent from Centre
Exchange equipment idle	1200 ohm earth on C wire	open C wire
Energise exchange (step)	—	neg. batt. on C wire
Energise exchange (crossbar)	—	neg. batt. on C wire earth on A & B wires
Offer call to Centre	200 ohm earth on C wire	—
Accept call	—	neg. batt. on C wire
Reject call	—	open C wire
End of call (step)	open C wire	—
End of call (crossbar)	no signal	—
Force-release call from Centre	—	open C wire
Hold call from Centre	—	pos. batt. pulse on C wire
Call held at exchange	open C wire	—
Implusing	S.C.D.C. pulses on A & B wires	—
Speech	V.F. on A & B wires	—
Meter pulses (step & crossbar)	pos. battery pulses on C wire	—
B Party answer (crossbar only)	pos. battery pulse on C wire	—

TABLE 2: SIGNALLING METHODS — SUBSCRIBER ASSESSMENT

Condition	Signal sent from Exchange	Signal sent from Centre
Outgoing call	earth on C & D wires	—
Incoming call	earth on D wire	—
End of call	open D wire	—
Speak to caller	—	pos. batt. on D wire
Hold call from Centre	—	pos. batt. (continuous) on C wire
Call held at exchange	short break in D wire earth when holding commences	—
Impulsing	S.C.D.C. pulses on A & B wires	—
Speech	V.F. on A & B wires	—
Meter pulses	pos. batt. pulses on C wire	—
B party answer	no signal	—

contacts of relay AA. Under normal conditions relay BB remains continually operated, but, if both sides of the line go to earth potential during a switching transient, both relays release and no false impulse is signalled. Further improvement is obtained by ensuring that AA is slightly slow to release, making it less sensitive to brief transients, and also by using a masking circuit in the digit receiving relay set at the assessment centre to reduce the effect of signals received during the interdigital pause.

Tests on live traffic have shown that this combination of guards is very effective, and that all the guarding elements contribute to the prevention of errors in the impulse displays.

Another element in the digit detection circuit is provided to overcome a different condition which tends to cause false impulse indications. This element is a combination of a diode and a capacitor intended to prevent the operation of relay AA by overshoot transient voltages which may appear on the line during genuine dial breaks. The fault and its cure are fully described in Ref. 3.

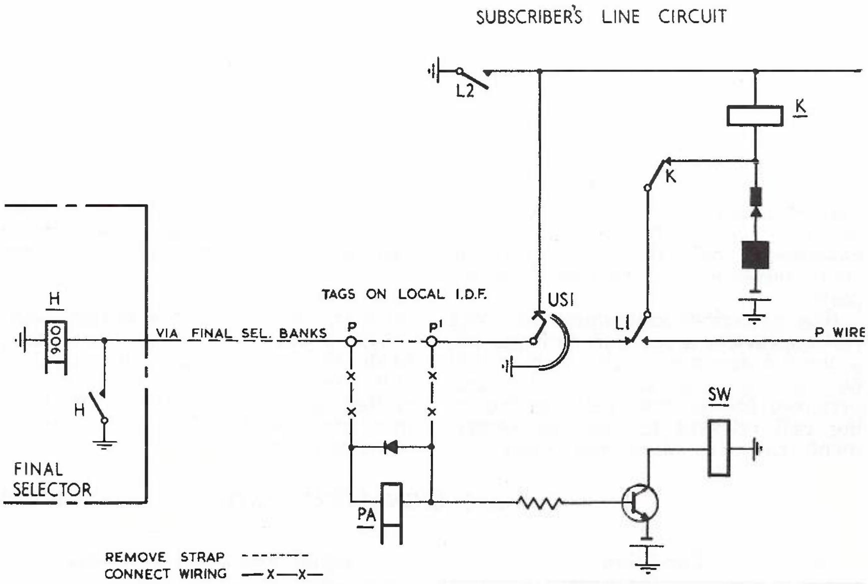

Fig. 7 — Subscriber Assessment — Step Exchanges.

Subscriber Assessment

The equipment provides for one line in an exchange to be connected for subscriber assessment. The connection is made by means of jumpers, on the local I.D.F. in step exchanges, and on the M.D.F. in crossbar exchanges. In the latter case, connection to the line circuit 'c' and 'r' wires also must be made at convenient points.

The most important differences between subscriber and service assessment is that in the former it is necessary to distinguish between incoming and outgoing calls. This information is signalled to the assessment centre where, apart from its own significance, it may be used to cancel any display already present on the position, because the display equipment is required for an outgoing subscriber call. If the subscriber call is incoming the display will be preserved, although any service assessment call on the position will be thrown off. Proof of whether a call is incoming or outgoing relies on quite different methods in the two cases of step and crossbar equipment, and is closely associated with the means used to detect that a call has occurred.

Step Exchange. The principles used to detect a call and identify its direction in a step exchange are shown in Fig. 7, which includes part of a uniselector line circuit. To connect this line for subscriber assessment the strap between the tags P and P¹ is removed and the element containing relays PA and SW is inserted as shown.

When the subscriber makes an outgoing call, earth from the wiper US1 (initially from the L2 contact and later from the bank arc) operates SW relay via its tranistor switch, indicating that a call has occurred. Because PA relay does not operate, an outgoing call is signalled to the centre.

Incoming calls which test the 'P' wire on the final selector banks will receive an earth potential through the 34 ohm winding of PA in parallel with the diode. (This diode is present for another purpose, explained later, and the circuit will operate satisfactorily without it in step exchanges.)

If an incoming call is received when the subscriber is free, earth from the final selector H relay contact will operate PA and K relays in series, and SW relay through its transistor switch. The combination of SW operated and PA operated signals that an incoming call has occurred.

Crossbar Exchanges. In crossbar exchanges the simple scheme outlined above is impossible because there is no equivalent of the P-P¹ strap. The most direct method of detecting a call and ascertaining its direction is probably to create a special category marking, using the KAN relay set in the subscribers stage marker to convey this information to the assessment equipment when the call commences. Another possible approach relies on the fact that an outgoing call generates a positive-going voltage pulse on the 'c' wire of the line circuit when the receiver is lifted off, whereas this pulse does not appear on incoming calls.

Each of these schemes has its problems and advantages. Another method has been adopted in the present circuit, largely because it has the merit of using circuit elements which already exist for other purposes, and because connection to the line circuit to be observed is fairly simple. The principles are shown in simplified form in Fig. 8.

Relays AA and BB in Fig. 8 are those which were used for digit detection in Fig. 6. Relays SW and PA have the same functions as in Fig. 7, i.e. operation of SW alone indicates an outgoing call, while operation of SW and PA indicates an incoming call. The principle of the circuit consists of examining the potentials on the line wires, 'a' and 'b', when a 200 ohm earth appears on the 'c' wire.

If the call is outgoing, when the register is connected to the calling line by RSV, 200 ohm earth on the 'c' wire operates relay SW via its transistor switch. SW operates relay WA which connects battery to relays AA and BB. Both of these relays will operate because the presence of the calling subscriber's loop ensures that a negative potential will appear on both the 'a' and 'b' wires as discussed in the section on impulse detection. Relay DX is operated and locked to prevent subsequent operation of relay PA on the release of AA during dialling. Relay PA is slightly slugged by the diode across its 34 ohm winding to prevent its operation under certain transient conditions which may arise in the situation where a subscriber assessment call seizes the circuit while a service call is being observed.

If the call is incoming, 200 ohm earth on the 'c' wire operates relay SW as before, but now the potentials found on the 'a' and 'b' wires are different to those in the case of an outgoing call. On the 'a' or negative side, there will be ringing voltage superimposed on neg. 50 volts which will operate relay BB when the resultant potential inevitably becomes negative with respect to earth. On the 'b' or positive side, however, the potential will be earth with a small superimposed voltage at ringing frequency, due only to the voltage drop across the earthed winding of the ringing relay. (At this stage there is, of course, no d.c. path via the subscriber's telephone.) Relay AA does not operate and BB contacts operate relay PA which applies potentials to the transistor switches controlling AA and BB to lock those relays in their present condition so that AA will not equipment type, but in this case only one group of relay sets is provided, and if the operator selects the wrong type of equipment, no calls will be observed.

Calls from Public Telephones at Crossbar Exchanges

A problem which arises in crossbar exchanges when a public telephone call is connected for service assessment has been described by Spratt (Ref. 2). The MR relay set used in these exchanges causes negative battery to appear on the 'r' wire of the SR almost from the moment of seizure. This potential must be distinguished from the normal meter pulse potential which appears on the 'r' wire later in the call. The solution adopted here is somewhat different from that due to Spratt, whose method is to provide a relay to signal a meter pulse to the assessment centre when the 'r' wire potential is removed, signifying B party answer, and another relay to operate to genuine meter pulses on the 'r' wire, also repeating these to the centre as meter pulses. Under these circumstances, a public telephone call causes a signal to the centre on answer, and on receipt of meter pulses, but an ordinary subscriber causes signals to be sent only in response to meter pulses.

The present circuit uses only one relay to respond to negative battery on the 'r' wire, but delays transmission of any signal to the centre until the 'r' wire battery has been removed. An answer detector is added to the circuit but is used only on ordinary subscriber's calls, which are identified by the absence of battery on the 'r' wire when the SR is seized. The answer detector sends a signal to the centre when the ordinary subscriber's call is answered, so that all service assessment calls, whether on crossbar or step equipment, and whether public telephone or ordinary subscriber, signal to the centre on answer, and on receipt of meter pulses. At the centre, the first pulse is absorbed without any display to the operator, if the call is from crossbar equipment, so that the display shows only the signals generated at the exchange by genuine meter pulses in all cases.

Impulse Detection

The basic principle usually employed for impulse detection is some form of a high-impedance transistor-switched relay sensing the changes of potential on one leg of the line, commonly the positive, as shown in Fig. 4. When the dial contacts are closed, the potential at point 'b' will be in the range of approximately neg. 4 to neg. 25 volts, depending on the line resistance, holding the transistor switch in a conducting state, and relay AA is operated. When the dial contacts open, point 'b' goes to earth potential, the transistor is turned off and AA releases for the duration of the dial contact break period.

This scheme is satisfactory for use in both crossbar exchanges, where the

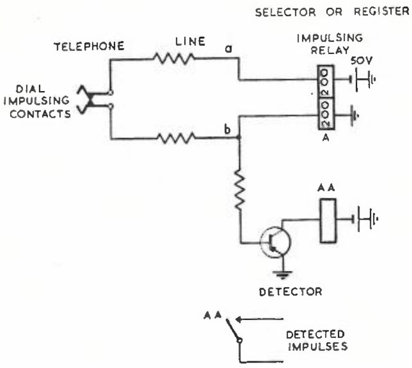

Fig. 4 — Impulse Detection.

impulsing relay is part of the register circuit, and step exchanges, where it is the A relay of a selector or repeater. However, a complication arises in step exchanges, as shown in Fig. 5. During the interdigital pause, the line is switched from a selector in one rank to a selector in the next, by changeover contacts, but the detector remains connected to the first selector. These changeover contacts rarely operate in perfect synchronism, so that the line potentials can vary in several ways during the switching period, according to the actual sequencing behaviour of the contacts.

For instance, if contact 1 operates before contact 2, for some period both the 'a' and 'b' wires will be at a potential of neg. 50 volts, which will do no harm as the transistor will remain turned on. However, if the reverse sequencing occurs, both sides of the line will be at earth potential which will release relay AA, signalling a false impulse. The actual changes in potential may be very complex and in extreme cases are believed to last for as long as 20 milliseconds. A further complication is caused by the telephone dial off-normal contacts. When these open at the end of an impulse train, an additional impedance is included in the circuit, causing a disturbance to the voltage levels around the loop. In most modern dials restoration of these contacts takes place just after the end of the last break in the train, but there are still in existence a number of older dials which have their lost motion period after the train instead of before. In these cases, the switching transient and the off-normal contacts' restoration will often coincide to produce particularly violent voltage fluctuations during the interdigital pause.

If a false pulse is signalled to the assessment centre during an interdigital pause, it may be registered as a genuine digit, but it is more probable that it will cause interference with the digit steering circuit which is also functioning in the interdigital pause. The most likely result is therefore a gap in the display, with the second digit, say, being registered on the third indicator with consequent confusion to the operator and to any automatic information processing equipment in use.

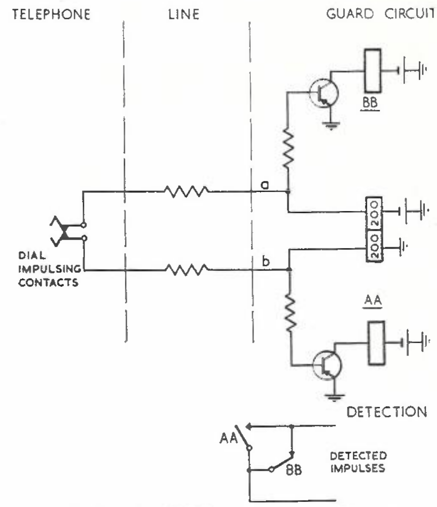

Fig. 6 — Impulse Detection — Guard Circuit.

It has been found in practice that most of these problems caused by voltage transients can be overcome by the use of a guard circuit, connected to the other side of the line as shown in Fig. 6. This guarding element may be an electronic circuit operating directly on the impulse detector, but in the present circuits a relay has been used as it provides a convenient method of carrying out an additional important function **described later.** The guard circuit is used to inhibit the

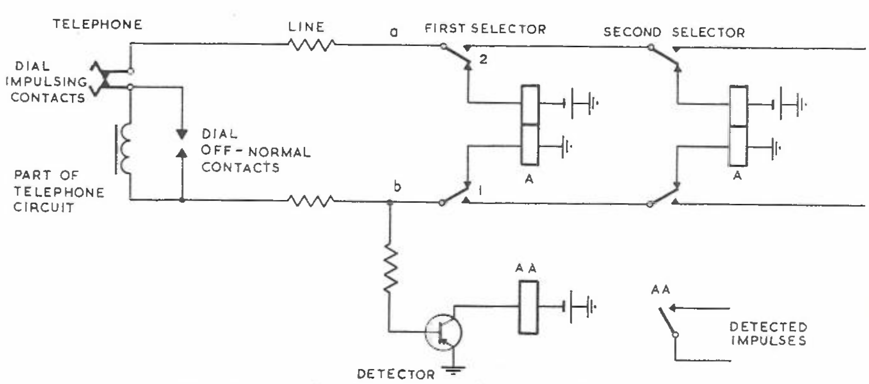

Fig. 5 — Impulse Detection — Switching Transients.

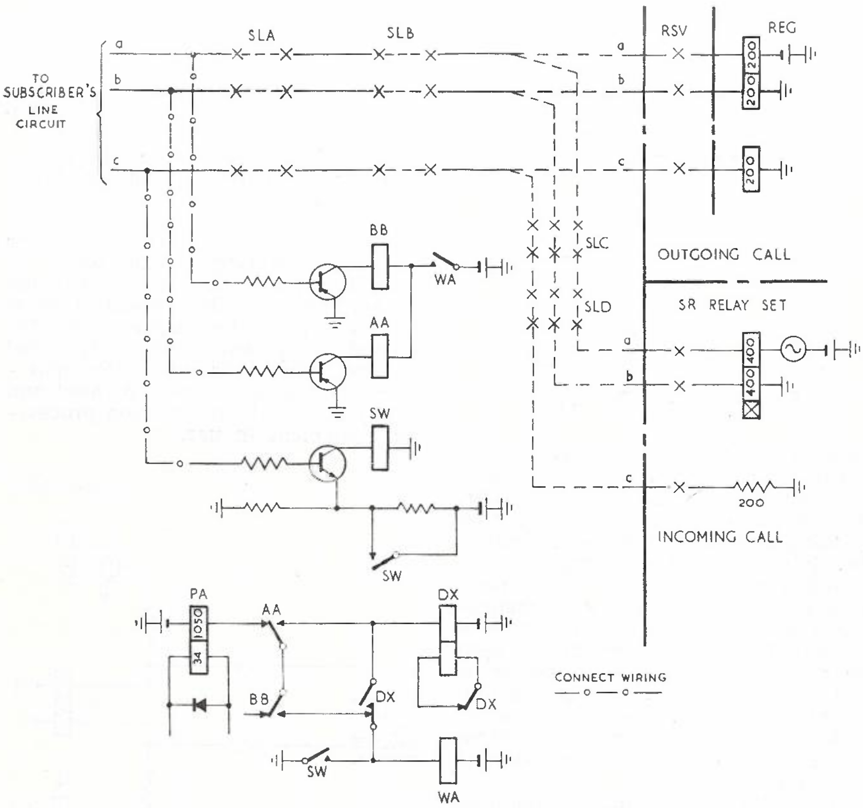

Fig. 8 — Subscriber Assessment — Crossbar Exchanges.

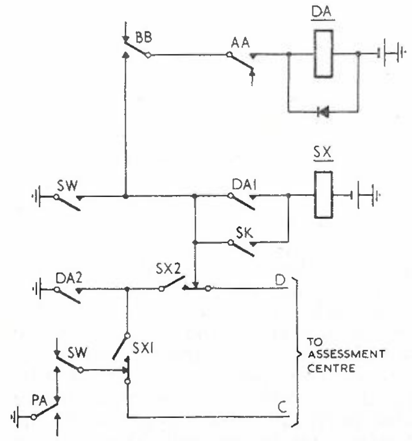

Fig. 9 — Follow-on Call Control — Step Exchanges.

operate when the ring is tripped. (This function of PA is not shown in the diagram.) Relay DX is made slow to operate so that a false outgoing call signal will not be generated if AA is momentarily operated by the small ringing voltage which may appear on the positive line.

It can be seen that this method of discrimination between incoming and outgoing calls depends on relay SW remaining unoperated until 200 ohm earth is connected to the 'c' wire. As mentioned earlier, a positive-going pulse of some 10-15 volts appears on this wire when the receiver is lifted to commence an outgoing call. This pulse, which is caused by transformer action between the two windings of the caller's LR relay, is ample to temporarily turn on the transistor switch to operate relay SW unless special arrangements are made. If SW is operated at this time, a false signal will be sent to the assessment centre, because, since no register has yet been connected, the caller's line will have an earth on the positive side, which will be interpreted as indicating an incoming call. Although SW will release with the end of the pulse, it will re-operate soon after when the register is connected. If PA relay has had time to release, an outgoing call will now be indicated, otherwise PA will be locked up. In either case the assessment operator will be confused by contradictory information.

To overcome this problem, the emitter of the transistor switch controlling SW is connected to a voltage divider which fixes the emitter at a potential such that the switch is not operated by the premature pulse. However, SW must hold to all the 'c' wire states which exist at any time when the receiver is off-hook, including the line-lockout condition. In this condition, the 'c' wire potential may fall to within a few volts of the supply (nominally neg. 50 volts), and, to ensure the holding of relay SW at this time, one of its own contacts is used to connect full supply voltage to the emitter while the relay remains operated.

Follow-on-calls

A subscriber on assessment may originate or receive a new call immediately after the completion of a previous one, and, if the observations are to be complete, this new call must also be registered. This situation causes no difficulties in crossbar exchanges as SW relay will always be released between calls, so that its re-operation will always signal a new call. However, in step exchanges, although there is no problem if one or both of the calls are incoming, when two outgoing calls are made without homing of the lineswitch, SW relay will not be released between the calls. This situation is readily obtainable if the switchhook is depressed between calls for about half a second. The display will not be reset at the assessment centre for the second call, so that some digits will not be observed although the call itself will be quite successful.

This defect is overcome by the provision of an additional circuit element, which is effective only in step exchanges, as shown in Fig. 9. When an outgoing call commences, the operation of SW relay connects earth to both the 'C' and 'D' leads to the assessment centre, signifying that an outgoing call has occurred. When both AA and BB relays operate as a result of the caller receiving connection to a first selector, DA and SX relays operate, and control of the 'C' and 'D' leads is transferred to contact DA2. Relay DA is slugged by a diode to hold during impulsing, but releases with a short delay when AA relay is released by replacement of the caller's receiver, signalling to the centre the end of a call. If a new call is made before SW has released, re-operation of AA relay causes re-operation of DA and a new call is signalled.

ASSESSMENT CENTRE EQUIPMENT

The basic functions of the equipment at the assessment centre are, firstly, to provide the operators with a convenient and efficient means of access to a number of exchanges for service assessment, secondly, to permit subscriber assessment to be provided on a limited number of individual subscribers' lines, and thirdly, to receive and display data derived from calls observed. It is convenient to discuss the operation of this equipment under those three broad headings.

Access to Exchanges for Service Assessment

To obtain the best results from service assessment, it is necessary that the samples of traffic taken from exchanges should be small and frequent rather than large and infrequent, so that the means of access to the exchanges must be simple and easy to use. In the past, to conserve cable pairs, patching arrangements at intermediate exchanges have been used but these are somewhat inconvenient and give rise to doubts as to the actual exchange connected. For the most efficient working all operators should have direct access to all exchanges, and each operator should be able to observe a number of exchanges simultaneously, to concentrate traffic in off-peak periods.

A possible method of meeting these requirements would be to provide each position with a bank of connecting keys, one per exchange, with the facility to have operated at the one time as many keys as desired, but such a field of keys would be large and probably unwarranted. An acceptable compromise would be to reduce the number of keys to, say, twenty or thirty, with correspondingly restricted access by individual operators. In these circuits, however, a further requirement has been introduced, with important effects on the problem of exchange access. This requirement is the facility to allot to each exchange a 'quota' of calls to be accepted in each sampling, the quota being determined by the size of the exchanges. The intention is that the assessment centre equipment should count the calls from each exchange as they are received, compare the count with the quota assigned to that exchange, block further calls when the quota has been filled, and inform the operator of this action.

The simple key field described above now requires considerable modification. Each exchange circuit must include a means of counting calls, such as a uniselector, or alternatively a common group of counters must be provided, together with some means of allocation to particular positions and exchanges as required. Provision must also be made for operators to read quotas and call counts, for exchange circuits to be busied to other positions if multi-position access is required, for counters to be zeroed if a quota is not completed, and other minor functions.

The approach adopted in these circuits provides access to the whole network by each operator at the expense of a reduction in the number of exchanges under simultaneous observation. The method used is to terminate the exchange circuits on the banks of uniselectors used as finders, i.e. with the wipers connected to the position. Using uniselectors with twenty-five bank positions, four switches give each operator access to one hundred exchanges. The finders are stepped at approximately three steps a second by depression of a key; an indicator shows the exchange access numbers while the finders are stepping. Only one finder can be stepped at a time, but, when all four finders are set, four exchanges can be energised to supply calls for assessment.

Associated with each finder is another uniselector which carries out the functions of counting the calls received and checking the count against the quota for the selected exchange. It may also be used to read and display the exchange quotas if desired. The quota may be any number from 0 to 49 and hybrid exchanges may have different quotas for the two equipment types. Calls are counted by a pulse delivered to the count uniselector at the moment when the call is released from the position. All calls which seize the position are counted unless no digits are dialled or a subscriber call interruption occurs.

Fig. 10 shows elements on the service assessment exchange access circuit. The wires 'A', 'B', and 'C' from the exchanges are terminated on the banks of the JA switch, which can be positioned on one of twenty-five exchanges. Calls are counted by the QC switch. Quotas are set by straps between JA6 bank outlets, representing exchanges, and QC bank outlets, representing call count. For hybrid exchanges, the straps pass via contacts of relay QMA-QMD which are operated when crossbar equipment is selected for observation, thus switching the quota strapping.

After the JA switch has been stepped to the desired exchange, key KCS or KCX is operated to operate relay SSP or SXB which energises the appropriate circuit at the exchange. Crossbar equipment is selected by feeding earth to the exchange on the 'A' and 'B' wires via retard SR. If another position is already connected to this exchange an earth from that position's JF contacts (operated) will be present on the JA5 bank and wiper. JB relay will be operated by this earth to battery via KCS or KCX and will indicate to the operator that the exchange is unavailable. JF relay cannot operate, being shunted down by the low resistance of JB. If no other position is connected to the exchange, JF relay operates, busying the exchange to other positions, and connecting relay SV to the 'C' wire. CV relay is normally operated.

As observations are completed, the QC switch is stepped until the quota is filled, when QF relay will operate. QF contacts display a lamp 'Quota Completed', and open the 'C' wire path to prevent the arrival of further calls.

Access to Exchanges for Subscriber Assessment

If all calls on a particular subscriber's line are to be observed, obviously one operator's position can accommodate only one subscriber. Be-

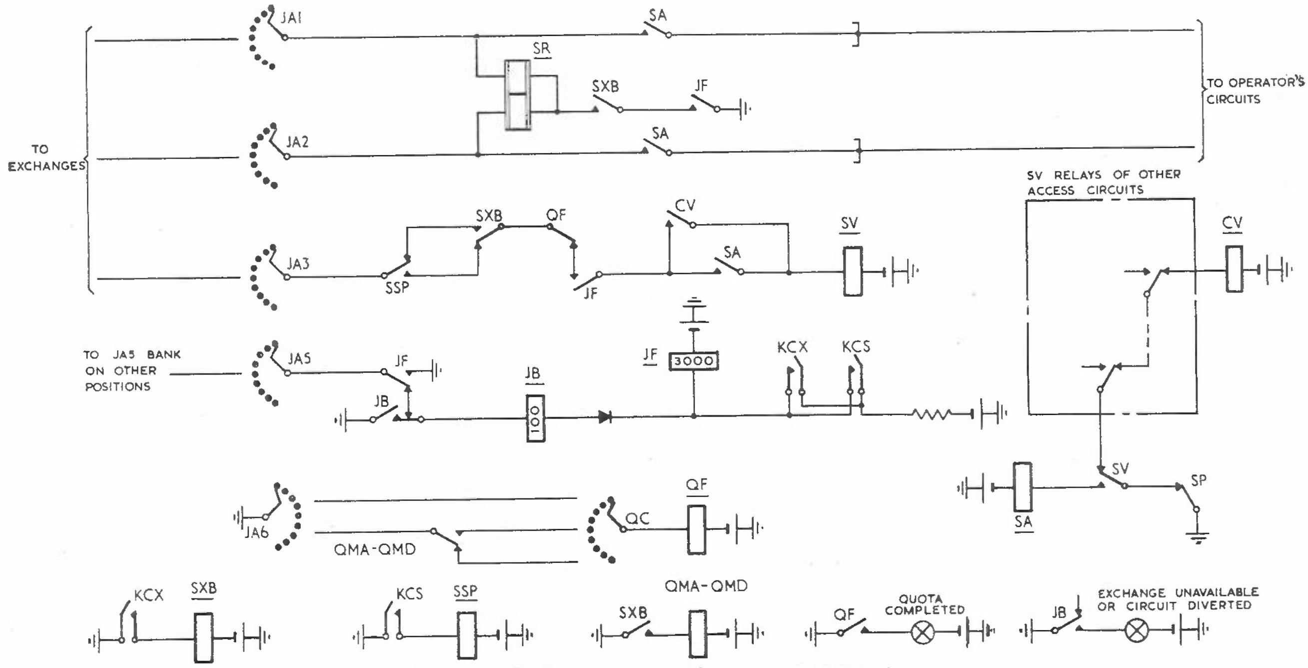

Fig. 10 — Exchange Access (Service Assessment)

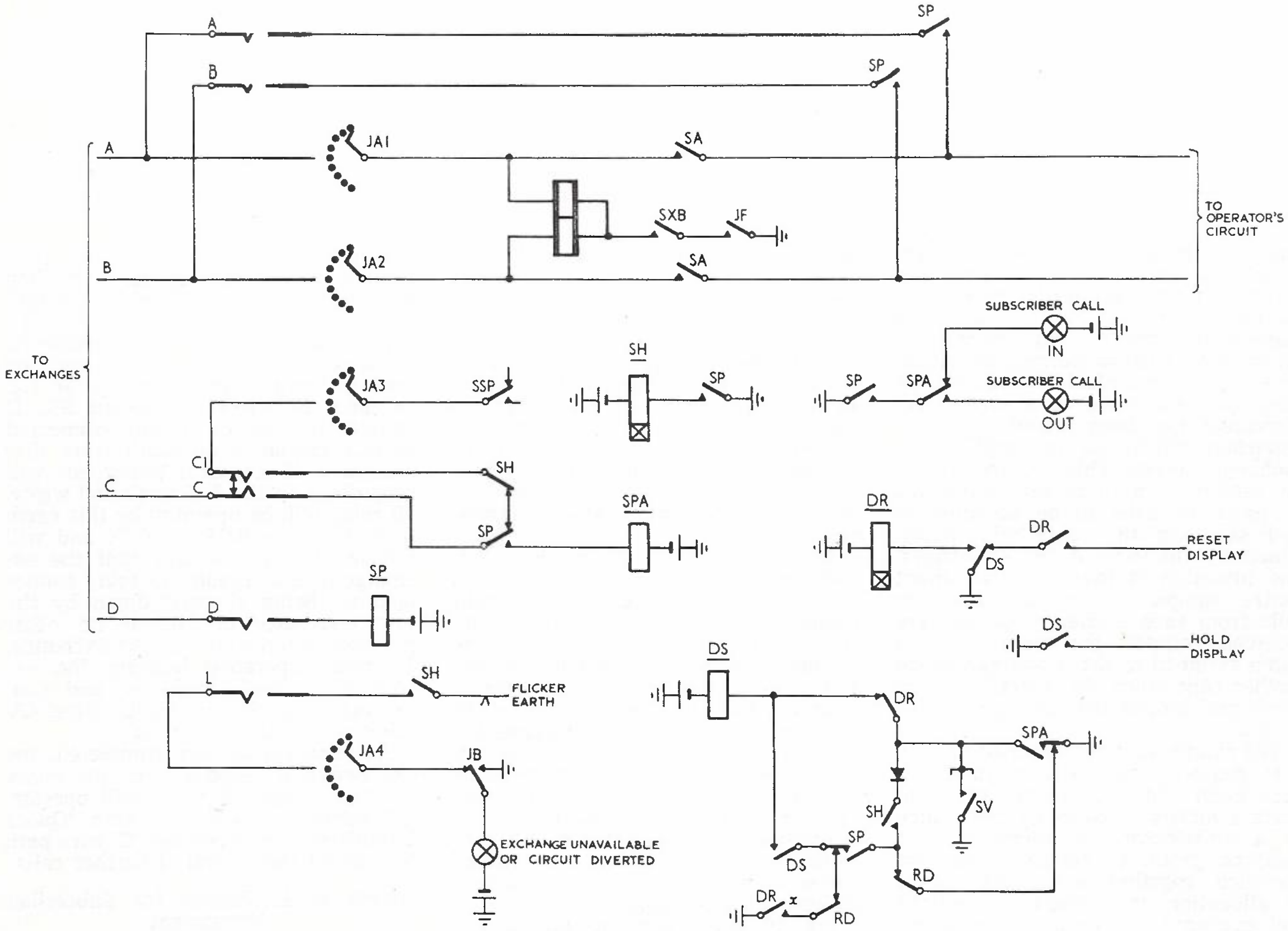

Fig. 11 — Exchange Access (Subscriber Assessment)

cause subscriber and service calls from the same exchange use the one circuit to the assessment centre, with preference for the subscriber calls, at any time a service assessment may be interrupted and replaced by a subscriber call. To give freedom of allocation of exchanges to positions, a patching technique is used, as shown in Fig. 11, which also includes the other circuit elements concerned with subscriber assessment.

To connect an exchange to a position for subscriber assessment, plugs connected to the chosen position are inserted in jacks 'A', 'B', 'C', 'C1', 'D', and 'L' associated with the required exchange. The 'A' and 'B' wires are now extended to SP contacts and the 'C' wire is diverted through the position circuit. The 'D' wire, on which the signal for a subscriber call is received from the exchange, is connected to the SP relay, and the 'L' wire is prepared to signal another position (which may be observing service calls on this exchange) that a subscriber call has occurred. Relays DS and DR control the display, which is reset by a pulse generated when the release of DS causes delayed release of DR. While DS remains operated the display will be held. Relay RD (which is controlled by the operator) can reset the display by releasing DS. For service calls, operation of relay SV, when the call is received, operates relay DS, which operates relay DR and holds to the DR 'x' contact. When a service call is completed or released from the position the display is held until it is restored by the operation of RD relay or by the occurrence of a subscriber outgoing call as described below.

When a subscriber call is received, relay SP operates to earth on the 'D' wire. SP connects SPA to the 'C' wire to determine whether the call is incoming or outgoing. SPA operating in the latter case. SP operates SH (slowly) which connects flicker earth to the 'L' wire to flash the 'Circuit Diverted' lamp of any other position which might have been receiving a service call from the same exchange.

SP releases SA relay on the position receiving the subscriber call, if a service call was in progress (See Fig. 10). SA relay releases SV to release the service call from the position. SP and SPA contacts operate lamps to show the presence and direction of the subscriber call.

The subsequent behaviour of the circuit depends on its state at the time the call was received and on the direction of the subscriber call. Study of the circuits controlling relays DS and DR will show that the following effects occur:—

Incoming call: The state of DS will not be changed. Any display present will be retained.

Outgoing call, display absent (DS released): DS will be operated to prepare the display, and will remain held at the end of this call.

Outgoing call, display present (DS operated): DS will be released to clear the old display and re-operated to prepare for the new one. DS will remain held at the end of this call.

Receipt and Display of Data

The information received and displayed on the position after each call consists of the digits dialled, meter pulses received, call duration, exchange and equipment type (service calls), and call direction (subscriber call). Other information is obtained by listening to the call — quality of transmission, post-dialling delay, B party failure to answer, wrong number, etc. The circuitry provided to receive and count meter pulses is simple, consisting of a relay to receive positive battery pulses from the exchange, and a decade counter which uses two miniature uniselectors to count to 100 pulses. The call is timed by a similar counter having three uniselectors which count 1 second pulses up to a

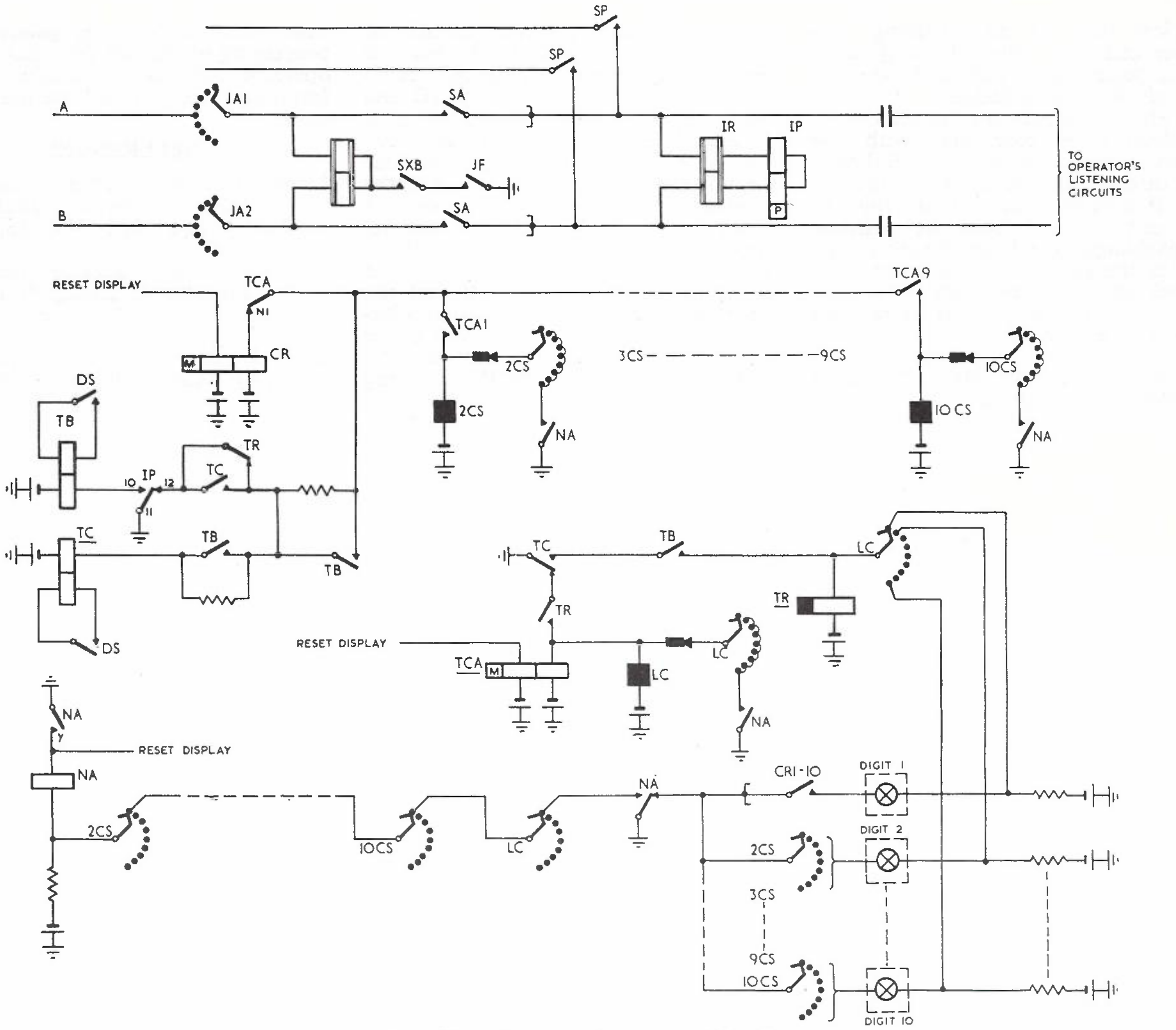

Fig. 12 — Digit Counting, Storage and Display.

total of 1000. These circuits will not be further described here.

As counting, storage, and display of dial pulses involves some circuitry which may be of interest, the principles employed are shown in Fig. 12. Pulses from either a service or subscriber call are received by the polarised relay IP as S.C.D.C. signals. When the circuit is first seized, operation of IP to contact 10 operates TB relay which is slugged by its second winding (since DS is operated when a call is received) to hold during each impluse train. With each break of the caller's dial contacts, the IP lever changes over to contact 12, so that the dial breaks of the first digit are received and stored on the magnetic counting relay CR. Relay TC, which operates on the first break, is also slugged to hold during the train and releases approximately 100 mS after the end of the last break. TR relay is controlled by TC so that during each interdigital pause a pulse is delivered by TC and TR contacts to another magnetic counting relay TCA. After the first train, contacts TCA N1 are opened, and TCA1 closed. The second train is steered to a miniature uniselector, 2CS, for counting and storage. In the same manner, subsequent digits are stored on uniselectors 3CS to 10CS. The total storage capacity is 10 digits.

Contacts of the counting relay CR and the uniselectors 2CS-10CS are connected to multiple lamp units to display the digits received. During each impluse train, earth from the bank of another uniselector, LC, shunts down the battery feed resistor of the appropriate lamp unit to prevent flashing of the lamps. This uniselector is stepped in synchronism with relay TCA during the interdigital pauses. As each step of LC takes place, the display of the digit just received becomes visible.

When the display is to be restored to receive another call, an earth pulse is received on the 'reset display' leads from DS and DR relays as described previously. This pulse resets the counting relay CR and the steering relay TCA, and operates relay NA which locks to its own contact. Other NA contacts apply earth to the homing arcs of the pulse storage uniselectors and the LC uniselector, and these switches self-drive to their home positions. When all the uniselectors are reset, NA relay is short-circuited and releases to disconnect the homing earths.

Contacts of relay TR and TC in series with contact 12 of relay IP inhibit the function of IP for part of the interdigital pause. This helps to guard against faulty digit displays which may occur if a false pulse, received from the exchange during the interdigital pause as described earlier, causes the steering relay TCA to take a double step.

It will be seen that the digit counting and storage circuit uses a mixture of magnetic counting relays and uniselectors. Each of these components has its own advantages. The uniselector occupies the space of a single relay and its three arcs give flexibility of application in a circuit. However, the homing time in some circumstances may be excessive; for instance, in these circuits, a quick reset is necessary in the case where a subscriber call seizes the position during a service call. A satisfactory compromise is obtained by the use of counting relays, which can be reset in about 10 mS, for storage of the first digit and for pulse train steering, with uniselectors storing all digits except the first. Even if the first digit of an intruding subscriber call is '1', the following inter-digital pause gives sufficient time for the uniselectors to home.

A further reason for the choice of uniselectors is connected with the facility of recording service call details on a card or tape for computer processing. If a caller clears before the call has been released from the position, the exchange signals the break of the loop to the centre, where, unless prevented, an additional digit '1' will be added to the display. This extra digit will not be present on all calls, as some will be released from the position by the operator before the call is completed. In the circuit shown in Fig. 12, the effect is avoided by the use of the 'reverse acting' characteristic of the uniselectors. When IP relay is restored at the end of the call, earth on contact 12 operates relay TC and the magnet of the uniselector connected to receive pulses at that time, but the display is unchanged because the uniselector does not step until the magnet is released, which does not occur because relay IP does not re-operate. After a delay, relay TB releases, inserting resistance into the operating paths of relay TC and the uniselector, to reduce dissipation without permitting their release. If a caller clears without dialling, a first digit '1' will be displayed because the counting relay CR will unavoidably operate one armature. However this is a special case which will be recognised in the processing of the call data, because the operator will insert the additional information 'did not dial' on the tape or card.

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LETTER TO THE EDITORS

Dear Sirs,

I have been pained and dismayed by the extent to which some of the contributors to the Telecommunications Journal are using wholly abstract expressions in their writings. One of the most frequently used is:— "on a . . . basis". Its use is quite common; one hears it over the air, and sees it in the papers, but this does not make it good or acceptable English. And when Engineers fall into this slovenly habit of avoiding direct and positive statements, it is time to do more than just passively register pain and dismay; it is time to do something about it. For this reason, then, I venture to emerge far enough from the vast obscurity of retirement to appeal to you to start an anti-litter campaign with the help of your distinguished panel of editors.

I have gathered some of the litter from the pages of the Journal, in which it is spread like autumn leaves on the grass, and from a truckload, so to speak, I have chosen a few samples, each from a different author, to illustrate my complaint. Here they are:—

The A.T.R. is available on a world-wide basis.

Statistics are analysed on a centralised basis.

The system will be operated on an asynchronous basis, rather than a synchronous basis. (A double bunger.)

Programming of minor works on a depot basis.

Particular routes on a priority basis.

Handle calls on a demand basis.

On a systematic sampling basis.

Staffed on a 24-hour basis.

Operated on a 4-wire basis.

All these have a vagueness and ambiguity about them, which is difficult to reconcile with the normal clear-thinking habits of professional Engineers; and why one should choose to say, for example, "Staffed on a 24-hour basis" instead of more simply: Staffed continuously, if that is what is meant, is quite beyond my powers of guessing. In most instances, a small amount of editing will remove the litter, but sometimes it will be more difficult, as when the author of the double bunger writes:—

The system will use a modified, rather than a standard, computer, on a duplicated basis.

When (and if) one recovers from the staggering effect of "on a duplicated basis", one may well wonder if there is such a thing as a modified computer per se, or if the author meant a modified standard computer. That is, if there is such a thing as a standard computer, which I doubt.

Of course, the sentence quoted may be pure jargon, and therefore quite intelligible to anyone as well informed on the subject as the author, but he was not (or should not have been) writing for experts and specialists, so I have taken the view that he was led into that loose form of expression simply by addiction to the ready-made phrase: "on a . . . basis". If such expressions were edited from author's manuscripts, and if by other means it could be made known that they were unacceptable, I believe greater attention would be paid to the choice of words generally, and this would enhance both the status of the writers and the Journal.

Basically, I am concerned with the reputation of Engineers as writers: I do not like to see them providing ammunition for their critics, of which there are plenty, as you know. My criticism is, of course, offered on a friendly and fraternal basis. (Ugh)

Yours Sincerely

C. Cruttenden

ARK-M EXCHANGES

D. D. MATTISKE, B.E., A.M.I.E.E.*

INTRODUCTION

Several types of L. M. Ericsson crossbar exchanges have been installed in the Australian network since 1959. The ARF type has been used in urban centres and the ARK in rural areas. The latter is a dependent exchange requiring an ARM parent exchange in the unmodified form, or a step-by-step or manual parent in the modified (ARK-D) form. (See Ref. 1.) More recently the development of a new register REG-ELP has allowed ARF exchanges to act as parents for ARK exchanges. This development coupled with the provision of registers REG-EHY2 at ARM exchanges will allow the introduction of an ARK-M multi-frequency compelled sequence (m.f.c.) controlled exchange to the network. (See Fig. 1.)

The ARK-M is a simple terminal exchange dependent on a parent at which the complex registers and route markers needed for the tasks of charging analysis and route selection have been concentrated. This allows them to be shared by several ARKs and thus used more efficiently. All calls from an ARK-M exchange to another exchange must be made under the control of the parent exchange which supervises the establishment of the connection. Local calls are normally set up with the aid of the parent exchange common equipment, but if there are no free junctions, a local call can be established entirely with the ARK-M equipment.

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EXCHANGE DESCRIPTION

As in the ARK-D case, there are two types of ARK-M exchanges, the ARK-M 511 and ARK-M 521. The trunking diagrams of these two types of exchanges are shown in Figs. 2 and 3 respectively. It will be seen that while the switching matrix is identical with the ARK-D exchanges, the peripheral equipment is somewhat different.

ARK-M 511: A code receiver-sender KM is connected to the outgoing and incoming relay sets via a connecting relay set AKL. The KM receives m.f.c. information from the parent exchange via the junction relay set, converts this information into signals which the ARK marker can act upon, and transmits to the parent m.f.c. information as requested by the parent. The manner in which this signalling occurs is described later. The REG-L is an overflow register for outgoing calls, used to accept dialled information and establishes local calls when no junctions are available to the parent.

ARK-M 521: Again, a KM is included in the peripheral equipment and is connected to the incoming and outgoing relay sets by connecting devices FID and FIG. The ARK-M has the facility of providing a direct route connection from the local exchange to an adjacent exchange. In order to achieve this a relay set KFID is used to through-connect the m.f.c. signals from the parent to the junction relay set of the direct route. A Reg-L is again provided as an overflow register, but as well as establishing local call connections, it can provide a direct

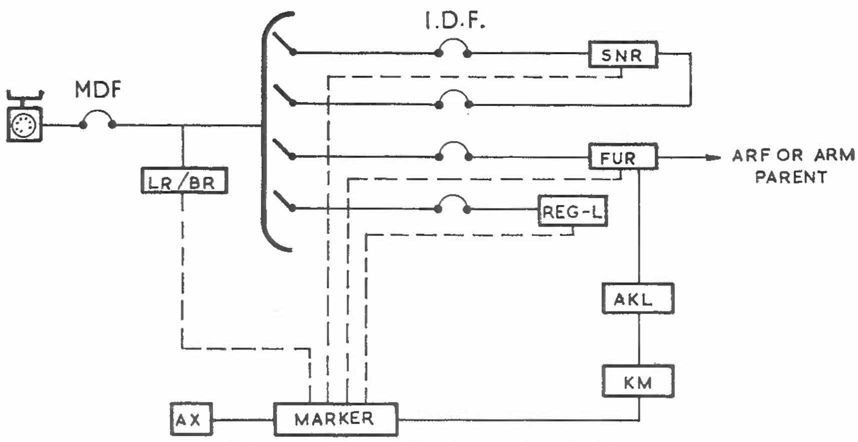

Fig. 2 — Trunking Diagram of ARK-M 511.

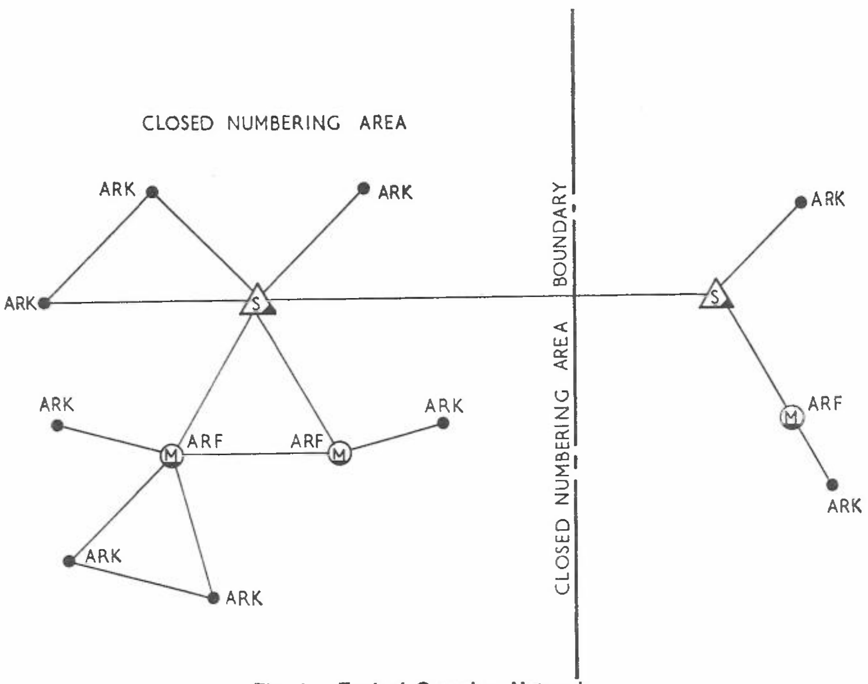

Fig. 1 — Typical Crossbar Network.

route connection to a manual exchange. The marker and the SNR relay sets are identical in function to the ARK-D equivalents but the MIR-REG caters for the KM as well as the Reg-L.

ARK-511 EQUIPMENT OUTLINE

Selector Stage SL

The selector stage of the ARK-M exchange is identical to that in the ARK-D exchange. The A.P.O. is considering a proposal to increase the number of verticals available to each group of 30 subscribers in the 90 line unit from 15 to 20. This could be achieved by utilising the spare verticals in SL4 which has access to the same outlets as SL5, and introducing another crossbar switch.

This would alleviate the internal congestion now being experienced in some ARK-D 511 exchanges with more than 60 lines connected.

Subscribers' Line Relays LR/BR BLR

These are identical with those in the ARK-D exchange.

Marker M

Provision has been made in the ARK-D marker to cater for either

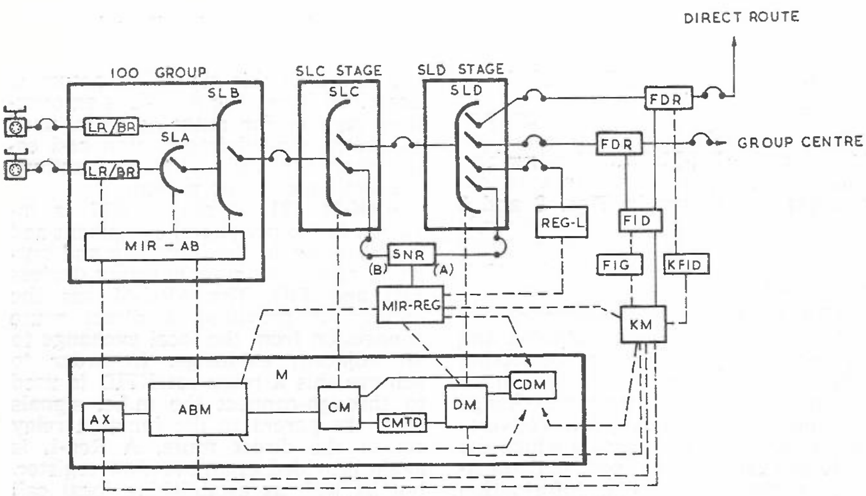

Fig. 3 — Trunking Diagram of ARK-M 521.

Reg-D's or Reg-L and KM's and so the same marker will be used in both ARK-D and ARK-M configuration.

Local Connecting Circuit SNR

Although this relay set performs basically the same function as its counterpart in ARK-D exchanges, provision has been made for the ARK-M version to provide the facility of non-metering numbers and suspension of time supervision. These new relay sets can be used in ARK-D exchanges although the added facilities will not be used. Provision will be made for 3 to 5 SNR's in the 90 line unit depending upon internal traffic requirements.

Junction Line Relay Sets FDR, FIR and FUR

A range of these types of relay sets will be produced to work with the various types of signalling methods in use.

Where necessary, the FDR's, FUR's and FIR's convert 4-wire junction circuits to 2-wire circuits by means of a hybrid. Attenuator pads are also located in these junction relay sets where necessary.

The FUR, when seized, will connect the subscriber's speech pair to the KM and the junction pairs to the KM. On command from the KM, the speech pairs are through connected to the junction. Other functions include:

— repetition of dial impulses.
— reconnection of the KM to the speech pair and junction pair with subsequent reconnection of the speech pair to the junction.
— reception of meter pulses from parent and conversion to meter pulses of + 100V on the C wire.
— time supervision.

The FIR, when seized, calls for and connects to a KM and connects the junction pair to the KM. When the called number is free and has been connected to the FIR, ring current is sent from the FIR to the called number and ring tone is sent back to the calling number. B-party switch hook signals are returned to the calling exchange.

The FDR combines the functions of the above relay sets as it can act in the FUR or FIR mode.

Overflow Register Reg-L

A maximum of two Reg-L's can be provided at an ARK-511 exchange. The Reg-L is seized when no junction to the parent is available and accepts dialled digits from the calling subscriber. If other than a local code is dialled, busy tone is fed to the subscriber and after a period of ten seconds the subscriber is placed on line lockout. On the other hand, if a local number is called the Reg-L directs the marker to establish a local connection via an SNR circuit.

AX, PBX and LFR

The AX is associated with the marker and stores the calling subscriber category and called subscriber category for each exchange number. Some subscribers' categories are determined by the combination of the marking in the AX and the presence or absence of a diode in the subscriber's loop. The subscriber can switch this diode in or out at the handset and thus vary the category of the line.

The relay set PBX is provided where PBX's are connected to the exchange.

LFR is an alarm relay set which transmits alarms to the parent or some other alarm control centre.

Code Receiver KM

Only one KM is provided for each ARK 511 exchange. It is equipped to receive six frequencies — 1380, 1500, 1620, 1740, 1860 and 1980 Hz — and transmit four frequencies — 780, 900, 1020, 1140 Hz. The flow chart in Fig. 4 describes the signalling which takes place between the parent and ARK exchange. During the Group 1-Series U signalling, a maximum of six digits can be stored in the KM. In order to transmit the backward signals Series K, U and B, the KM interworks with other relay sets to obtain the required information. To send the K series, the KM requests the marker

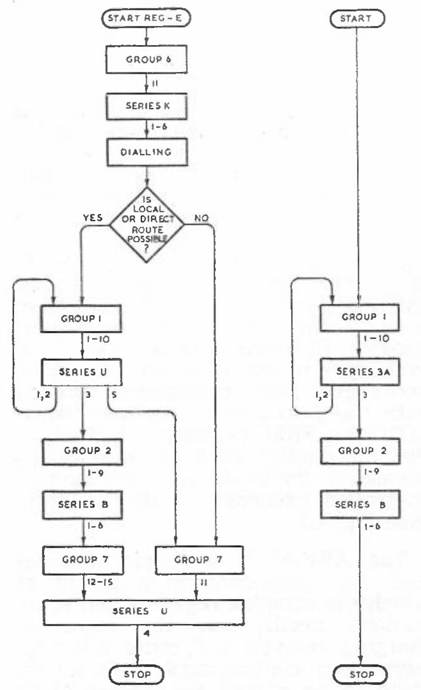

Fig. 4 — Flow Chart of Signalling Scheme for ARK-M Exchanges.

for the AX (part of the marker) category marking and performs a fleeting test reversal on the subscriber line to detect a diode in the subscriber's line which would further classify the category marking.

The U series are sent after analysing the digits being stored in the KM, while the B series signals are sent after receiving information from the marker about the condition of the B subscriber's line and its B subscriber category.

ARK 521 EQUIPMENT OUTLINE

As can be seen in Fig. 3, the selector stages and marker configurations in the ARK-M exchange are identical to the ARK-D exchange. The MIR-REG is slightly different in ARK-M because it has access to both Reg-L and KM. Only one per exchange is provided. Three direct routes of 12 lines each may be connected to an ARK-M 521 exchange. However, a direct route to a SXS exchange is not possible for signalling reasons which will be explained below. A direct route to a manual exchange is possible with a junction line relay set similar to FDR-L-M or its T1 or T3 equivalent. This requires an appearance of the relay set on the SLB stage and a special category marking for that appearance in AX in order to connect a Reg-L to that appearance in the case of an incoming call from the direct route exchange. In most cases, the direct route exchanges will be capable of handling m.f.c. signals.

The peripheral equipment has no parallel in an ARK-D exchange and so will be described.

Reg-L

In addition to those facilities already described in the ARK-511 Reg-L, the ARK-521 is capable of receiving dialled information for calls to manual exchanges on direct routes. The register will set up such a call providing that a junction on the required direct route is free.

FID and FIG

Five junction line relay sets (FDR's, FUR's and FIR's) are connected to an FID relay set which in turn has the capability of establishing a connection to one of two FIG's.

Twelve FID's can be connected to one FIG which in turn can establish a connection to one of two KM's providing that one is idle.

These two relay sets thus provide a concentrating switching matrix between the junction line relay sets and the KM's.

KM and KFID

The KM in the ARK 521 exchange provides the same facilities as the ARK 511 KM with the additional features of being able to establish a connection via a direct route and being able to analyse seven digit numbers.

The KFID is used to establish a bypath so that the parent register may send m.f.c. information to the terminating exchange via a direct route. A KFID may be used by 5 KM's to search for a free circuit in a maximum of twelve on each of the three direct routes when the KM has indicated which direct route is to be selected.

ORIGINATING CALLS

When an ARK subscriber lifts his handset, the subscriber's line circuit calls the marker and if a free junction is available to the parent exchange, the marker connects the subscriber to the junction line relay set, either an FUR (or FDR). The operation of the marker is identical to the ARK-D case, except that the FUR calls for a KM instead of a Reg-D. The FUR then connects the subscriber's line to the KM and at the same time connects the junction line to the tone receiver.

On seizure, the FUR seizes forward on the junction and the FIR at the other end of the junction calls for a register. The register type depends upon the type of exchange, being a Reg-EHY2 for an ARM parent and a Reg-ELP for an ARF. The register, on seizure, calls for a code sender KS and instructs it to send Group 6, tone 11 which is a request for class of service.

When this signal arrives at the KM, the subscriber's class of service, which has been transferred to the KM from the marker and checked by a fleeting reversal test, is transmitted to the parent by one of the K series signals. Acknowledgment by the parent of this signal is relayed to the KM by cessation of the tone 11 signal and causes the KM to cease sending the category signal and release from the FUR. The subscribers speech pair is then connected to the junction.

At the parent the cessation of the class of service signal causes the register to release the code sender KS, and then send dial tone to the calling subscriber.

Time supervision commences in the KM when it is seized and if tone 11 is not received within 5 seconds, busy tone is returned to the calling subscriber who is then put on line lockout as it is presumed that at the parent end either no register was available or that the called register was unable to find a free KS.

As mentioned previously, if no junction to the parent is available, the subscriber is connected to Reg-L, or in the case of no free Reg-L, placed on line lockout.

On receipt of dial tone the subscriber can then dial the required number. The FUR repeats the impulses to the junction and the dialled information is stored in the parent register.

The register can then analyse the digits and determine into which of the following categories the call falls (see Fig. 1):

(a) called subscriber may belong to originating exchange;

(b) called subscriber may belong to an exchange which is connected to originating exchange by direct route;

(c) called subscriber may belong to an exchange which does not fall into categories (a) and (b);

(d) called subscriber is barred to originating subscriber because of class of service category limitations.

In the case of category (d), busy tone is sent to the called subscriber.

Local Call (See Fig. 5)

When all the dialled digits have been received at the parent exchange and analysis of the digits indicates that a local connection is to be made, the register calls for a KS and sends a line signal to the ARK exchange calling for a KM. This is achieved in the following manner for the different types of signalling equipment:

L type 150 ms line potential reversal.

T type 150 ms pulse on the E lead.

T1 type 150 ms pulse of 83 Hz.

The FUR at the ARK exchange detects this line signal as the first of its kind and establishes a connection to the KM, once again splitting the subscriber's speech pair and junction pair and connecting them to the KM.

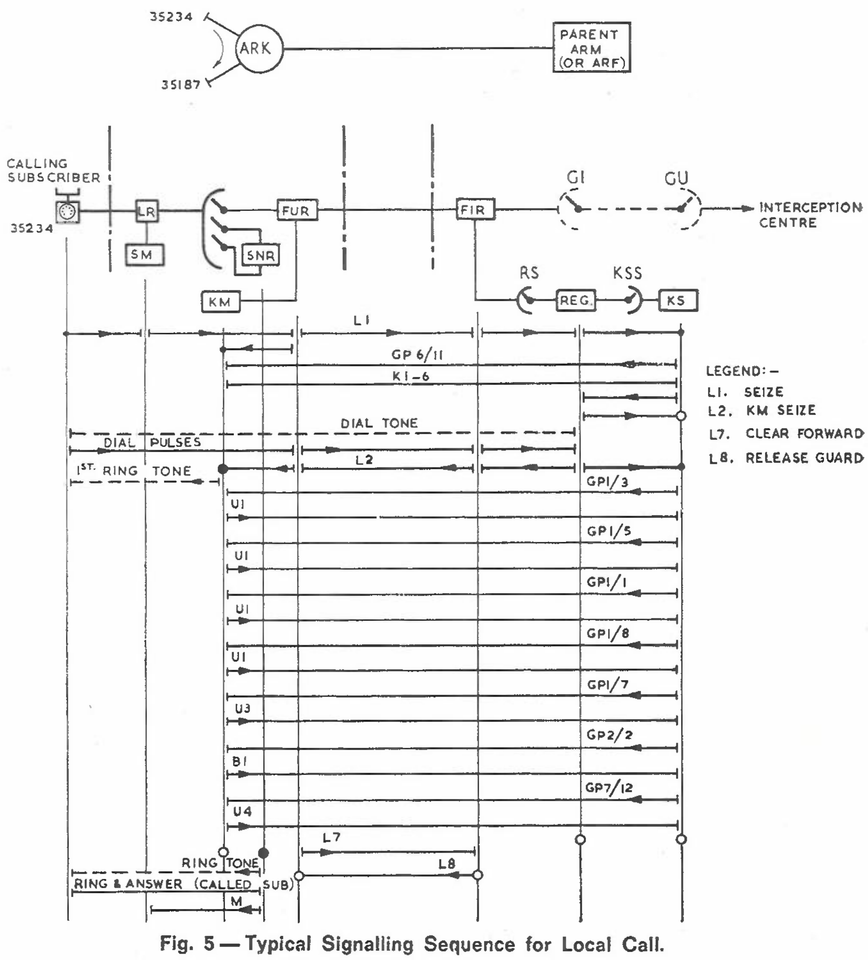

Fig. 5 — Typical Signalling Sequence for Local Call.

The parent register then instructs the KS to send the called subscriber's number in m.f.c. code (Group 1 signals). As they arrive at the KM they are acknowledged by the series U signals and analysed. When all the digits have been received at the KM, the series U signal 3 is sent and the KM is set to receive a Group 2 signal indicating the type of calling subscriber. In most cases this would indicate an ordinary subscriber although provisions have been made to indicate the following originating subscribers category:

Group 2 signal 1 — Call from an operator.

Group 2 signal 3 — Call from a test position.

Group 2 signal 4 — Call from an interception centre.

The KM, having received this last piece of information, then calls a marker and transfers the called subscriber's number to it. The marker performs tests on the C-wire and determines from the AX the terminating class of service. This information is forwarded to the KM and then to the parent exchange by one of the B series signals. If this test indicates that the subscriber is free, the parent in response to B series signal 1 instructs the KM by Group 7 signal 12 to establish a local connection by means of an SNR which in turn is acknowledged by Series U signal 4. When the register receives this signal it ceases transmission of the Group 7 signal and releases the KS and its connection with the FIR. The KM then instructs the marker to set up a connection between the called subscriber and the B side of an SNR and then, by means of a 'jump', connects the calling subscriber to the A side of the same SNR and then releases. This operation is identical to the equivalent ARK-D local call connection except that it is directed from the KM and not the Reg-D. When the jump has occurred the FUR then clears forward on the junction.

If the called subscriber was in the busy condition when the marker tested its C-wire, B series signal 2 would be sent to the parent. The parent register then instructs the KM to release its connection to the FUR and to restore the through connection of the speech path to the junction by sending a Group 7 signal 11. Before carrying out this instruction the KM acknowledges with U series signal 4 and then releases. The parent register then returns busy tone to the calling subscriber.

Direct Route Call

If the number dialled represents a call for a subscriber connected to an exchange which has a direct route connection from the originating exchange, the parent register calls a KM at the originating exchange and offers it the dialled number in m.f.c. code.

The KM analyses each digit to ensure it represents a number accessible from the originating exchange, i.e. by a local connection or a direct route connection. When sufficient digits have been analysed to determine the direct route the KFID is called and the particular direct route code is transferred. Selection of a free circuit in the direct route is made and a bypath connection established. Information transfer continues between parent register and terminating exchange KM until the B series signal is sent.

When the parent changes to the Group 7 signals, the originating exchange KM, which has been ignoring all the numerical Group 1 signals, recognises this signal as the command to release its connection to the FUR. In the case of Group 7 signal 12, it starts the 'jump' to connect the calling subscriber to the direct route FUR and releases the junction connection but in the case of Group 7 signal 11, releases its connection to the FUR and leaves the release of the FUR under control of time supervisory equipment in the originating register.

If the parent exchange register is unable to tell whether a direct route connection is possible, the dialled number is offered to the originating exchange until either Series U signal 3 is received — indicating that a direct route connection is possible and has been established — or Series U signal 5 is received — indicating that the connection must be made via the parent exchange. The latter also applies where all circuits in a selected direct route are busy.

B-party switch hook signals are returned to the originating exchange FUR which produces a meter pulse on answer.

Calls to Other Exchanges in the Same Numbering Area

If, on analysing the dialled number, the parent register is unable to determine whether the call can be established by a local connection, a direct route connection, or by an external connection via the parent, the digits of the dialled number are offered to the originating exchange. Where the connection must be made via the parent, the originating exchange returns U series signal 5 when sufficient digits have been received and analysed. This indicates that no connection via the originating exchange can be made.

The parent register will then release the originating exchange KM by sending Group 7 signal 11 and will establish the call via the parent exchange.

If the subscriber is free, ring tone will be returned to the originating subscriber from the terminating exchange. However, if the subscriber is busy, busy tone will be returned to the originating subscriber from the parent register where the terminating exchange is a crossbar exchange capable of handling m.f.c. signals. Otherwise busy tone is returned from the terminating exchange.

When the call is established via the parent, modified Karlsson signals are returned to the originating exchange.

Calls to Another Numbering Area

If the number dialled by the originating subscriber indicates that the call is for a number in another closed numbering area, no attempt is made to offer the dialled number to the originating exchange but rather the appropriate route is selected and the signalling continues as described in the previous section.

TERMINATING CALLS

ARK exchanges can receive incoming calls from other exchanges from either the parent exchange or from a direct route. The signalling which takes place to transfer the called subscriber's number and calling subscriber's category to the KM at the ARK exchange differs slightly from that described for a local call. No attempt has been made to provide trunk switching facilities at an ARK exchange and so only terminating traffic will be incoming to the ARK. This allows certain economics in signalling.

When an ARK FIR (or FDR used in the FIR mode) is seized from the parent or a direct route exchange, the KM is seized in such a manner that an abbreviated form of signalling will be expected. This allows only those digits necessary to set up the call to be sent. Hence the number of Group 1 signals sent to the ARK for an incoming call will be

2 for an ARK 511

3 for an ARK 521 with less than 1000 lines connected

4 for an ARK 521 with more than 1000 lines connected

The signalling sequence ends when the B series signals are sent to the originating exchange. Because the mode of connection is known, no Group 7 signals are necessary.

CONCLUSION

The introduction of ARK-M exchanges will extend the m.f.c. network to the country areas, and in so doing, increase the facilities of the existing small country terminal exchanges. This can be done with savings in the cost of these exchanges because of the elimination of the costly discriminating registers now being used in ARK-D exchanges. With the progress being made in the ARM installation programme and the development of Reg-ELP for use at ARF Minor Switching Centres there will be considerable scope for ARK-M exchanges in the near future.

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MATTISKE — ARK-M Exchanges

SLIDE RULE COMPOUND GROWTH CALCULATIONS

C. W. PRATT, B.Sc., M.Eng.Sc., Ph.D., F.S.S.*

INTRODUCTION

There are many slide rules on sale and in use which have only two log log scales, the LL_2 scale covering the range from 1.10 to 3.0 and the LL_3 covering the range from 2.6 to 10^5. Some slide rules also have a third scale, the LL_1 scale which covers the range 1.01 to 1.105. This third scale is useful for compound growth calculations where the annual percentage increase lies between 0.01 and 0.10, i.e. 1-10%; this range covers most interest rates used in economic comparisons.

The following short note describes how a slide rule without an LL_1 scale may be used for compound growth calculations by exploiting a good approximation. The maximum size of the error involved will be shown to be about three thousandths of an inch on a 10 inch slide rule.

METHOD

Positions of Points on the LL_1 Scale.

The following result forms the basis of a method for using a slide rule as though it had an LL_1 scale even if this scale is missing: The position of the point labelled $w = 1 + i$ on the LL_1 scale is almost the same as the position of the point labelled $\dfrac{100i}{(1 + \frac{i}{2})}$ on the D scale, for $i \leqslant 0.1$.

An an example suppose we wish to set the cursor K to the position of 1.04 on the LL_1 scale. In this case $i = 0.04$ and we see that the position of 1.04 on LL_1 is the same as the position of $\dfrac{4}{1.02}$ on D. This is most easily found by the following two steps:

1. Against D 1.0 set C 1.02.
2. Move K to C 4.0.

Example 1.

Suppose that in a compound interest calculation a principal P is invested for $n = 7$ years at interest rate $i = 0.05$, i.e. 5%. At the end of this time the investment will grow to amount

$$A = P(1 + i)^n,$$
$$= P(1 + 0.05)^7.$$

We wish to calculate $(1 + 0.05)^7$ without having an LL_1 scale. The procedure is as follows:—

1. Against D 1.0 set C 1.025.
2. Move cursor K to C 5.0. The cursor is now in the position of LL_1 1.05 if the rule had an LL_1 scale.
3. Move C 10.0 to cursor K.
4. Move K to C 7.0.
5. Read off the result 1.407 from LL_2.

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Example 2.

In Example 1, the result is easily obtained since it falls above the range of an LL_1 scale and within the range of the LL_2 scale; it is therefore read directly from LL_2. In some cases, however, the result will be within the LL_1 range, and then the answer is found by an inverse procedure which may be illustrated by the following example.

Suppose we wish to find $(1 + 0.02)^4$. The first four steps are similar to those of Example 1:—

1. Against D 1.0 set C 1.01.
2. Move K to C 2.0.
3. Move C 1.0 to K.
4. Move K to C 4.0.

At this point the result $(1 + r)$ say, would be read from LL_1 if we had one. Note that the cursor stands at D 7.93 so that $7.93 = \dfrac{100r}{1 + \frac{r}{2}} \doteqdot 100\ r$; thus $r \doteqdot 0.08$ and $\dfrac{r}{2} \doteqdot 0.04$. To get an exact value for 100 r we multiply the D scale reading by $1 + \dfrac{r}{2}$ and this is achieved by the following two steps:

5. Against D 1.0 set C $1.04 \doteqdot 1 + \dfrac{r}{2}$.
6. On the C scale at K read off $8.24 = 100\ r$.
   Thus the exact result is 1.0824.

Theoretical Justification.

In what follows we shall be concerned with the C, D and LL_1 scales. Suppose that the point marked 1.0 at the left hand end of the D scale is taken as the origin for purposes of measuring distances along the rule, and that the length of the D scale from the point marked 1.0 to the point marked 10.0 is taken as 1 unit. Thus a mark labelled x on the D scale is a distance d from the origin where

$$d = \log x,$$

and log denotes logarithm to base 10. Thus for the point labelled 1.0,

$$d = \log 1.0 = 0,$$

as we expect since we have already defined this point as the origin. Also for the point labelled 10.0,

$$d = \log 10.0 = 1.0,$$

as we expect since we regard the D scale as being of unit length.

Consider now the log log scales. A point labelled z on the LL_3 scale is at distance l_3 from the origin, where

$$l_3 = \log (\ln z),$$

where ln denotes logarithm to base e. Thus for the point e = 2.718 ....,

$$l_3 = \log (\ln e),$$
$$= \log 1.0,$$
$$= 0.0,$$

so that the point 2.718 will be found on the LL_3 scale opposite the origin, i.e., opposite point 1.0 on the D scale. Further, for the point 22,000 ($= e^{10}$),

$$l_3 = \log (\ln 22{,}000),$$
$$= \log 10.0,$$
$$= 1.0$$

so that the point 22,000 on the LL_3 scale is opposite the right-hand end of the D scale, i.e. opposite point 10.0 on the D scale.

In a similar way, it is easy to verify that a point labelled y on the LL_2 scale is at a distance l_2 from the origin where

$$l_2 = \log (10 \ln y),$$

and that where a LL_1 scale is present, a point labelled w on the LL_1 scale is at a distance l_1 from the origin where

$$l_1 = \log (100 \ln w).$$

Approximating the LL_1 Scale.

In carrying out compound growth calculations, we are concerned with knowing the position on the LL_1 scale of a point $w = 1 + i$, where i is the annual growth rate, or interest rate as the case may be, and lies in the range 0.01 - 0.10. We have seen above that the desired position is distance l_1 from the origin where

$$l_1 = \log (100 \ln w),$$
$$= \log (100 \ln (1 + i)).$$

If ln (1 + i) is expanded as an infinite series thus:

$$\ln (1 + i) = i - \frac{i^2}{2} + \frac{i^3}{3} - \frac{i^4}{4} + \text{........},$$

we obtain

$$l_1 = \log (100\, i\, (1 - \frac{i}{2} + \frac{i^2}{3} - \frac{i^3}{4} + \text{........})),$$
$$= \log 100\, i + \log (1 - \frac{i}{2} + \frac{i^2}{3} - \frac{i^3}{4} + \text{........}),$$
$$= \log 100\, i - \log (1 + \frac{i}{2}) + \log (1 + \frac{i}{2}) (1 - \frac{i}{2} + \frac{i^2}{3} - \frac{i^3}{4} + \text{........}).$$

This last line is obtained by adding and subtracting the same quantity $\log (1 + \frac{i}{2})$. As will be seen shortly the choice of this term determines the accuracy of the approximation. Now

$$l_1 = \log 100\, i - \log(1 + \frac{i}{2}) + \log (1 + \frac{i^2}{12} - \frac{i^3}{12} + \text{........})$$

For i small, say 0.1 or less, the last term is approximately zero since

$$1 + \frac{i^2}{12} - \frac{i^3}{12} + \ldots\ldots$$

is approximately unity. This approximation is a good one since the factor $(1 + \frac{i}{2})$ was chosen so that the product $(1 + \frac{i}{2})(1 - \frac{i}{2} + \frac{i^2}{3} - \ldots)$ would not have a term in i.

Thus

$$l_1 \doteqdot \log 100\,i - \log (1 + \frac{i}{2})$$

$$\doteqdot \log \frac{100\,i}{(1 + \frac{i}{2})}$$

$\doteqdot$ distance of the point $\frac{100\,i}{(1 + \frac{i}{2})}$ on the D scale from the origin.

Thus we have shown that the point labelled $(1 + i)$ on the LL_1 scale is approximately opposite the point marked $\frac{100\,i}{(1 + \frac{i}{2})}$ on the D scale for $i \leqslant 0.1$.

Accuracy of the Approximation.

The error involved in using $100\,i \,/\, (1 + \frac{i}{2})$ on the D scale as the position for $w = 1 + i$ on the LL_1 scale is

$$E = \log (1 + \frac{i^2}{12} - \frac{i^3}{12} + \frac{3i^4}{40} - \frac{i^5}{15} + \ldots\ldots),$$

$$= \frac{1}{2.3026} \ln (1 + \frac{i^2}{12} - \frac{i^3}{12} + \ldots\ldots),$$

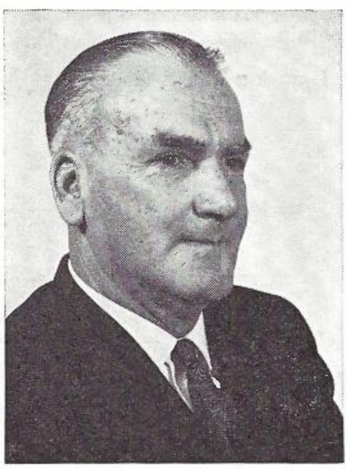
$$= \frac{1}{2.3026} \left(\frac{i^2}{12} - \frac{i^3}{12} + 0(i^4)\right)$$

For the range of values of i of interest (i.e. for $i \leqslant 0.10$), the error is largest when $i = 0.10$, in which case

$$E = 0.000\,326.$$

This error is expressed in terms of the unit length we have defined as the length of the D scale. Thus if a 10 inch rule is being used, the greatest error is at the right-hand end, and is approximately three thousandths of an inch.

MR. J. H. W. WHITE, A.M.I.E., Aust.



MR. J. H. W. WHITE, A.M.I.E., Aust.

Mr. J. H. W. White, Director, Posts and Telegraphs, Western Australia, began his career in Perth as a Junior Mechanic in 1925. An appointment in 1928 as Cadet Engineer, Adelaide, set the stage for a notable engineering career which began in country areas of South Australia. He was promoted Divisional Engineer, Newcastle, in the New South Wales Administration in 1945, where for seven years he managed one of the busiest country divisions in Australia. He was promoted to the position of Supervising Engineer, General Works, Sydney, in July 1962.

He returned to Perth in 1955 to assume control of the Western Australian Engineering Division at a time when development of the State was starting to show signs of its current sharp upward trend. Major engineering works undertaken in the eleven years he was Assistant Director (Engineering) include the installation of the Perth/Bunbury coaxial cable, introduction of national television, reconstruction of the East/West aerial trunk route, introduction of TRESS, introduction of crossbar equipment, extension of the trunk system northwards from Meekathara, first to Marble Bar and Port Hedland and then to Broome and Derby, and establishment of microwave radio links for television and telecommunications.

An active interest in Telecommunication Society of Australia prompted Mr. White to become the Foundation Chairman of the State Division when it was created in 1960. He occupied this position for six years, contributing significantly to the growth of the Society in Western Australia and to the development of its activities.

Mr. White was appointed to his present position in February 1966 and has controlled all Post Office activities in Western Australia in a period of exciting and phenomenal growth.

APPLYING EPOXY RESINS

*M. J. DAWKINS**

INTRODUCTION

Thermo-plastic and thermo-setting resins have become common place in industry, particularly in the electrical and communication industries. Epoxy resin, a more recent thermo-setting plastic has not been as widely used as some of its properties would suggest, mainly because it is not easily adapted to modern production techniques.

A more detailed knowledge of this potentially useful material may assist the technologist to solve the practical problems which appear at present to inhibit a wider use. The emphasis in this paper will therefore be practical, with only brief reference to the chemical and physical structures of the material. The bibliography lists some sources of more theoretical information.

History

In the late 1930's the first evidence of the commercial exploration of epoxide resins was seen when a German patent was granted to I. G. Farbenindustrie describing liquid polyepoxides which could be hardened by a variety of methods. Shortly afterwards an American patent was granted covering the curing of phenolic epoxide resins and was exploited by CIBA Company. However, it was not until 1950 that commercial scale production was undertaken. As the production of epoxide resins is reliant on the supply of by-products from the petroleum chemical industry, it is natural that this industry has been responsible for the major development of epoxide resins. It is estimated that from no production in 1950, 45,000 tons in 1960, consumption in 1967 will have reached 71,000 tons in the United States alone.

What is Epoxy Resin?

Some description of the physical structure of epoxy resins is necessary to enable us to understand methods of use and the suitability of the material for various applications. The reader who seeks a chemical explanation is referred to the references in the bibliography.

An epoxy resin is a viscous liquid or brittle solid of no use until reacted with other materials. Examination of the molecules, enlarged 10 million times, would show needles varying in length from half an inch in the liquid form to several inches solid. When the resin is cured or hardened, these needles are joined together at the ends and along the sides and form a cross-linked structure similiar to a fish-net but of a non-uniform pattern.

The final product is thermo-set plastic, a solid that may soften when heated, but will not liquify. The curing of epoxies is like the setting process of concrete; it is completely irreversible. The greater the density of cross-links, the better will be the electrical characteristics, the resistance to heat softening and attack by chemicals and water.

The curing process is accomplished in one of two ways:

(a) By directly linking the resin molecules to other epoxy molecules with the aid of a 'catalyst' e.g. boron triflouride, or

(b) by linking the resin molecules to a 'reactive hardener' e.g. diethylenetriamine. The resultant molecule then combines with one or more additional molecules of resin.

The curing reaction of epoxides is highly exothermic and as the temperature rises so does the rate of curing. This can lead to a runaway condition and a degraded final product or damage to components in contact with the resin. A variety of temperature controling techniques are used to avoid these troubles.

Design Requirements

The main properties required for a plastic to be suitable for use in electrical applications can be summarised as follows:

(a) Whilst the product in its final form must have all the required properties, electrical, physical and chemical, it must also have characteristics which will ensure that no damage is done to the other components during manufacture.

(b) Resistance to oxidization, light and atmospheric corrosion is required if the products are to be suitable for prolonged outdoor use. A good resistance to humidity, with low water absorption and high surface resistivity are also required.

(c) Complete encapsulation of equipment sub-assemblies can result in savings in weight and space as components can be supported over their entire outside surface and additional supports will not be required. The epoxy resin therefore, acts as sealing, support and, where applicable, as a dielectric.

Definitions

The terms casting, potting, encapsulation and sealing are used quite loosely in industry but the following definitions will help to clarify them and will be adhered to in this article:

Casting — pouring a liquid mass of material into a definite mould to give rod stock, spheres, gears, bushings, valve seats, and all varieties of moulded items.

Potting — filling of a container or housing with a low-viscosity resin to achieve deep embedment and thorough impregnation.

Encapsulation — to surround an item with shielding material, using either external moulds, which may be removed to reveal the final product. Alternatively the item may be dipped into a thixotropic sealant.

Sealing — to close off a portion of a device against the environments.

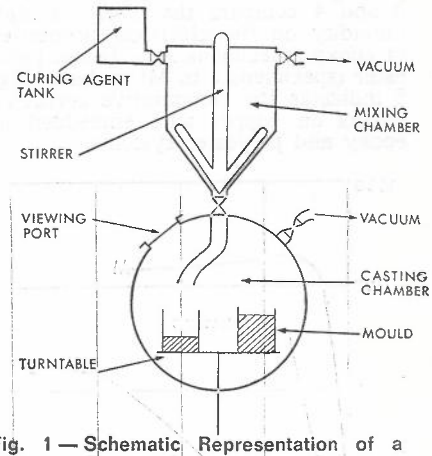


Fig. 1 — Schematic Representation of a Typical Casting Plant.

Whilst each of the above procedures can be done quite successfully at atmospheric pressures, considerable benefit may be obtained, particularly in the cases of casting encapsulation and potting, if these are carried out in a vacuum. Air voids are removed and if, for example, a transformer winding is to be encapsulated, the winding will be completely impregnated resulting in more effective insulation between turns and winding. As a result some of the cost of encapsulation may be offset by reducing the grade of the initial insulation of the component. A schematic representation of a typical vacuum assisted casting plant is shown in Fig. 1.

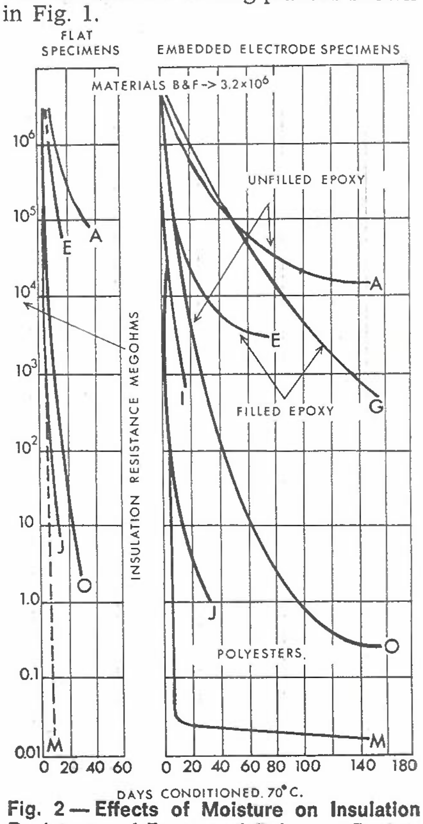


Fig. 2 — Effects of Moisture on Insulation Resistance of Epoxy and Polyester Resins.

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The high moisture resistance of epoxy resins is particularly valuable in potting and encapsulation work. Fig. 2, 3 and 4 compare the effect of high humidity on the electrical properties of epoxy (specimens A to I) and polyester (specimens J to M) systems. Fig. 5 indicates the comparative corrosive effects on copper wire embedded in epoxy and polyester systems.

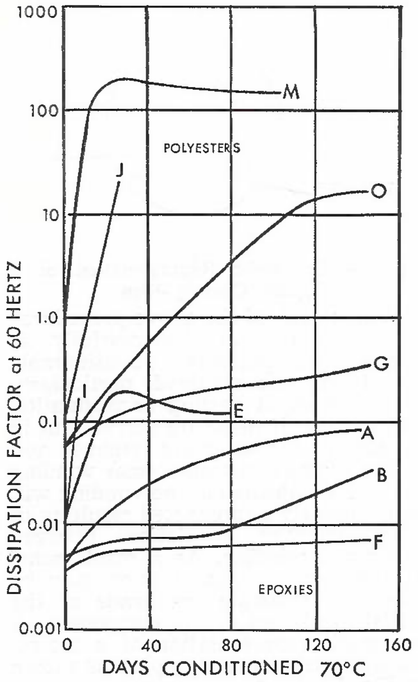


Fig. 2 — Effects of Moisture on dissipation Factor of Epoxy and Polyester Resins.

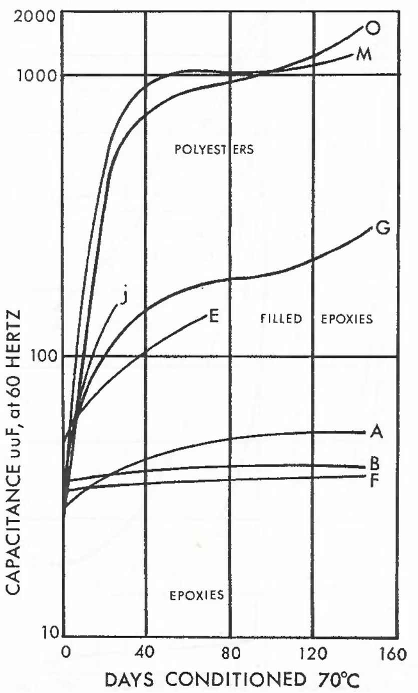


Fig. 4 — Effect of Moisture on Capacitance of Epoxy and Polyester Resins.

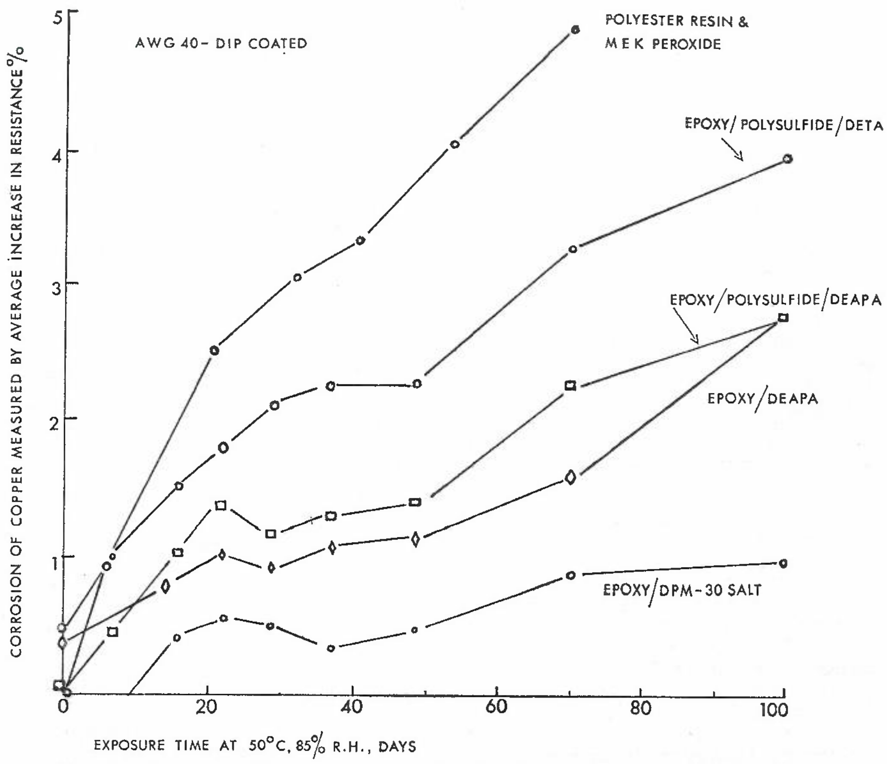


Fig. 5 — Corrosive Effects of Various Casting Compositions on Copper Wire.

Commercial electrical applications for epoxy resin potting compounds are shown in Table 1. It should be noted when considering the use of epoxy resins that the electrical properties of cured systems are dependent on frequency. The power factor, for example, is lowest at about 50 Hz and remains fairly constant up to about 55 kHz. It then increases as the frequency is raised to 1 MHz. This frequency dependence, restricts the use of epoxy

TABLE 1: APPLICATIONS FOR EPOXY RESINS

Electrical Equipment

- Small aircraft armatures and stators
- Transformer bushing manufacture and repair
- Magnetic chucks
- Circuit-breaker components
- Commutator and slip-ring repair
- Bus-bar insulation
- Power, distribution, and high-voltage transformers

Electronics Equipment

- Multivibrators as timing circuits for computers, amplifiers, and power supplies
- Selenium rectifiers
- Metallized, paper and ceramic capacitors
- Antenna-matching and torroidal transformers
- Ferrite pot cores
- Radio-frequency chokes
- Inductors
- Vacuum-tube and magnetic amplifier circuits
- Germanium diodes and transistors
- Miniature and subminiature vacuum tubes
- Printed circuits
- Hermetically sealed relays

Cables

- Cable splices for mineral, lead and rubber cables
- Dams for gas-filled cables
- Conduit sealing
- Cable terminal sealing

resins for high frequency applications, but they may still be used if correct design procedures are applied.

The fungus-resistant nature of epoxy resin insulation is particularly valuable in moist tropical climates. Epoxy resin compounds have been successfully used for military applications where high resistance to fungus is required.

Modification of Epoxy Resins

Unmodified cured epoxies tend to be brittle. When subject to sharp impact, they may break. In thin films as adhesives or coatings they may crack when flexed. Their peel strength is low.

To improve elongation and toughness of epoxy resins, various approaches have been used, all primarily aiming to build more flexibility into the resin molecule. Two of these are:

(a) 'Thiokol' resins, which are liquid polysulphide rubbers linking epoxide molecules together by chemically combining at either end of the molecules to provide flexibility to the chain. They are used in conjunction with amine curing agents. The mixture is less viscous during mixing, cures faster and gives more flexible and resilient products than an unmodified epoxy. A typical composition, by weight is 33/10/100, Thiokol/amine/epoxy.

(b) The amino-polyamide class of hardeners of which the 'Versamid' resins are members, are generally viscous brown liquids. These give a higher tensile strength but lower elongation than the Thiokol/epoxy blends. However, as the amino-polyamides are themselves curing agents, the composition need contain no additional amine. A typical mix in this case would be 50/100, being the weight ratio of Versamid to epoxy. Ratios up to 100/100 produce satisfactory cures.

The change of properties produced by various quantities of LP-3, a Thiokol resin, can be seen in Table 2.

Whilst not strictly a modification to the resin, fillers are quite often used to produce a modified end result. Fillers are inert solid particles which are incorporated into an epoxy primarily to reduce the resin content. However, the ideal filler improves the characteristics in which the pure resin is lacking, without causing any serious impairment of the resin's more desirable characteristics.

Fillers do not normally increase the strength of the resin. To do this, reinforcements in the form of glass fibres, Dacron, metallic or natural fibres or cotton are normally used. These will produce high strength in the fibre direction. Suitable fillers on the other hand improve heat resistance, reduce shrinkage on curing and reduce the coefficient of thermal expansion. Typical fillers include calcium carbonate, black iron oxide, aluminium oxide, graphite and silicon carbides. Each of these produces different characteristics, thus extending the range of uses of the material.

It should be remembered, however, that whereas an unfilled exopy is normally transparent, allowing inspection of the inner portions of a casting, filled epoxy will not provide this advantage.

For larger castings, filling gives additional advantages as the quantity of high cost epoxy resin may be greatlly reduced by careful choice of a suitable filler.

ADHESIVES

The introduction of epoxy resins has produced a revolution in the arts of joining and fastening. The resinous adhesives are replacing welding, soldering, brazing, rivets and even nails and the epoxies are leading the way. They form powerful bonds between metals, glass, ceramics, polyesters, phenolics, cloth, paper and many other materials. A few materials are not bonded effectively with epoxies, and are listed here to serve as a warning. They are the crystalline and less polar plastics, polyethylene, silicones, fluorocarbons, plasticized vinyl chloride and butyl rubber. Use is made of this property by employing silicone greases as release agents for moulds being used for casing epoxies. In some cases, complete moulds are being made from butyl rubber compounds thus preventing the occurrence of mould release problems.

Unlike the phenolics and some other resinous adhesives, the epoxies cure without releasing water or other condensation by-products, making it possible to bond the epoxies at only contact pressures, or with no pressure at all. The epoxy adhesives better resistance to moisture places them well ahead of adhesives based on proteins, starches, dextrins, gums and polyvinyl alcohol, while their resistance to solvents is also outstanding.

The properties of epoxy adhesives can be changed as can be those of epoxy resins. The same basic methods are used:

(a) Selection of base resin and curing agent;
(b) Alloying the epoxy with another resin;
(c) Compounding with fillers.

Addition of a liquid modifier usually brings about a reduction in viscosity and hence better wetting, but there is some impairment of strength. In many formulations, unmodified and modified liquid epoxies are blended.

By choice of a curing agent it is possible to obtain an adhesive to cure at a predetermined temperature. However, to obtain a 'Room Temperature Cure' difficulty may be encountered, since the glue-line is ordinarily thin and the heat developed by the curing reaction is largely conducted away into the materials being bonded. To overcome this, the faster acting hardeners such as the aliphatic amines (e.g., tetraethylenepentamine) are used.

'One component adhesives' are based on curing agents that do not react at room temperature, but are activated when heated to the 200 to 400 degrees F range.

Fillers often improve the shear strength of the bond, when added in moderation. Reduced shrinkage and thermal expansion account in part for their beneficial effect. Experiments have shown aluminium and aluminium oxide to be especially desirable. See Table 3.

For highest bond strengths, the surfaces to be bonded must be chemically clean. Particular attention should be paid to the possible presence of any of the materials mentioned earlier to which epoxy resin will not adhere.

TYPICAL USES OF EPOXY RESIN

In Table 1 we saw various applications of epoxy resin. These and many others cover an extremely wide range from its use as an adhesive in the assembly of miniature semi-conductor components to its use as an adhesive used for splicing together 30 feet lengths of prestressed concrete piles for the support of electrical transmission line towers. Using exopy resin mixes, micro-miniature solid state circuits are being encapsulated with no other means of support or protection. High voltage (100kV) transformers impregnated with epoxy resins even have the output leads insulated with exopy resin. Large, complicated castings are often avoided by using smaller simple castings cemented together using epoxy adhesives. In the automotive and aircraft industries, steel up to 0.040 inches and aluminium up to 0.060 inches thick are being formed using epoxy-faced forging dies. Due to its high stability, resistance to corrosion and reduced weight, epoxy resin is being used for a large variety of master gauges, inspection tools, prototype models and secondary tools. Alterations to prototype dies can be made at only

TABLE 2: CHANGE OF PROPERTIES DUE TO THE USE OF A POLYSULPHIDE MODIFIER

	Polysulphide LP-3	LP-3/EXPOXY RATIO 3/1	2/1	1/1	1/2	Epoxy Resin
Elongation, %	200	100	50	30	10	—
Hardness (Shore A)	35	50	70	95	98	100
Volume shrinkage, %	5	2.5	2.8	3.5	4.5	6
Dielectric constant at 1 mega Hertz	7.5	6.5	5.5	4.0	3.8	3.5
Volume resistivity megohms/cm	10^3	10^4	10^5	10^6	10^7	10^8

TABLE 3: CHANGE OF PROPERTIES DUE TO FILLERS

Filler	Amount phr	Coefficient of Thermal Expansion x 10^6 per °C	Shear strength psi. Room Temp.	135°F
None	—	65.0	1030	1205
Aluminium dust	40	61.1	2525	3725
Aluminium oxide	50	55.7	3615	3600
Mica powder	14	49.7	2360	2815
Silica	90	43.8	1460	1225
Talc	60	45.4	2650	2655

Notes: 1. The resin formulation was:
75 parts Epon 834
25 parts Epon 562
10 parts DMP-30
2. Specimens were cured for 16 hours at 135 degrees F.

a fraction of the cost involved in similar operations on metal dies.

In Australia, the P.M.G.'s Department is using epoxy resin in many different ways, the majority of which are associated with external plant.

Prior to placing a multi-pair cable in a cable duct, it is necessary to attach a hauling rope to the cable to draw it through the duct. This task is now aided by epoxy resin. In the cable factories, a hauling eye is bonded to the cable with epoxy resin. The eye includes a wiring reinforcing cage soldered onto the lead sheath and cast into the resin thus preventing cracking at the junction of the resin and the sheath. See Fig. 6.

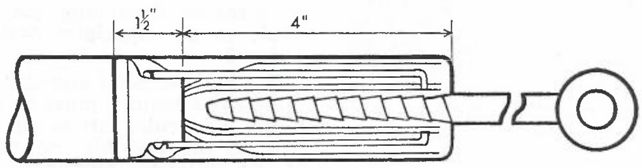


Fig. 6 — Construction of a Bonded Hauling Eye.

The specified minimum strength of this type of hauling eye is:
(a) ½ inch eyebolt — 7,000 pounds
(b) ¾ inch eyebolt — 18,000 pounds

The introduction into service of small sized plastic cables for Departmental applications brought with it the need for effective methods to seal joints and to repair the moisture-proof damaged cables. Solutions using epoxy resins have been developed and introduced into service. Field packs have been developed which allow successful use of epoxy resins by adequately trained linemen and cable jointers in the field.

Experiments in 1954-56 resulted in successful design of cable terminations cast into a single unit for cables ranging in size from 2 pair to 200 pair cables. The smaller units are mounted in sheetmetal or cast aluminium alloy boxes and are used to connect aerial lines to cables. The 50, 100 and 200 pair units are mounted in pillars and cabinets where provision is made for jumper wires to be run between any two cable pairs as required. This gives greater flexibility in the cable network.

The modern trend to pressurize cables for added protection and detection of faults required gas seals to be placed at the ends of all cables concerned and at strategic positions along the cables to isolate sections. Fig. 7 shows a sectional view of a gas pressure seal in a length of lead-covered cable.

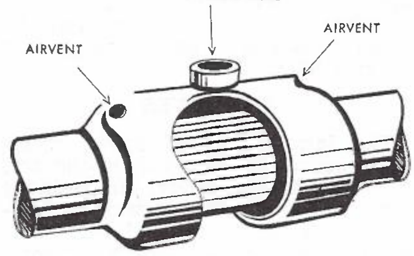


Fig. 7 — Gas Seal.

For large sized plastic and moisture-barrier sheathed cables, new jointing techniques are being investigated and a typical joint for this purpose is shown in Fig. 8. The figure shows the use of an aluminium foil band bonded to the outside of the sheath to ensure satisfactory adhesion of the epoxy resin.

Epoxy resin joints enabled satisfactory jointing of a 74 pair 10 lb. per mile polythene sheathed submarine cable installed by the P.M.G.'s Department between Cleveland and Dunwich across Moreton Bay in Queensland (Ref. 1).

In this case, the joints were not only required to prevent water entering the cable, but in the event of major mechanical damage occurring to the cable, the joint had to provide a barrier to prevent water in one cable passing to another one. High tensile strength was also required as the resin was used to bond together the armour wires of each of the two cable ends and to produce a union at least equal to the strength of the cable itself.

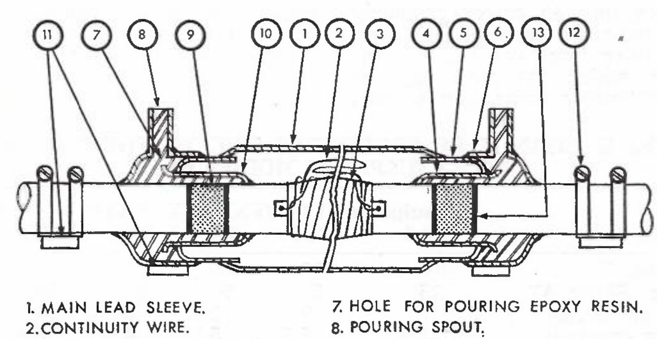
The installation of another similar submarine cable, in this case between Townsville and Magnetic Island, involved a distance of approximately 5.5 miles. Final jointing of this cable was also sealed using epoxy resins (Ref. 2).

SAFETY PRECAUTIONS

In many industrial operations today, the operator has to be protected against contact dermatitis. This danger, whilst being no greater with epoxy resins than many other compounds being used, is none the less very real.

The liquid epoxide resins, curing agents and formulated resin compositions incorporating curing agents or reactive diluents are primary skin irritants. When in contact with the skin for a sufficient period of time, these materials are capable of producing contact dermatitis in most individuals.

To prevent such ill effects, recommended working precautions generally aim to protect the operator from direct contact with the materials and vapours during handling, mixing and while the resin is curing. The prescribed precautions will of course depend upon the type of application, the time of exposure and the working situation, but generally the use of disposable gloves is essential, aprons and long sleeves desirable, and good ventilation must be provided to remove the vapours. Non-abrasive soap and



1. MAIN LEAD SLEEVE.
2. CONTINUITY WIRE.
3. WRAPPED CONDUCTOR JOINT.
4. AUXILIARY LEAD SLEEVE.
5. LEAD BASE.
6. LEAD MOULD.
7. HOLE FOR POURING EPOXY RESIN.
8. POURING SPOUT.
9. EPOXY RESIN.
10. BREATHING HOLE.
11. CABLE BEARERS.
12. CABLE CLAMP.
13. ALUMINIUM FOIL.

Fig. 8 — Epoxy-resin Joint in Moisture-barrier Polythene Sheathed Cable.

water is effective in removing accidental contamination and a high standard of personal hygiene is advised. Some authorities recommend the application of protective cream and skin lotions though it is generally accepted that prompt and thorough washing is the best insurance against skin irritation of the exposed parts which may have become accidentally affected.

Workers having dark complexions are reputedly more resistant to contact chemical dermatitis. However, it is not possible to identify in advance the individuals in any group who are predisposed to allergy in work with epoxy resins, and who, after displaying dermatitis, may have to be transferred temporarily from the exposure area. It is because of the possibility of producing contact dermatitis and a superimposed allergic dermatitis in hypersensitive workers that protection of the skin is imperative for all workers and compromises cannot be allowed.

CONCLUSION

Since the introduction of epoxy resins to general industry in 1950, uses have been found for them in almost every conceivable field and it is likely that the range of uses will expand to cover applications not at present visualised.

Epoxy resin is not the final answer to every problem encountered in industry (or the home) today, but it does provide a more than satisfactory solution to many problems which had been intractable before the advent of this material.

ACKNOWLEDGMENT

The personal advice received from Mr. H. J. Ruddell, P.M.G. Research Laboratories, Melbourne, and Mr. C. Maclaggan, of Tellec Pty. Ltd., Burwood, is gratefully acknowledged.

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TECHNICAL NEWS ITEM

FIRE PROTECTION OFFICERS COURSE

The first formal course in the principles and practice of Fire Protection ever conducted in Australia was held over the period 2nd June-29th June, 1968. The Australian Post Office joined with the Country Fire Authority of Victoria in jointly sponsoring the course — a fully residential one of four weeks duration. The course was conducted under the Statutory Authority of the Country Fire Authority of Victoria with the Post Office providing the Course management and a joint Director of Studies in addition to students drawn from the Fire Protection units of the Engineering Division in all States and Headquarters. Other organisations from which course students were drawn were:—

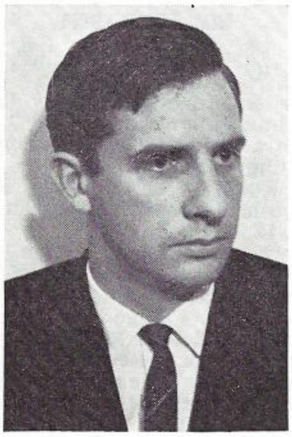
Country Fire Authority of Victoria.
West Australian Fire Brigade.
Northern Territory Fire Brigade.
Commonwealth Department of Works.
Imperial Chemical Industries of Australia and New Zealand Ltd.

The official opening by Hon. Sir Arthur Rylah, Chief Secretary, Victoria was conducted at Panorama House, Kalorama on Monday 3rd June. Sir Arthur Rylah was supported by Mr. B. F. Jones, Deputy Director-General. The first two weeks consisted of lectures and syndicate discussion work led by experts in many aspects of Fire Protection drawn from many organisations throughout Australia and New Zealand. For the third week all students travelled to Sydney for lectures on the physics and chemistry of combustion and the general effects of fire on building constructions. This unit of the course was based at the Commonwealth Building Experimental Research Station at Ryde, and included visits of inspection to several high rise buildings and Port installations for the purpose of studying major Fire control systems.

Upon return to Melbourne a further series of lectures and Syndicate discussion work culminated in a three hour examination. Six distinctions were awarded from amongst the twenty-nine students. Three of these gained by Fire Protection Officers of the Post Office. Additionally, an A.P.O. Fire Protection Officer received the honour of being Dux of the Course. The course was officially closed on Friday 28th June after the reading of the final paper 'The Importance of the Fire Protection Officer to Australia' by Mr. E. Sawkins, Deputy Director-General.

Senior Officers of the Australian Post Office were presented at the closing session. Chief Officer A. G. Pitfield of the Country Fire Authority presented the awards and the closing address was delivered by Mr. R. T. Eason, Chairman of the Country Fire Authority.

OUR CONTRIBUTORS



K. A. ENDACOTT

A. TRAILL

A. KELLOCK

K. A. ENDACOTT, author of the article 'P.C.M. Radio Relay Systems', joined the Postmaster-General's Department in 1958 after completing a Diploma of Electrical Engineering at the Caulfield Technical College. In 1959 he completed a Bachelor of Engineering at the University of Melbourne. After one year attached to Country Branch, Victoria, he was appointed an Engineer Class 2 in Radio Section, Headquarters, where for three years he was engaged in the design of MF and HF broadcasting antenna systems. Since 1964 he has been involved in the design of radio relay systems including the East-West Broadband Radio Relay System. He has also been responsible for the application of computers to radio design work and is currently in charge of a division concerned with the specification of radio relay equipment. Mr. Endacott is an Associate Member of the Institution of Electrical Engineers.

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A. TRAILL, co-author of the article 'Modern Methods of Meeting the Increasing Demand for Trunk Circuits', joined the Post Office as a Cadet Engineer in 1950 while he was undertaking a course in Electrical Engineering at the University of Tasmania. He received his B.E. degree in 1953. With the exception of a 12 months period in 1957 when he was awarded a Scholarship in Telecommunication Engineering at Coventry, England, he has been employed in the Tasmanian Planning Section since its inception in 1956. He was appointed Divisional Engineer, Transmission and Line Planning, in May, 1962, and as such is responsible for the planning of the Tasmanian Trunk network. He is an Associate Member of the Institution of Engineers, Australia, and is currently Chairman of the Tasmanian Electrical and Communications Branch of the Institution.

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A. KELLOCK, co-author of the article 'Modern Methods of Meeting the Increasing Demand for Telephone Trunk Circuits', entered the Postmaster-General's Department in 1941 as a Clerk and was appointed Cadet Engineer in 1944, qualifying as Engineer in 1947. His early experience was in District Works in Victoria until his transfer to Long Line Equipment Section, Headquarters, in 1952. In 1956 he was seconded as full-time General Secretary of the Professional Officers' Association, resuming with the Department in 1959 to take up duty as Liaison Engineer in the London office. Since his return to Australia in 1963 he spent two years on material specification and testing and has been Sectional Engineer, Plan Development, in the Transmission and Line Planning Section since 1965. Early in 1968 he spent 10 weeks overseas studying various transmission aspects, particularly the use of satellites for domestic communications. He is an Associate Member of the Institution of Engineers, Australia.

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I. G. COOK, author of the article 'Trunk Circuit Testing in the S.T.D. Network', is an Engineer Class 2 in the Installation and Service Standards Sub-section of the Telephone Exchange Equipment Section at Headquarters. He joined the Postmaster-General's Department in Western Australia as a Cadet Engineer in 1955. After qualifying for his Bachelor of Engineering Degree in 1958 he was appointed as a Grade 1 Engineer in Central Division in Perth. In 1960 he was appointed Engineer Class 2 in the Telephone Exchange Equipment Section, Headquarters, where since 1962 he has been involved in the development of installation and maintenance techniques for crossbar equipment.

I. G. COOK

C. W. PRATT, author of the paper 'Slide Rule Compound Growth Calculations', joined the Postmaster-General's Department as a Cadet Engineer on Matriculation, and took degrees of Bachelor of Engineering, Bachelor of Science and Master of Engineering Science at the University of Queensland. He spent two years in London (1961-63) as a Public Service Board Scholar carrying out research in queueing and congestion problems in telephone networks; this work led to the degree of Doctor of Philosophy. Since 1963 he has spent two years in the Planning Branch of the Victorian Administration, and for the last two years he has been Traffic Research Engineer in the Headquarters Planning

C. W. PRATT

D. D. MATTISKE

M. J. DAWKINS

Branch where he has also helped to conduct two courses in Telephone Traffic Engineering. He represented the Australian Post Office at the Fifth International Telegraph Congress in New York, June 1967.

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V. F. FINDLOW

V. F. FINDLOW, author of the article 'Service Assessment Equipment — Circuit Operation', entered the Postmaster-General's Department in 1942 as a Technician-in-Training. He served in metropolitan telephone exchanges in Melbourne on maintenance work as a Senior and Supervising Technician until 1956 when he qualified as an Engineer. After further experience with the Victorian Administration on exchange installation and internal plant planning, he transferred in 1961 to the Telephone Exchange Equipment Section at Headquarters. For the past seven years he has occupied his present position of Engineer Class 3 responsible for the circuit design of trunk and country equipment in the Circuit Standards Subsection.

D. D. MATTISKE, author of the article, 'ARK-M Exchanges', joined the Department in 1957 as a Cadet Engineer and attended the University of Adelaide where he completed the degree of Bachelor of Engineering. On graduation he was appointed, in March 1961, to the position of Engineer Grade 1 in the South Australian Country Branch at Whyalla. In March 1964 he took up an Overseas Fellowship with A.E.I. (Woolwich) Ltd. in London, where he studied development techniques in exchange and transmission equipment and spent some time at Leighton Buzzard where the British Post Office installed an electronic exchange. After a brief visit to L. M. Ericsson in Stockholm, Sweden, Mr. Mattiske returned to Australia to take up a position as Engineer Class 2, Switching Systems Design in Central Office. Since February 1968, he has occupied the position of Engineer Class 3, Crossbar Development, in the P.M.G. Research Laboratories.

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A. H. FREEMAN, author of the article, 'Network Design for S.T.D.', joined the P.M.G.'s Department in 1938 as a cadet draftsman in Sydney and was appointed as engineer in the buildings division in 1946. Between 1956 and 1965 he worked in the N.S.W. transmission planning section and during this period participated in the development of switching and transmission plans for Sydney and the N.S.W. trunk network. This work included the COMET project which employed an electronic computer for investigating the costs of various tandem layouts in the Sydney network. In 1964 he was an A.P.O. delegate at the 4th International Teletraffic Congress in London and presented a paper on the results of that study. Since January 1966 he has held the position of Supervising Engineer, Trunk Service and Telegraphs, N.S.W.

M. J. DAWKINS, author of the article 'Applying Epoxy Resins', was educated at Colac High School and joined the Postmaster General's Department as a Technician-in-Training in 1948. Qualifying as a Senior Technician in 1954 he joined the Material Testing Division where, as a result of his duties he came in contact with some of the production problems associated with epoxy resin cable terminations. In 1963 Mr. Dawkins transferred to the Technicians School, Melbourne, as a Technical Instructor, Grade 2. In 1967 he was promoted to Technical Officer, Grade 2, and moved to the Traffic Engineering (Metropolitan) Division. As a result of part-time studies, Mr. Dawkins completed an Associateship in Communications Engineering in November, 1967. In February, 1968, he resigned from the Department to join I.C.I.A.N.Z., where he is currently employed as Instrument Engineer at their Central Research Laboratories, Melbourne. Mr. Dawkins is a Student Member of the Institution of Engineers, Australia.

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A. H. FREEMAN

ANSWERS TO EXAMINATION QUESTIONS

Examinations Nos. 5785 to 5794; 29th June 1968 and subsequent dates to gain part of the qualification for promotion or transfer as senior technician (telecommunications), Postmaster-general's Department.

TELECOMMUNICATION PRINCIPLES

QUESTION 1. (a).

A battery of voltage E is connected across a resistor R and current of I amps flows in the circuit.

(i) Express the value of I in terms of R and E, and calculate the percentage change in I when E is reduced by 33⅓ per cent and R is reduced to 75 per cent of its original value.

(ii) Express in terms of R and E the power (P) which is dissipated in the resistor, and calculate the percentage change in P when the circuit conditions are changed as in (i).

ANSWER 1. (a).

(i)

Original current $I_o = E/R$

When the circuit conditions are changed E becomes $\frac{2}{3}$E, and R becomes $\frac{3}{4}$R

$$\text{New current } I_N = \frac{2E}{3} \div \frac{3R}{4} = \frac{2E}{3} \times \frac{4}{3R} = \frac{8E}{9R}$$

$$\text{Percentage change} = \frac{I_o - I_N}{I_o} \times \frac{100}{1} = \left(1 - \frac{I_N}{I_o}\right) \times 100 = \left(1 - \frac{8E}{8R} \times \frac{R}{E}\right) \times 100 = \left(\frac{9-8}{9}\right) \times 100 = \frac{100}{9} = 11\tfrac{1}{9}\%$$

(ii)

$$\text{Original power dissipated } P_o = \frac{E^2}{R}$$

$$\text{New power dissipated } P_N = \left(\frac{2E}{3}\right)^2 \div \frac{3R}{4} = \frac{4E^2}{9} \times \frac{4}{3R} = \frac{16E^2}{27R}$$

$$\text{Percentage change} = \frac{P_o - P_N}{P_o} \times \frac{100}{1} = \left(1 - \frac{P_N}{P_o}\right) \times 100 = \left(1 - \frac{16E^2}{27R} \times \frac{R}{E^2}\right) \times 100 = \left(\frac{27-16}{27}\right) \times 100 = \frac{1100}{27} = 40{\cdot}7\%.$$

QUESTION 1. (b).

The energy stored in a charged capacitor is represented by the formula:—

Energy = $\frac{1}{2}CE^2$

where C = capacitance, and E = voltage.

Calculate the difference, if any, in the total energy stored in two identical capacitors in the following two conditions:—

(i) two capacitors connected in parallel and charged to voltage E;

(ii) one capacitor is charged to voltage E and then connected in parallel with the second uncharged capacitor.

ANSWER 1. (b).

Let each capacitor = CμF.
Voltage = E volts.

(i) CONDITION 1.
For two capacitors in parallel:—
Total Energy = $2 \times \frac{1}{2}CE^2$
= CE^2 μ Joules.

(ii) CONDITION 2.
One capacitor will hold a charge = CE μ coulombs. When an identical uncharged capacitor is connected in parallel the total charge divides equally and, therefore, the voltage across the parallel combination is halved.

$Q = CE$ (initial condition).

$Q = 2C \cdot \frac{E}{2}$ (final condition).

Total energy stored in the parallel combination.

$$= \tfrac{1}{2}(2C)\left(\frac{E}{2}\right)^2 = \frac{1}{2}\frac{2CE^2}{4} = \frac{CE^2}{4}$$

The difference in total energy stored.
= Condition 1 − Condition 2.
= $CE^2 - \frac{1}{4}CE^2$
= $\frac{3}{4}CE^2$.

QUESTION 2.

In the circuit (Fig. 1), the AA contacts are closed and after a relatively long time interval are opened. With the aid of simplified circuits (omitting springsets) which show the external circuit conditions of the K1 relay, describe the basic principles of the operation and of the release of the differentially wound relay K1.

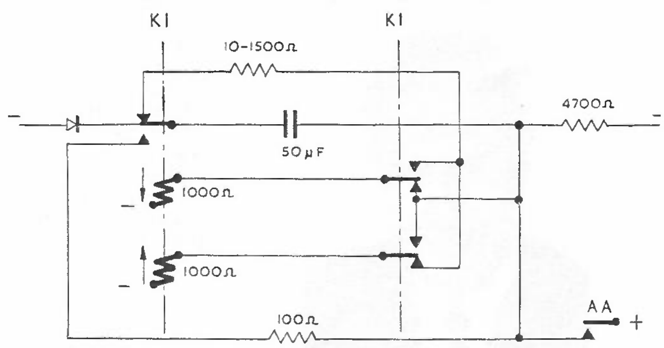


Fig. 1

ANSWER 2.

The question asks for a description of the BASIC PRINCIPLES of the operation and of the release of the K1 relay and is not concerned with other circuit operation details.

Operation. A simplified drawing of the external circuit conditions of the K1 relay in the normal condition is shown in Fig. 2. Immediately contacts AA are closed, current flows in both coils of K1. The flux developed in the upper winding is opposed by the flux developed by the capacitor charging current in the lower winding (the relay being differentially wound). As the capacitor charges, the potential across the plates builds up and opposes the applied potential, so reducing the current and flux in the lower winding. After a time delay, which depends on the value to which the 10–1500Ω resistor has been adjusted, the difference between the values of current in each winding is such that the resultant flux operates the relay. The relay therefore has a timed operation lag.

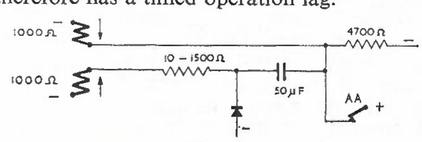


Fig. 2

A rapid discharge path is now provided for the capacitor through the 100 ohm resistor; the capacitor is discharged. (See Fig. 3).

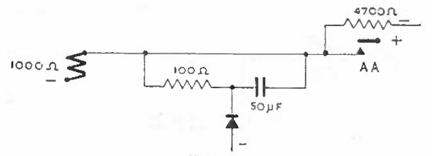


Fig. 3

Release. The external circuit conditions for the release of the K1 relay are shown in Fig. 3. When contacts AA are opened the flux in the operating winding of relay K1 collapses. The collapsing flux induces an e.m.f. in the coil which causes current to flow through the external circuit components which are in parallel to the relay coil. This current prolongs the flux in the coil and the release lag is increased.

QUESTION 3. (a).

The vector diagram of a circuit is shown in Fig. 4, state:—
(i) the components of the circuit;
(ii) how the components are connected;
(iii) what is the reference vector;
(iv) the value of the circuit current.

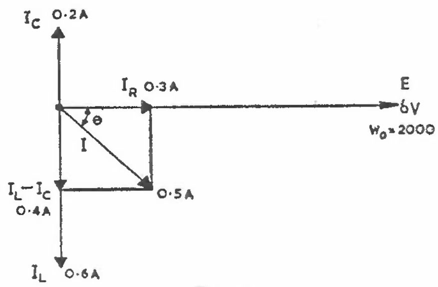


Fig. 4

ANSWER 3. (a).

(i) Resistance, capacitance and inductance.
(ii) In parallel.
(iii) Voltage E
(iv) 0·5 Amps.

QUESTION 3. (b).

Calculate—
(i) the phase angle;
(ii) the power factor;
(iii) the impedance;
(iv) the value of each circuit component;
(v) the angular velocity (Wr), in radians per second, of the frequency at which the circuit is resonant. ($\sqrt{3} = 1{\cdot}732$.)

ANSWER 3. (b).

(i) $\tan\theta = \dfrac{0{\cdot}4}{0{\cdot}3} = 1{\cdot}3333$

$\theta = 53^\circ\ 8'$ lagging.

(ii) Power Factor $= \cos\theta = \cos 53^\circ\ 8' = 0{\cdot}6$.

(iii) $Z = \dfrac{E}{I} = \dfrac{6}{0{\cdot}5}$
$= 12\Omega.$

(iv) $R = \dfrac{E}{I_R} = \dfrac{6}{0{\cdot}3}$
$= 20\Omega.$

$X_L = \dfrac{E}{I_L} = \dfrac{6}{0{\cdot}6}$
$= 10\Omega.$

$L = \dfrac{X_L}{\omega} = \dfrac{10 \times 10^3}{2000}$
$= 5\text{mH}.$

$Xc = \dfrac{E}{Ic} = \dfrac{6}{0{\cdot}2}$
$= 30\Omega.$

$C = \dfrac{1}{\omega Xc} = \dfrac{10^6}{2000 \times 30}\,\mu F$
$= 16{\cdot}7\mu F.$

(v) $Wr = \dfrac{1}{\sqrt{LC}} \qquad L = \dfrac{X_L}{\omega} \qquad C = \dfrac{1}{\omega Xc}$

$$\therefore\ Wr = \frac{1}{\sqrt{\dfrac{X_L}{\omega} \times \dfrac{1}{\omega Xc}}} = \frac{1}{\dfrac{1}{\omega}\sqrt{\dfrac{X_L}{Xc}}}$$
$= \omega\sqrt{Xc/X_L}$
$= 2000\sqrt{30/10}$
$= \sqrt{3} \times 2000 = 1{\cdot}732 \times 2000$
$= 3{,}464$ radians/sec.

Question 4. (a).

Draw the standard symbols and name the electrodes for a P-N-P transistor and a triode electron tube.

ANSWER 4. (a).

See Fig. 5(a).

QUESTION 4. (b).

Electron tube and transistor amplifiers may each have the input and output circuits arranged in three different ways. Name and draw the three basic circuit configurations for both electron tube and P-N-P transistor amplifiers.

ANSWER 4. (b).

See Figs. 5(b), 5(c) and 5(d).

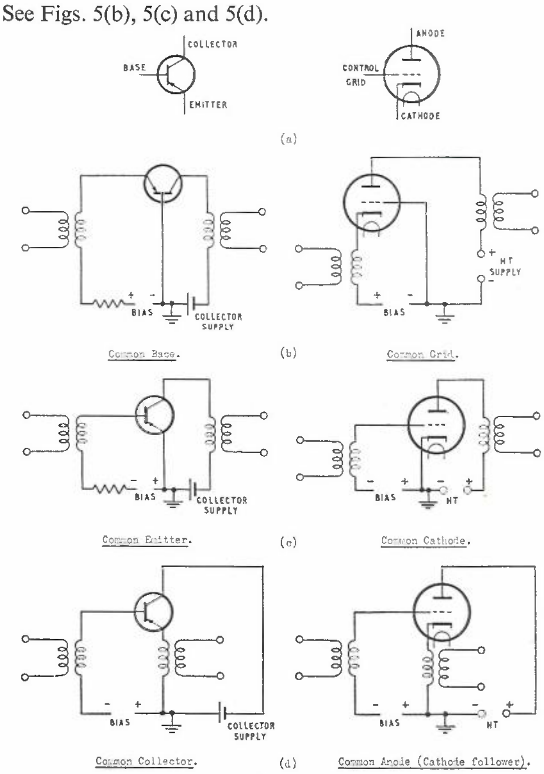


Fig. 5

QUESTION 5. (a).

State the general characteristics of the output voltage of a blocking oscillator. Draw the basic circuit of a free running type of blocking oscillator and sketch the waveform of the output voltage.

ANSWER 5. (a).

A blocking oscillator conducts for a short period of time and is cut off (blocked) for a much longer period. It produces pulses of relatively large amplitude, short duration and having very steep rise and fall. The basic circuit of a free running type of blocking oscillator and a sketch of the typical output voltage is shown in Fig. 6.

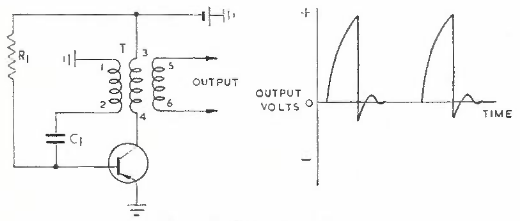


Fig. 6

QUESTION 5. (b).

Given 3 contacts (A1, B1 and C1), a lamp and a battery; draw circuit diagrams which produce:—
(i) an 'OR' gate;
(ii) an 'AND' gate.

ANSWER 5. (b).

See Fig. 7.

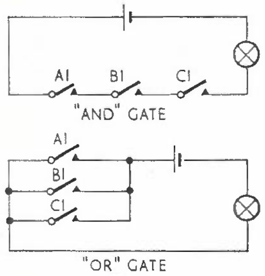


Fig. 7

QUESTION 6. (a).

With the aid of four explanatory diagrams, explain the principle of Thevenin's Theorem.

ANSWER 6. (a).

The network in Fig. 8(a) supplies current to impedance Z_L. With Z_L disconnected the voltage between A and B is E_0, as in Fig. 8(b), and the impedance looking into A and B, with any voltage sources in the network replaced by their equivalent impedances, is Z_0, see Fig. 8(c). The equivalent circuit for the network is then as in Fig. 8(d), with a voltage E_0 being applied to terminals A and B via an impedance Z_0. (See CP 308).

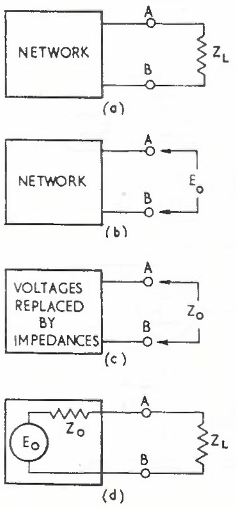


Fig. 8

QUESTION 6. (b).

With reference to the circuit in Fig. 9, apply Thevenin's Theorem to calculate and construct its equivalent circuit and hence calculate:—
(i) the voltage across the capacitor 210mS after the switch is closed (from exponential functions $1 - \varepsilon^{-x}$, voltage on capacitor after 1·75 time constants = 0·8262 of maximum);
(ii) the initial charging current through the capacitor.

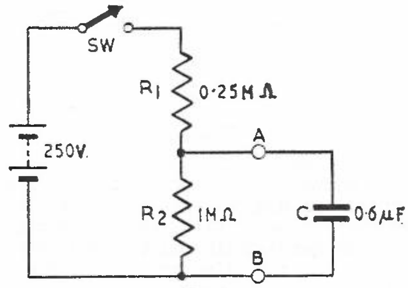


Fig. 9

ANSWER 6. (b).

Voltage across A and B with capacitor disconnected

$$= \left(\frac{1}{1 + 0{\cdot}25}\right) \times 250 = \frac{250}{1{\cdot}25} = 200\text{V}.$$

Resistance of source with battery replaced by a short circuit

$$= \frac{(0{\cdot}25 \times 10^6) \times (1 \times 10^6)}{(0{\cdot}25 \times 10^6) + (1 \times 10^6)} = \frac{0{\cdot}25 \times 10^6}{1{\cdot}25}$$

$= 200\text{k}\Omega$.

The equivalent circuit is as shown in Fig. 10.

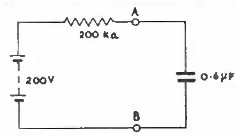


Fig. 10

(i) Time constant of equivalent circuit = CR

$$= \frac{0{\cdot}6}{10^6} \times 200 \times 10^3 \times 10^3 = 120\text{mS}.$$

210mS expressed in time constants $= \frac{210}{120} =$ 1·75 time constants.

= 0·8262 of maximum voltage.

Therefore, Voltage across capacitor = 0·8262 × 200.

= 165·24V.

(ii) From the equivalent circuit, the initial charging current

$$= \frac{E}{R} = \frac{200}{200 \times 10^3} \times 10^3 = 1\text{mA}.$$

QUESTION 7. (a).

Draw a circuit diagram and the vector diagrams which illustrate the NO LOAD condition of a transformer having a turns ratio of 1 : 1.

ANSWER 7. (a).

See Fig. 11.

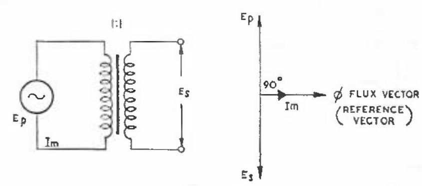


Fig. 11

QUESTION 7. (b).

A transformer is used to operate four 50 volt, 100 watt soldering irons from the 240 volt supply. Neglecting losses, calculate:—
(i) the turns ratio;
(ii) the secondary current;
(iii) the primary current.

ANSWER 7. (b).

Referring to Fig. 12.

(i) Turns ratio $T = \frac{Es}{Ep} = \frac{50}{240}$

$= 1 : 4{\cdot}8.$

(ii) Current in secondary winding $Is = 4 \times \frac{W}{E} = 4 \times \frac{100}{50}$

$= 8$ Amps.

(iii) Primary current $= T \times Is = \frac{1}{4{\cdot}8} \times \frac{8}{1}$

$= 1{\cdot}67$ Amps.

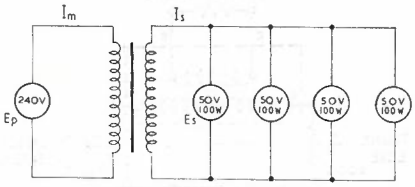


Fig. 12

QUESTION 7. (c).

Explain what is meant by 'reflected impedance' of a transformer.

ANSWER 7. (c).

When the impedance of the secondary load circuit is changed, the subsequent change in secondary current causes a corresponding change in primary current. As this change in primary current is fundamentally due to a change in primary impedance, the change in secondary load impedance causes a proportional change in impedance in the primary winding. This action is commonly called 'reflection', and the impedance of the load as 'seen' by the energy source through the transformation ratio, is referred to as a 'reflected impedance'.

QUESTION 8. (a).

Draw the typical circuit and briefly describe the operation o two diode units when used as a full wave rectifier.

ANSWER 8. (a).

Full wave rectification is obtained using two diode units as shown in Fig. 13. A centre tapped transformer is needed and the alternating voltage across each winding of the transformer must be sufficient to provide the required d.c. output voltage. One diode conducts for each alternate half cycle giving a current through the load in the same direction (− to +) for each half cycle.

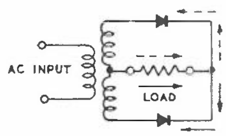


Fig. 13

QUESTION 8. (b).

Sketch the current waveform in the load of the circuit given in (a) above:—
(i) in the absence of any smoothing circuit;
(ii) with a typical capacitor input smoothing circuit.
Sketch and explain the action of the smoothing circuit.

ANSWER 8. (b).

(i) See Fig. 14.
(ii) See Fig. 15.

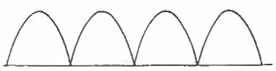


Fig. 14

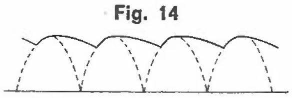


Fig. 15

A sketch of a typical capacitor input smoothing circuit is shown in Fig. 16. The charged capacitor across the output of the rectifier prevents current flow until the voltage reaches that across the capacitor terminals. The rectifier therefore supplies its energy in pulses of short duration. The capacitor C1 discharges to the load between the charging pulses from the rectifier and the output voltage waveform is as shown in Fig. 15.

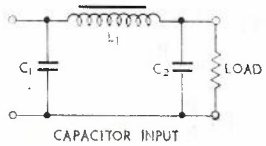


Fig. 16

QUESTION 9. (a).

Solve the equations for x:—
(i) $5(x - 2) - 3(x + 4) = \frac{3}{4}$;
(ii) $\log(10 + 9x) - \log(11 - x) = 2$;
(iii) $(25x - 41)^2 = 81$.

ANSWER 9. (a).

(i) Removing brackets:—

$5x - 10 - 3x - 12 = \frac{3}{4}$
$2x - 22 = \frac{3}{4}$
$2x = 22\frac{3}{4}$
$x = 11\frac{3}{8}.$

(ii) $\log(A) - \log(B) = \log\left(\frac{A}{B}\right)$

and

$\log(10 + 9x) - \log(11 - x) = \log\left(\frac{10 + 9x}{11 - x}\right)$

Therefore, $\log\left(\frac{10 + 9x}{11 - x}\right) = 2$

and $\frac{10 + 9x}{11 - x} = \text{antilog } 2$

$= 100$
$10 + 9x = 1100 - 100x$
$109x = 1100 - 10$
$= 1090$
$x = 10.$

(Examiners Note:—

A number of candidates made the error of treating the equation as a simple algebraic expression involving brackets—thus:—

$\log(10 + 9x) - \log(11 - x) = 2$
$10 + 9x - 11 + x = \text{antilog } 2 = 100$
$10x - 1 = 100$
$x = 10{\cdot}1$

OR

$\log(10 + 9x) - \log(11 - x) = 2$
$\log 10 + \log 9x - \log 11 + \log x = 2.$
$-\log 1 + \log 10x = 2$
$-1 + 10x = \text{antilog } 2 = 100$
$x = 10{\cdot}1.$

It should be carefully noted that both the examples above are INCORRECT.)

(iii) Taking the square root of both sides of the equation

$25x - 41 = \sqrt{81} = \pm 9$
$25x = 41 + 9 = 50.$
$x = 2.$

(The answer for -9 was not required, but gives $x = 1\frac{7}{25}$).

QUESTION 9. (b).

Express:—

(i) $\log\left(\frac{xy}{z}\right)$ *in terms of log x, log y and log z;*

(ii) P_1 *in terms of* P_2 *and N, when given that* $N = 10 \log \frac{P_1}{P_2}$;

(iii) 126 microwatts in dBm;
(iv) the decimal number 47 as a binary number;

(v) tan θ in terms of t, when given that $\sin\theta = \dfrac{1 - t^2}{1 + t^2}$,

$$\cos\theta = \frac{1 + t}{1 + t^2},$$

ANSWER 9. (b).

(i) $\log x + \log y - \log z$

(ii)
$$N = 10 \log \frac{P_1}{P_2}$$
$$\frac{N}{10} = \log \frac{P_1}{P_2}$$
$$\text{antilog} \frac{N}{10} = \frac{P_1}{P_2}$$
$$P_1 = P_2 \text{ antilog} \left(\frac{N}{10}\right).$$

(iii) $N \text{ dBm} = 10 \log \dfrac{P_1}{P_2}$

As 126 microwatts is less than 1 milliwatt, $P_1 = 1$

$$\therefore\ N = -10 \log \frac{1}{P_2} = -10 \log \frac{1}{0{\cdot}126}$$
$$= -10 \log 7{\cdot}9343.$$
$$= -10 \times 0{\cdot}90$$
$$= -9\text{dBm}.$$

(iv)
$$47 = 32 + 0 + 8 + 4 + 2 + 1$$
$$= 1 \times 2^5 + 0 \times 2^4 + 1 \times 2^3 + 1 \times 2^2 + 1 \times 2^1 + 1 \times 2^0$$
$$= 101111.$$

(v)
$$\tan\theta = \frac{\sin\theta}{\cos\theta} = \frac{\sin\theta}{1} \times \frac{1}{\cos\theta}$$
$$= \frac{1 - t^2}{1 + t^2} \times \frac{1 + t^2}{1 + t}$$
$$= \frac{1 - t^2}{1 + t}$$
$$= \frac{(1 - t)(1 + t)}{1 + t}$$
$$= 1 - t.$$

QUESTION 10. (a).

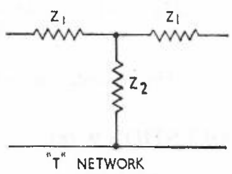
State what is meant by the Characteristic Impedance (Zo) of a transmission line. Illustrate your answer, by drawing the equivalent 'T' Network of a line and calculate the value of Zo in the terms of the impedance shown in the 'T' Network. Show all working.

ANSWER 10. (a).

For every type of transmission line, irrespective of length, there is a particular value of impedance, which when used to terminate the line, results in a maximum transfer of power from the signal source to the terminating equipment, and a minimum reflection of energy. This value of impedance is individual to the particular type of line construction and is termed the 'characteristic impedance' (Zo) of the line.

The equivalent 'T' Network of a line is shown in Fig. 17.

$$Zo = \sqrt{Zoc \times Zsc}$$
$$Zoc = Z1 + Z2$$
$$Zsc = Z1 + \frac{Z1 \times Z2}{Z1 + Z2}$$
$$Zo = \sqrt{(Z1 + Z2)\left(Z1 + \frac{Z1\,.\,Z2}{Z1 + Z2}\right)}$$
$$= \sqrt{Z1^2 + \frac{Z1^2\,.\,Z2}{Z1 + Z2} + Z1\,.\,Z2 + \frac{Z1\,.\,Z2^2}{Z1 + Z2}}$$
$$= \sqrt{Z1^2 + Z1\,.\,Z2 + Z1\,.\,Z2\left(\frac{Z1 + Z2}{Z1 + Z2}\right)}$$
$$= \sqrt{Z1^2 + 2Z1\,.\,Z2}.$$



"T" NETWORK
Fig. 17

QUESTION 10. (b).

Draw a simplified circuit of an unbalanced hybrid coil, representing the amplifier connections, trunk line and balance network by appropriate impedances. Show relative values of the impedances for a trunk line impedance of 600 ohms. State the modifications required to your circuit to produce the balanced type of hybrid coil.

ANSWER 10. (b).

See Fig. 18.

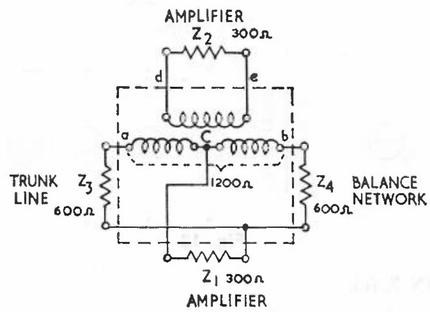


Fig. 18

In the balanced type of hybrid coil, the windings are divided into two halves, one half of the winding being in each side of the line to preserve balanced impedance conditions for cross-talk considerations as shown in Fig. 19.

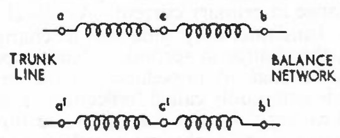


Fig. 19

QUESTION 11. (a).

Draw a block diagram of a cathode ray oscilloscope which shows the arrangement of its cathode tube, sweep generator, amplifiers, power supply and the main terminals for the connection of external voltages.

ANSWER 11. (a).

See Fig. 20.

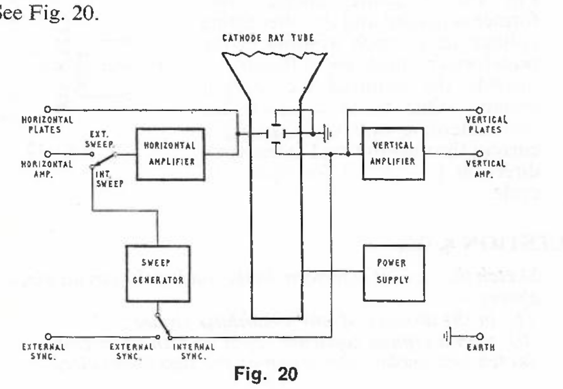


Fig. 20

QUESTION 11. (b).

Briefly describe the main principles of the operation of the following major components of the C.R.O.:—
(i) Sweep Generator
(ii) 'Y' Amplifier.

ANSWER 11. (b).

(i) This is a variable frequency oscillator from which the 'sweep voltage' for the horizontal deflection of the electron beam is derived. The sweep voltage has a saw tooth wave form so that the electron beam is swept across the screen at uniform speed. Coarse and fine frequency controls enable the sweep frequency to be the same as, or a sub-multiple of, the frequency of the voltage applied to the vertical deflection plates.

(ii) The vertical or 'Y' amplifier amplifiers the voltage to be applied to the vertical deflecting plates to a value sufficient to obtain the desired vertical deflection of the electron beam. The gain must be controlled over a very wide range of voltages usually with the aid of a stepped attenuator as the 'coarse' control, and a continuously variable 'fine' gain control.

QUESTION 12. (a).

State four reasons why D.C. power supplies always have one pole connected to earth. State which pole is earthed, and give reasons, in the following installations:—

(i) 50V main battery of telephone exchanges;
(ii) 130V supply at long line stations;
(iii) 24V supply at long line stations.

ANSWER 12. (a).

D.C. power supplies always have one pole connected to earth for the following main reasons:—

1. For conductors above earth potential, fusing and switching may be single pole.
2. To ensure prompt indication of insulation faults and assist in locating them.
3. To prevent the risk of crosstalk and other disturbances arising from foreign currents in leakage or capacity unbalance paths.
4. Lead cable sheaths may be used as earth return for P.B.X. power leads.
5. Earth return signalling possible on some types of junction lines.
6. Enables identification of separate wires of a pair away from the exchange by earth potential method.
   (i) Positive pole earthed—minimises troubles from the corrosive electrolytic effects of leakage currents; also partial earth faults show up more definitely.
   (ii) Negative pole earthed—for the functioning of electron tubes an anode supply with the positive pole well above earth potential is required.
   (iii) Positive pole earthed—to raise the effective anode to cathode potential for electron tubes; also to operate relays with minimum electrolytic corrosion troubles.

QUESTION 12. (b).

Draw a simplified (typical) circuit of a single stage magnetic amplifier.

ANSWER 12. (b).

See Fig. 21.

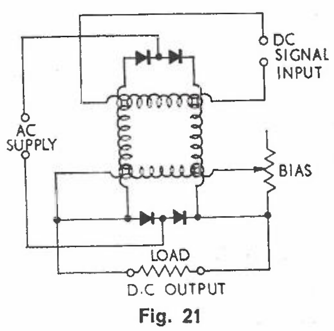


Fig. 21

QUESTION 13. (a).

The circuit shown in Fig. 22 is a differentiating circuit with a sine wave input. The output is a cosine wave.
The differentiation of cos θ is − sin θ. In the space below sketch the differentiated output of a sine wave and of a cosine wave.

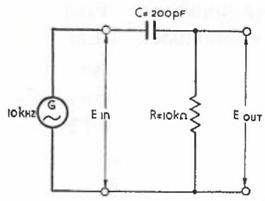


Fig. 22

ANSWER 13. (a).

See Fig. 23.

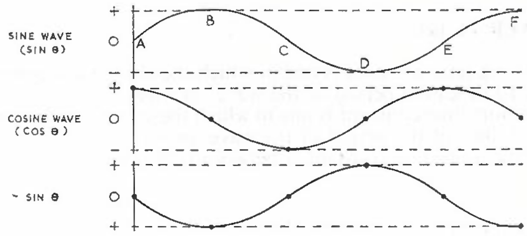


Fig. 23

QUESTION 13. (b).

With reference to the circuit above:—

(i) draw its vector diagram;
(ii) calculate the phase angle;
(iii) calculate the time constant of the circuit;
(iv) state the relationship between variations in the time constant of the circuit with:—
1. phase shift;
2. output voltage;
(v) calculate the ratio of the output and input wave amplitudes.

ANSWER 13. (b).

(i) See Fig. 24.

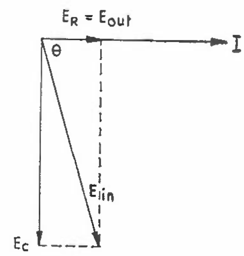


Fig. 24

(ii) $$Xc = \frac{1}{2\pi fc} = \frac{10^{12}}{6{\cdot}28 \times 10^4 \times 200} = 80{,}000\Omega$$

$$Ec = I \times 8 \times 10^4 \text{ volts.}$$
$$Eout = E_R = I \times 10^4 \text{ volts.}$$
$$\text{Tan } \theta = \frac{Ec}{E_R} = \frac{I \times 8 \times 10^4}{I \times 10^4} = 8{\cdot}0.$$
$$\theta = 82^\circ\ 54' \text{ Eout leading Ein.}$$

(iii) $$\text{Time Constant } T = CR = \frac{200}{10^{12}} \times 10^4 \times 10^6 = 2\mu S.$$

(iv) $$\theta \propto \text{Tan } \theta \propto \frac{Ec}{E_R} \propto \frac{I\,.\,Xc}{IR} \propto \frac{1}{\omega CR} \propto \frac{1}{CR} \propto \frac{1}{T}$$

1. Therefore, as time constant is reduced, phase shift increases and becomes closer to the ideal (90°).
2. Also, as time constant is reduced, the output voltage (E_R) is reduced since $\frac{1}{E_R} \propto \frac{1}{T}$.

(v) $\frac{\text{Output wave amplitude}}{\text{Input wave amplitude}} = \frac{\text{Eout}}{\text{Ein}}$

$= \cos\theta$ (from the vector diagram)

$= \cos 82^\circ 54'$

$= 0{\cdot}124.$

QUESTION 14. (a).

State in terms of the period of a wave, the way in which the variations in long, short and medium time constant circuits are described.

ANSWER 14. (a).

A long time constant is one in which the charging is completed in 10 times the period of the wave, or more.
A short time constant is one in which the charging is completed in 1/10th of the period of the wave, or less.
A medium time constant is between these values.

QUESTION 14. (b).

With reference to the circuit shown in Fig. 25 which shows a rectangular wave input to the circuit, complete the diagrams below to show the wave shapes across the output terminals e_C and e_R.

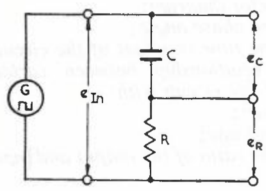


Fig. 25

ANSWER 14. (b).

See Fig. 26.

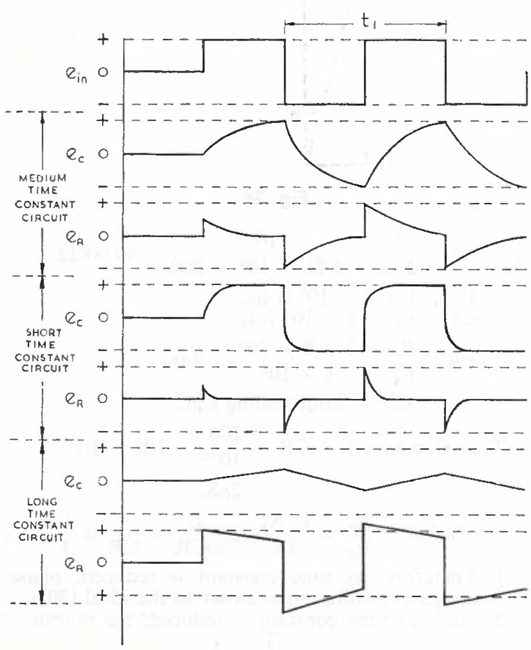


Fig. 26

Examination Nos. 5801–5805, 20th July, 1968 and subsequent dates to gain part of the qualifications for promotion or transfer as Technician (Telecommunications), Postmaster-General's Department.

SECTION A

QUESTION 1. (a).

A 50 Volt battery with no internal resistance is connected across the terminals of Fig. 1. What is the potential difference (p.d.) across the resistor R2 when the switch contacts are open?

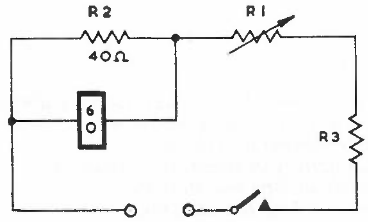


Fig. 1.

ANSWER 1. (a).

Zero, because there is no current through R2.

QUESTION 1. (b).

Calculate the value to which R1 must be adjusted so that the power used by the relay when the switch is closed is 0·6 watts.

ANSWER 1. (b).

$$\text{E across Relay} = \sqrt{\text{P} \times \text{R}} = \sqrt{0{\cdot}6 \times 60} = 6\text{V}$$

$$\text{I through Relay} = \frac{\text{E}}{\text{R}} = \frac{6}{60} = 100\text{mA}$$

$$\text{I through R2} = \frac{60}{40} \times 100 = 150\text{mA}$$

$$\text{E(R3)} = \text{I} \times \text{R} = 250 \times 76 \times 10^{-3} = 19\text{V}$$

$$\text{E(R1)} = 50 - (19 + 6) = 25\text{V}$$

$$\text{R1} = \frac{25 \times 1000}{250} = 100\Omega.$$

QUESTION 1. (c).

The resistor R2 has a power rating of 3 watts. Determine whether this rating would be exceeded if R1 becomes short-circuited.

ANSWER 1. (c).

$$\text{Joint R} = \frac{60 \times 40}{60 + 40} = 24\Omega$$

$$\text{E(R2)} = \frac{\text{Rj}}{\text{Rj} + \text{R3}} \times E$$

$$\text{E(R2)} = \frac{24}{24 + 76} \times 50 = 12\text{V}$$

$$\text{P(R2)} = \frac{12^2}{40} = 3{\cdot}6 \text{ Watts.}$$

So rating *is* exceeded.

QUESTION 2.

A circuit containing an inductance L, a resistance R and a capacitance C all in parallel is at resonance. Complete the table below to show the effects on the circuit conditions when the changes listed in the first column are made. Assume the supply has negligible internal impedance and use one of the following terms for each of your answers:

Increase *Remain the same* *Increase to Infinity*

Decrease *Decrease to Zero*

ANSWER 2.

CIRCUIT CHANGE	EFFECT ON				
	CIRCUIT IMPEDANCE	**CIRCUIT CURRENT**	**CURRENT IN R**	**CURRENT IN C**	**CURRENT IN L**
Capacitance C Increased	Decrease	Increase	Remain the same	Increase	Remain the same
Inductance L Increased	Decrease	Increase	Remain the same	Remain the same	Decrease
Resistance R Open Circuited	Increase to Infinity	Decrease to Zero	Decrease to Zero	Remain the same	Remain the same
Frequency Increased	Decrease	Increase	Remain the same	Increase	Decrease

QUESTION 3. (a).

A moving coil meter has a resistance of 1,000 ohms and a full-scale deflection (F.S.D.) of 100μA. Show how it can be used as a ammeter with a F.S.D. of 25mA and calculate the value o, any components used.

ANSWER 3. (a).

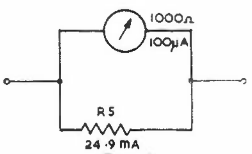


Fig. 2.

See Fig. 2

$$I \text{ shunt} = 25 - 0{\cdot}1 = 24{\cdot}9\text{mA}$$

$$R \text{ shunt} = \frac{1}{249} \times \frac{1000}{1} = 4{\cdot}016\Omega.$$

QUESTION 3. (b).

Draw the circuit that would be used to adapt the 100μA meter to indicate A.C. volts and briefly explain the operation of your circuit.

ANSWER 3. (b).

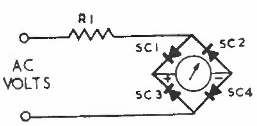


Fig. 3.

See Fig. 3.
First half cycle—top terminal negative. Current through R1, SC2, meter, SC3.
Second half cycle, through SC4, Meter, SC1, R1.
Each half cycle is through meter in same direction and meter responds to average value.
R1 is multiplier to drop excess voltage.

QUESTION 4. (a).

Explain why it is necessary to use bias on valve type audio amplifiers.

ANSWER 4. (a).

To reduce distortion by making the valve work over the negative straight portion of its characteristic. Without bias, the grid goes positive for one half cycle and the resultant grid current causes distortion.

QUESTION 4. (b).

Draw the circuit elements necessary to provide Cathode Bias for a pentode valve and briefly explain its operation. Include references to the factors which determine the value of the bias provided by your circuit.

ANSWER 4. (b).

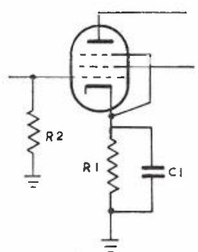


Fig. 4.

See Fig. 4.
Cathode current through R1 causes a voltage drop across R1 which is connected to the grid by R2. The value of bias voltage is dependent upon values of R1, Anode Current and Screen Current. C1 maintains a steady value of bias with signal variations (prevents feedback).

QUESTION 4. (c).

Name two other bias methods which may be used in Class A valve amplifiers.

ANSWER 4. (c).

Battery Bias. Back Bias.

SECTION B

QUESTION 1. (a).

With the aid of sketches, briefly explain why the current does not reach its final value immediately when a D.C. supply is connected to a resistance and inductance in series.

ANSWER 1. (a).

A current changing in an inductor produces an e.m.f. (EL in Fig. 5a) which opposes the change of current. In the circuit shown, the sum of EL and ER is always equal to the supply voltage E.

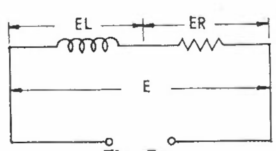


Fig. 5a.

At the instant that circuit is completed there is no p.d. across R, and the voltage across the inductor (EL) is equal to the supply. The current commences to increase from zero at a maximum rate of change (rate of change of current is determined by the value of inductance and EL). As the current increases, ER increases and EL decreases. The reduced EL reduces the rate of change of current. The current still increases, but at a reduced rate.

ER progressively increases as I increases and EL progressively decreases, and the rate of change of current progressively decreases (Fig. 5b). When the current reaches a maximum value (which is determined by E and R), ER is equal to E, EL is zero and there is no change in current.

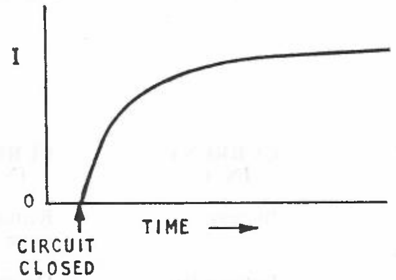


Fig. 5b.

QUESTION 1. (b).

A relay with a resistance of 250 ohms and an inductance of 8 henries is connected to a 50 volt D.C. supply. What will be the maximum current through the relay?

ANSWER 1. (b).

$$I = \frac{E}{R}$$
$$= \frac{50}{250}$$
$$= 200mA.$$

QUESTION 1. (c).

How long would it take the relay in (b) to reach its operate current of 80mA?

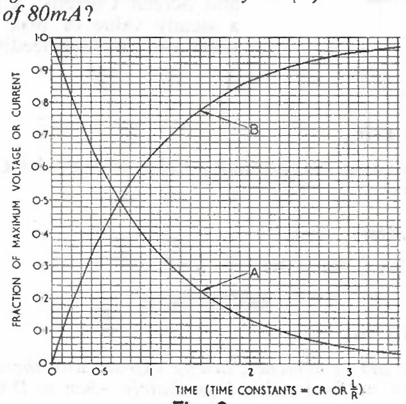


Fig. 6.

ANSWER 1. (c).

$$T.C. = \frac{L}{R} = \frac{8}{250} \times 1000$$
$$= 32mS.$$

Fraction of Maximum Current

$$= \frac{80}{250} = 0{\cdot}4$$

From Graph (Fig. 6)

0·4 = 0·5T.C.

Operate Time = 32 × 0·5

= 16mS.

QUESTION 2. (a).

A transformer with twice as many secondary as primary turns is connected to a resistive load. Draw a vector diagram showing the relationships between the primary and secondary voltages and currents. Include the magnetising current.

ANSWER 2. (a).

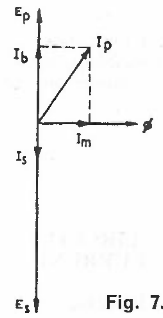


Fig. 7.

See Fig. 7.

Ep is primary voltage
Es is secondary voltage
Ib is primary balancing current
Im is magnetising current
Ip is primary current
Is is secondary current
ϕ is flux.

QUESTION 2. (b).

When 50 volts A.C. is connected to the 2000 turn primary of an auto transformer, the current in the 800 ohm secondary load is 0·25 amps. Draw the circuit showing the connections of the primary and secondary windings and calculate the number of turns used on the secondary. (Assume that the transformer has no losses).

ANSWER 2. (b).

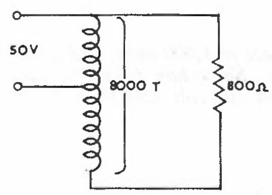


Fig. 8.

$$E\ load = 800 \times 0{\cdot}25$$
$$= 200V$$
$$Ns = \frac{200}{50} \times 2000$$
$$= 8000\ Turns\ (Total)$$

For connections, see Fig. 8.

QUESTION 3. (a).

Draw a vector diagram to show the relationships between the circuit currents and voltage in a parallel A.C. circuit containing resistance and capacitance.

ANSWER 3. (a).

See Fig. 9.

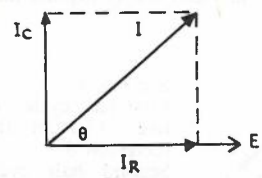


Fig. 9.

QUESTION 3. (b).

Determine the value of capacitor which must be connected in parallel with a 440 ohm resistor to give a phase angle of 22° when a 100 volt 800Hz (c/s) supply is applied to the combination ($2\pi = 6{\cdot}25$).

ANSWER 3. (b).

$$IR = \frac{100}{400}$$
$$= 0{\cdot}25A$$
$$Tan\ \theta = \frac{IC}{IR}$$

From Tables, Tan 22° = 0·4

$$Ic = IR \times 0{\cdot}4$$
$$= 0{\cdot}25 \times 0{\cdot}4$$
$$= 0{\cdot}1A$$

$$Xc = \frac{100}{0{\cdot}1}$$
$$= 1000\Omega$$
$$C = \frac{1}{2\pi Xc}$$
$$= \frac{10_6}{5000 \times 1000}$$
$$= 0{\cdot}2\mu F.$$

QUESTION 4. (a).

Two resistors, R1 = 15kΩ and R2 = 10kΩ, are connected in series to a 10 volt D.C. supply with no internal resistance. What is the p.d. across R1?

ANSWER 4. (a).

$$E(R1) = \frac{15k}{15k + 10k} \times 10$$
$$= 6 \text{ Volts.}$$

QUESTION 4. (b).

An A.P.O. multimeter, which has a sensitivity of 1000 ohms per volt on all ranges, is used to measure the p.d. across R1 on the 0–30 volt and 0–3 volt ranges in turn. Determine the voltage indicated by the meter in each case.

ANSWER 4. (b).

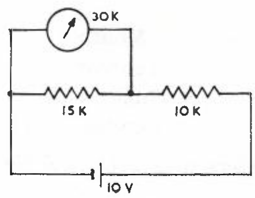


Fig. 10.

$$Rm = 30k\Omega$$
$$\text{Joint R} = \frac{30k \times 15k}{30k + 15k}$$
$$= 10k\Omega$$
$$\text{E meter} = \frac{10}{10 + 10} \times 10$$
$$= 5 \text{ Volts.}$$

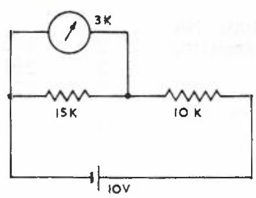


Fig. 11.

$$Rm = 3000\Omega$$
$$\text{Joint R} = \frac{3000 \times 15000}{3000 + 15000}$$
$$= \frac{45 \times 10^6}{18 \times 10^3}$$
$$= 2500\Omega$$
$$\text{E meter} = \frac{2{\cdot}5}{10 + 2{\cdot}5} \times 10$$
$$= 2 \text{ Volts}$$

QUESTION 4. (c).

Briefly explain the reasons why the readings in part (b) differ from the p.d. calculated in part (a).

ANSWER 4. (c).

The meter when connected across R1 shunts it and draws extra current through R2, causing an increased drop across R2 and so lowering the voltage across R1. The lower the resistance of the meter, the greater the shunting effect and the lower the voltage.

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(T.N.I. refers to a Technical News Item or a Letter to the Editors.)

Answers to Examination Questions

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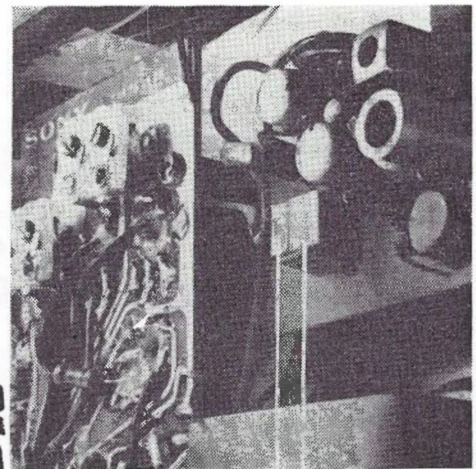
Senior Technician (Telecommunications)—				
Telecom. Principles.	July, 1968	5785	3	288
Telephone Exchange Equipment	July, 1967	5632	1	72
Telephone Subscribers' Equipment	July, 1967	5631	1	78
Transmission Equipment				
Part A—Line Transmission Equipment	July, 1967	5633	1	82
Part B—Radio Communication Equipment	July, 1967	5633	1	85
Part B—Radio Communication Equipment	July, 1967	5633	2	199
Radio and Broadcasting Equipment—				
Part A—Broadcasting Equipment	July, 1967	5634	1	86
Telegraphs—				
Telegraph Equipment	July, 1967	5635	1	94
Research—				
Telecommunication Practice and Measurements	July, 1967	5637	1	99
Control Systems—	Nov., 1966	5599	1	108
Control Systems	July, 1967	5636	2	201
Technician (Telecommunications)				
Telecom. Principles	July, 1968	5801	3	294
Control Systems	July, 1967	5645	2	210

Sony replaced IFT in this 4-band transistor radio with the new Murata ceramic filter SF-455D.



BF-455A ┘ └ SF-455D

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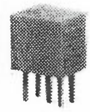


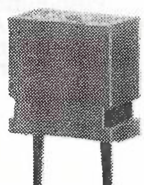
ACTUAL SIZE

SF-455D

Throughout the world electronic design engineers have begun to realise the many benefits offered by Murata Ceramic Filters. These include high gain, low spurious response, negligible ageing characteristics (0.4% over 10 years) and, since no alignment is necessary, considerable cost saving in production.
Sony engineers have taken advantage of these benefits and have incorporated two Murata Ceramic Filters SF-455D and BF-455A in the quality model TR-1000 4-band transistor radio.

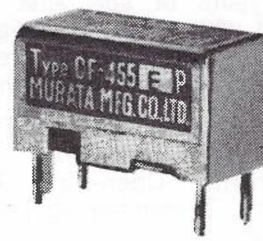
Combining excellent overall response and selectivity characteristics with space saving and production economy, the Murata Ceramic Filters are proving superior to conventional IF transformers.

Include Murata Ceramic Filters in **your** next design.



MODEL BF-455A improves the selectivity of transistor radios when used as an emitter by-pass in transistor IF Stages.

SERIES TYPE (Model SF-455) is a resonance type filter of 455 Khz. It replaces the transistor radio's IFT or can be used in combination with IFT's.



LADDER TYPE Ceramic Filters CF-455 and CF-455P (Popular Type) are ideal for IF stages of high quality communication receivers.

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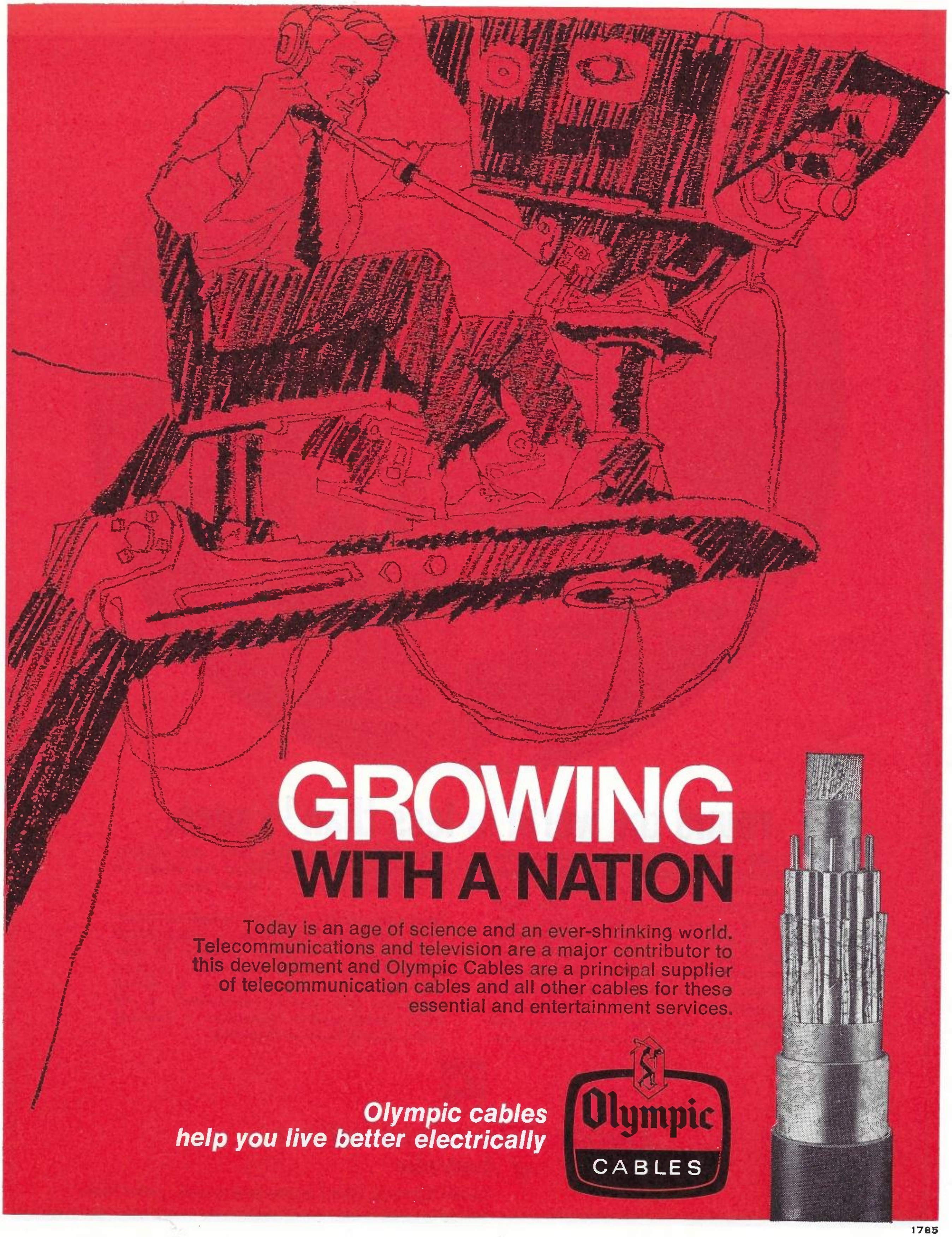
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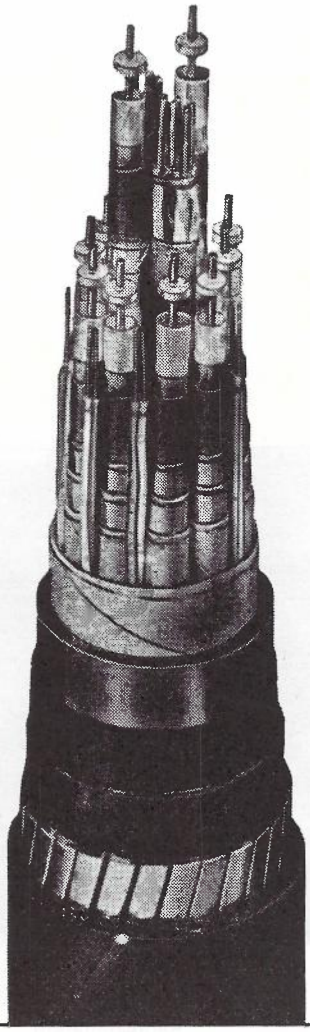

SIEMENS

Underground Repeater Stations for Coaxial Cables

facilitate planning and simplify operations

Telecommunications Cables

with coaxial tubes 1.2/4.4 and 2.6/9.5 mm — coaxial tubes and cable make-up to suit any application.

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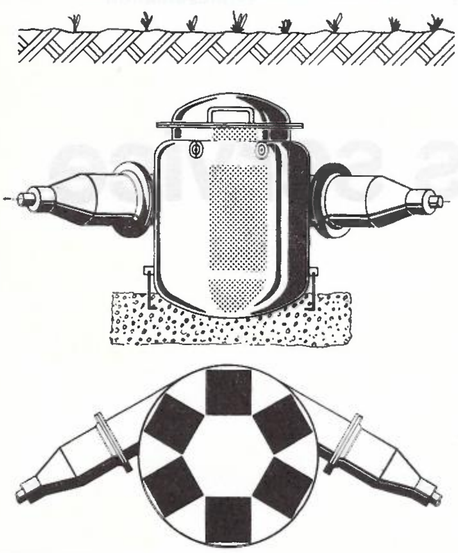

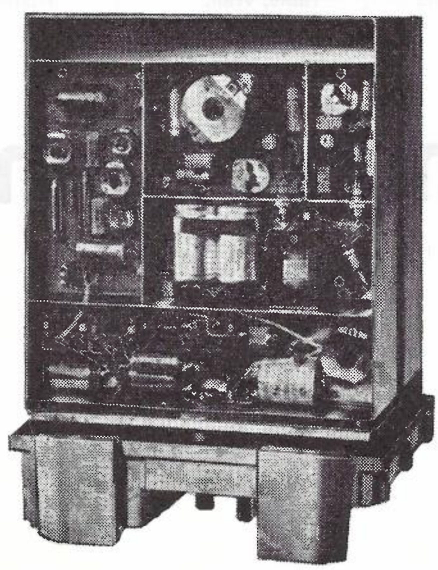

For additional information contact

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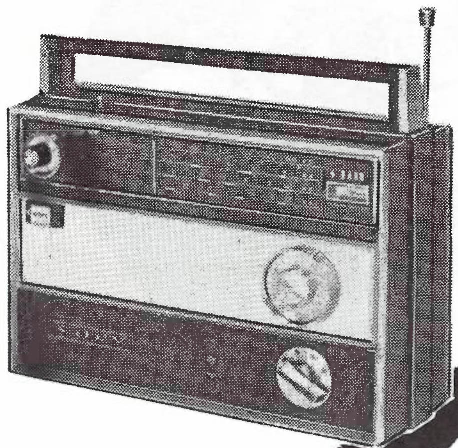

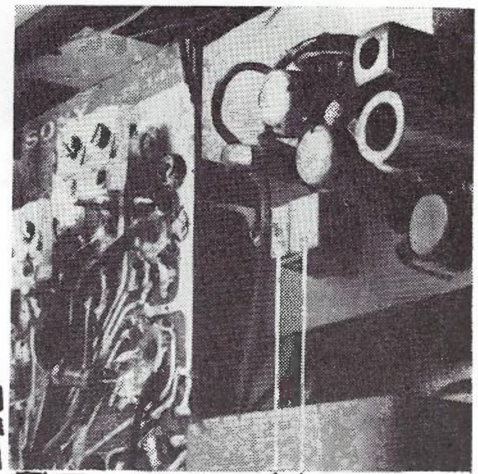

BF-455A ┘ └ SF-455D

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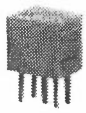

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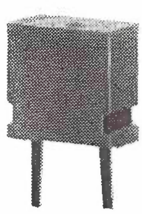

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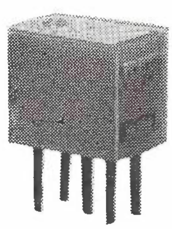

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THE TELECOMMUNICATION JOURNAL OF AUSTRALIA

VOL. 18 No. 3
OCTOBER 1968

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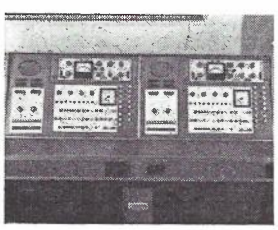

COVER
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Haymarket Exchange

The TELECOMMUNICATION JOURNAL of Australia

ABSTRACTS: Vol. 18, No. 3

COOK, I. G., 'Trunk Circuit Testing in the S.T.D. Network'; Telecom. Journal of Aust., Oct. 1968, Page 261.

This paper briefly outlines the test access facilities and the various test units under development for this purpose in the A.P.O. Access arrangements for small and large exchanges and the salient features of remote trunk test consoles are described. Reference is made to automatic trunk routiner functions and a test call access relay set which permits manual or automatic transmission testing.

CREW, G. L., 'C.C.I.T.T. System No. 6 — A Common Channel Signalling Scheme'; Telecom. Journal of Aust., Oct. 1968, Page 251.

The C.C.I.T.T. has specified and is preparing to conduct a field trial of a common channel signalling scheme for telephone networks. All signals between exchanges are passed over a 2400 bit per second data channel, and include the signal information, speech circuit label and an error detection code. The signalling system is described, covering such aspects as signal unit format, error control, synchronisation, continuity check and security. Some comments on the effect of this signalling scheme on a telephone network are included.

DAWKINS, M. J., 'Applying Epoxy Resins'; Telecom. Journal of Aust., Oct. 1968, Page 281.

This non theoretical treatment of the applications of epoxy resins outlines the way the materials react, describes some methods of modifying the resins for different applications, and mentions some uses to which resins are being applied. A brief description of safety precautions to be observed by operators using the raw products is included.

ENDACOTT, K. A., 'P.C.M. Radio Relay Systems'; Telecom. Journal of Aust., Oct. 1968, Page 257.

This paper describes equipments of differing capacity and modulation method offered by three manufacturers. The general system design aspects of P.C.M. radio relay systems are discussed and applications to the Australian network, particularly for 'thin line' systems in remote areas, are considered.

FINDLOW, V. F., 'Service Assessment Equipment — Circuit Operation'; Telecom. Journal of Aust., Oct. 1968, Page 264.

The paper briefly describes the circuit operating principles of equipment designed to provide centralised service and subscriber assessment facilities in large networks of automatic exchanges. The equipment is intended for use in areas in which physical circuits are available between the exchanges and the assessment centre.

FREEMAN, A. H., 'Network Design for S.T.D.'; Telecom. Journal of Aust., Oct. 1968, Page 229.

Switching principles for heirarchical trunk networks are discussed through an anlysis of the basic components of a network and the general properties of star and mesh methods of interconnection. Network design principles to meet traffic and cost requirements are developed and illustrated using the N.S.W. trunk network as an example. The self perpetuating trend due to the influence of the investment in the existing network is discussed and illustrated by reference to the switching plans in other countries.

HOUSLEY, T. A., 'New Financial Arrangements for the Post Office'; Telecom. Journal of Aust., Oct. 1968, Page 221.

Changes to Post Office financial arrangements introduced in July 1968 are discussed with particular reference to the implications for engineering management at the various levels. Some possible further developments are outlined.

KELLOCK, A., and TRAILL, A., 'Modern Methods of Meeting the Increasing Demand for Trunk Circuits'; Telecom. Journal of Aust., Oct. 1968, Page 238.

The extent of demand for provision of trunk telephone circuits in more developed countries is increasing rapidly. In volume the major requirement is for economic, low- to medium-capacity systems, and systems of this type available are briefly described in this paper with a general perspective on their range of application. The paper indicates the increasing operation of broadband systems in Australia and the principles adopted in planning their integration into a national network. Finally, future trends in system media and techniques to provide economic capacity for a very large number of channels are discussed.

MATTISKE, D. D., 'ARK-M Exchanges'; Telecom. Journal of Aust., Oct. 1968, Page 275.

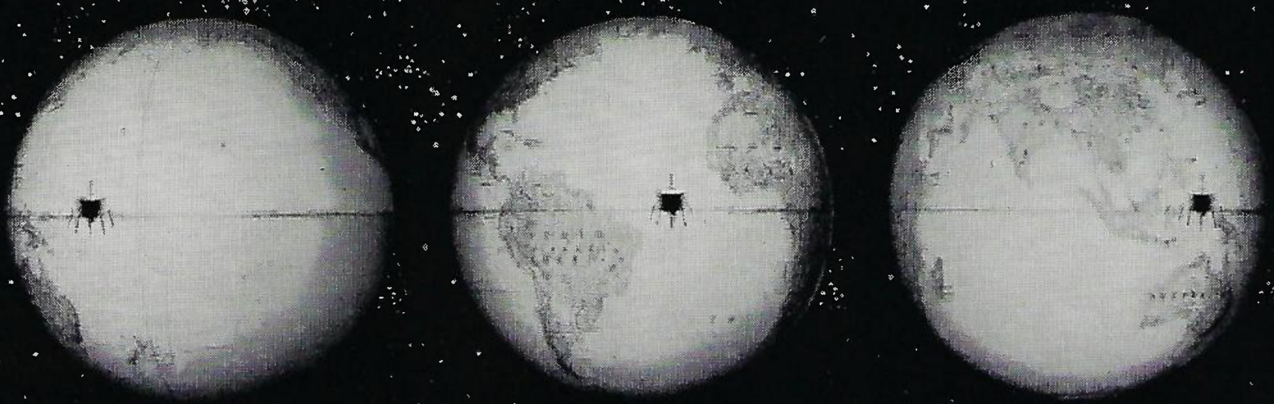
This paper describes the ARK-M exchange which is designed for small country exchanges as an integral part of the L. M. Ericcson crossbar system. This exchange is dependent on a higher order parent exchange which provides control of route selection and switching.

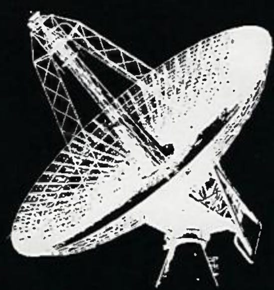
PRATT, C. W., 'Slide Rule Compound Growth Calculations'; Telecom. Journal of Aust., Oct. 1968, Page 279.

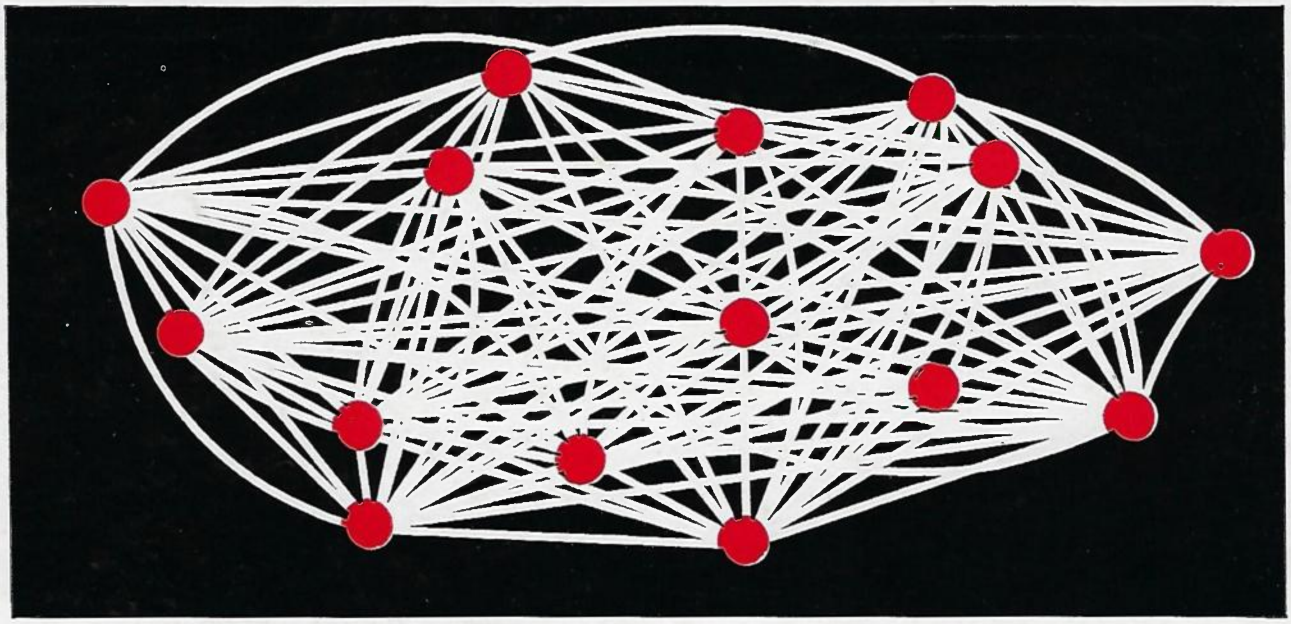
This note describes how a slide rule without an LLI scale may be used for compound growth calculations.

SAWKINS, E., 'Fire Protection and the Australian Post Office'; Telecom. Journal of Aust., Oct. 1968, Page 224.

The cost to the community of life and property loss by fire is given to emphasize the importance of fire protection activities in the community in general, and in the Post Office in particular. Major fires which have destroyed Post Office plant in the last two decades are described and their influence on the development of Post Office fire protection policies are discussed.







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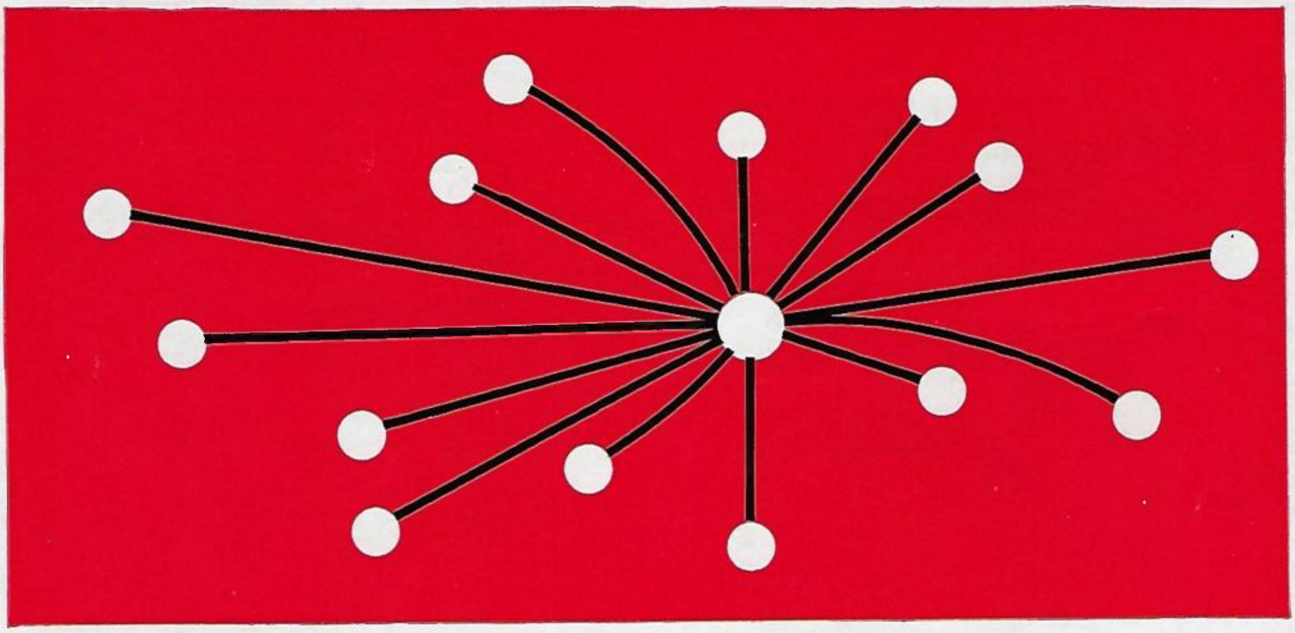

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