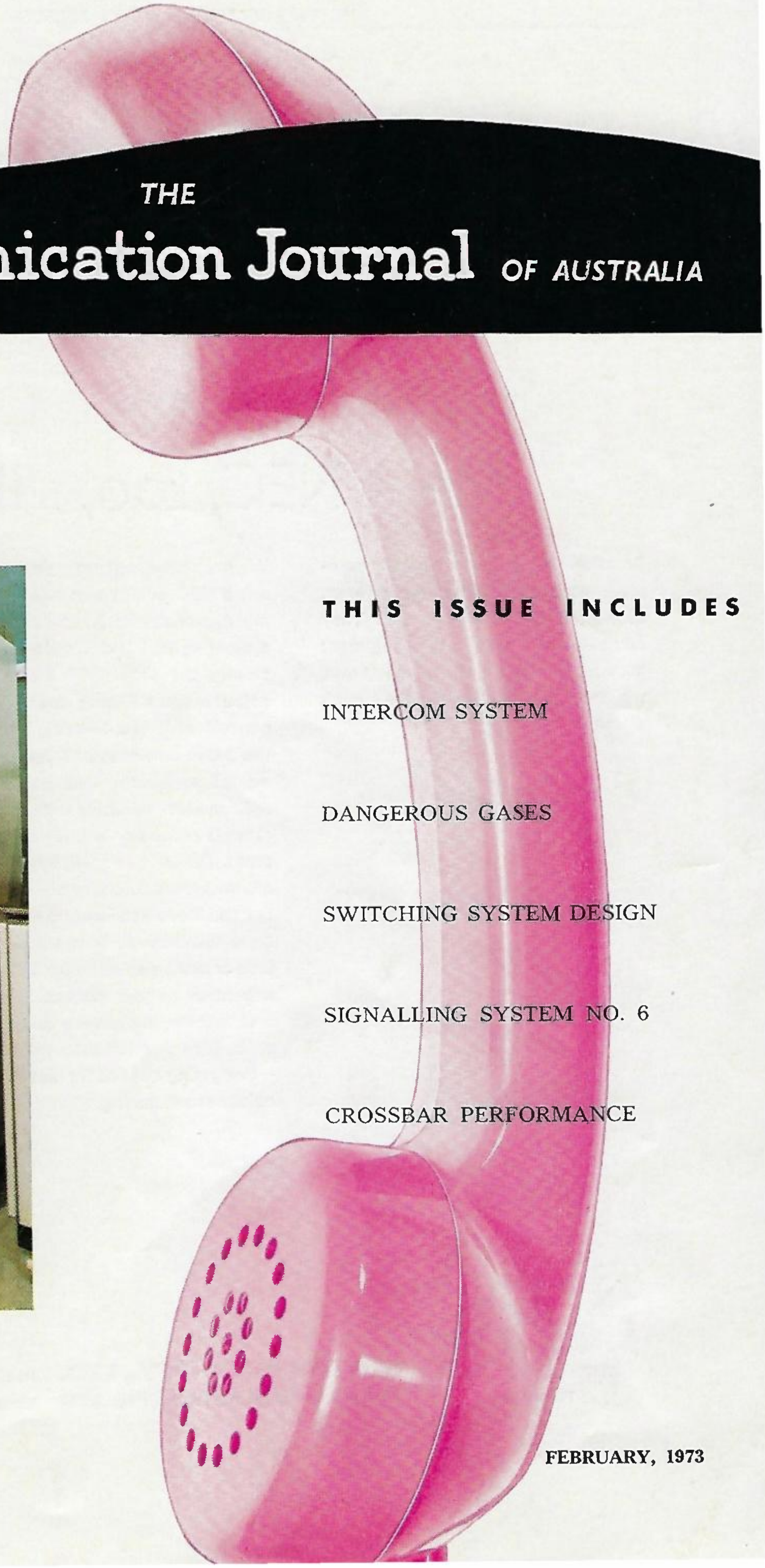
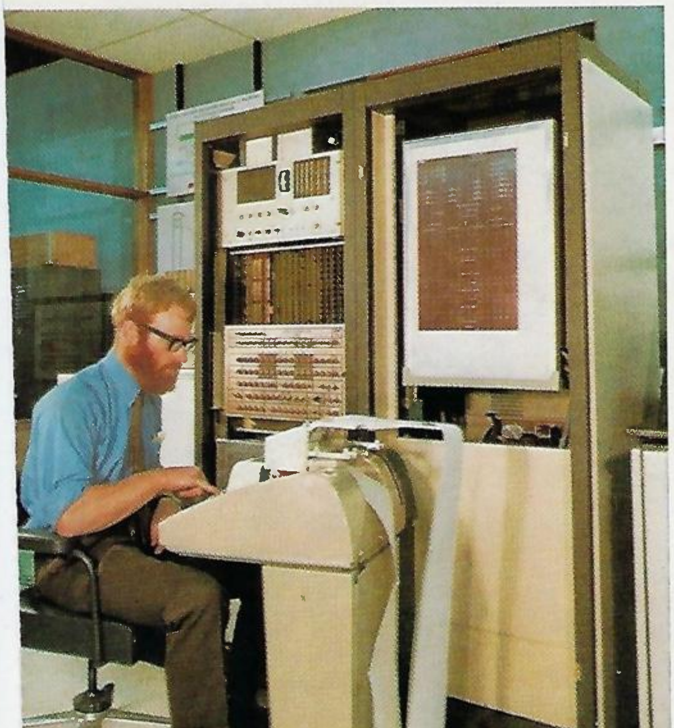
THE Telecommunication Journal OF AUSTRALIA





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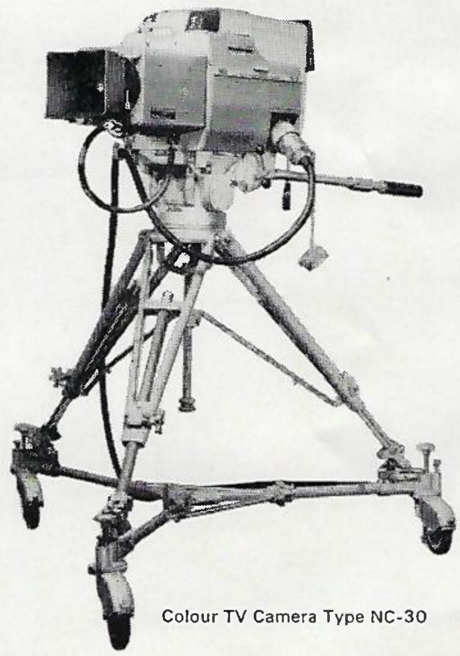

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TELECOMMUNICATION JOURNAL
OF AUSTRALIA

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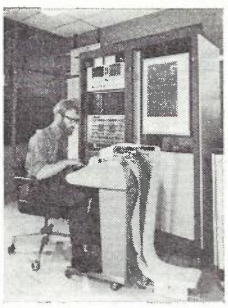
CONTENTS



COVER
BTMX Processor,
Signalling System No. 6.

The TELECOMMUNICATION JOURNAL of Australia

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THE 2/6 AND 4/11 INTERCOM SYSTEMS

*W. J. TREBILCO, A.R.M.I.T.**

INTRODUCTION

Direct push-button intercom systems have found wide application in offices, banks, factories, hospitals etc. and since 1938 this service has been provided by the A5 and A10 intercom systems. The A5 system provides access to one exchange line with intercom between six speaking points and the A10 system provides access to two exchange lines with intercom between eleven speaking points.

These systems stood the test of time in facilities and operation but they became outdated. They were bulky, their appearance was out of date and office space was needed to mount the ugly transfer unit at the main answering point. In addition they were considerably mechanical in operation with a high maintenance. Further, Australian business demanded a higher ratio of exchange lines to intercom speaking points.

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Tenders were called in 1968 from overseas manufacturers of intercommunication systems. In August, 1969, the tender for supply of two different size systems was accepted from the Telefonbau and Normalzeit Co. of West Germany, through their Australian agents, Amalgamated Wireless, Australasia. The tender covered two systems:

Access to two exchange, P.A.B.X. or P.M.B.X lines, with intercom between six speaking points (2/6 system).

Access to four exchange, P.A.B.X. or P.M.B.X. lines with intercom between eleven speaking points (4/11 system).

THE 2/6 AND 4/11 INTERCOM SYSTEMS

The 2/6 and 4/11 systems are similar in appearance and identical in operation and facilities. The systems are made up of push-button telephone instruments, terminal connecting units (TCU's) and a combined central power supply and switching unit (PSSU). Figs. 1 and 2 show in block diagram form the layout and interconnection of these components for the two systems. Normally one point is wired as the answering point for incoming exchange calls. The answering point transfers these calls to other speaking points as required.

Telephone Instruments

Instruments for both systems are the same size, not much larger than the 802 telephone. The cases are made of grey ABS plastic and fitted with a hand recess for easy carrying.

Push-button Keys

As shown in Fig. 3, the 2/6 instrument has two rows of interacting keys: In the top row are two non-locking keys for exchange line access, one non-locking key to release individual exchange lines and two locking keys for monitoring exchange lines. However, initial supplies of this equip-

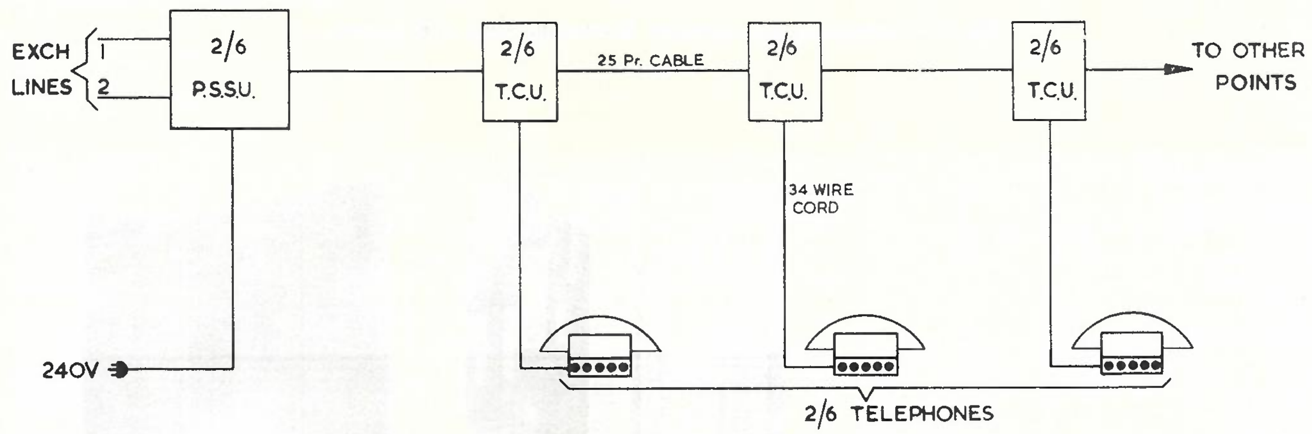


Fig. 1 — Block Diagram of 2/6 System.

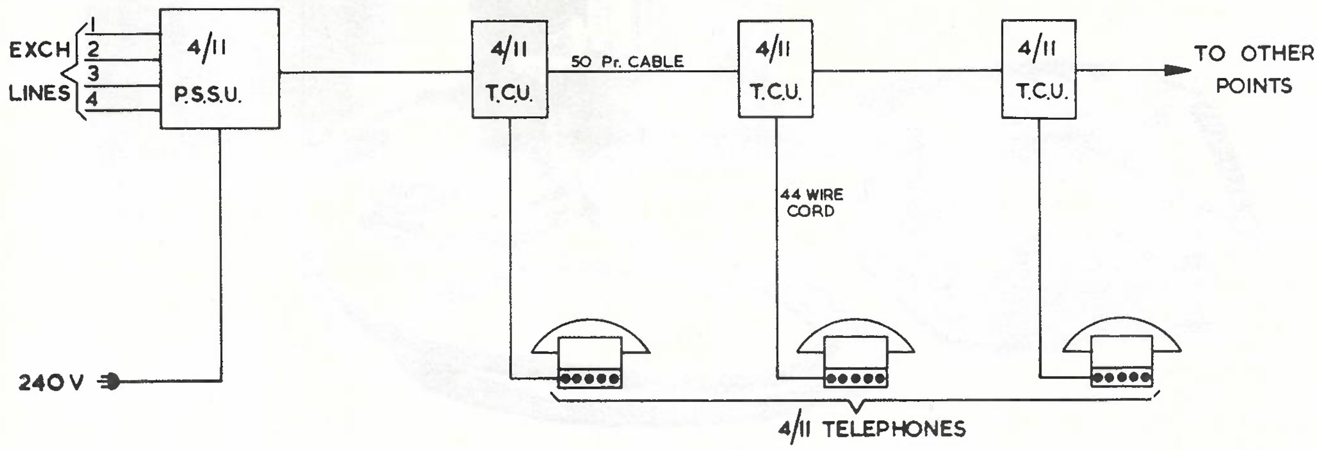


Fig. 2 — Block Diagram of 4/11 System.

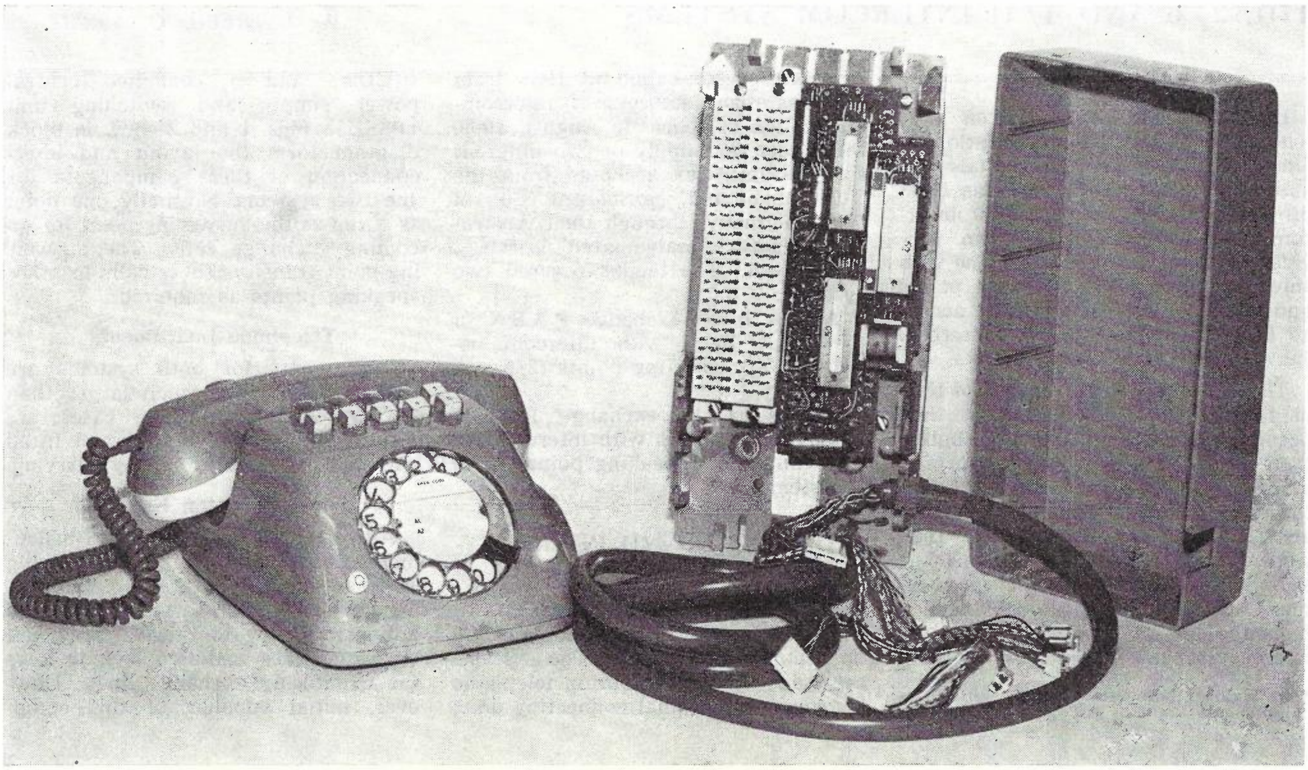


Fig. 3 — Telephone and Terminal Connecting Unit, 2/6 System.

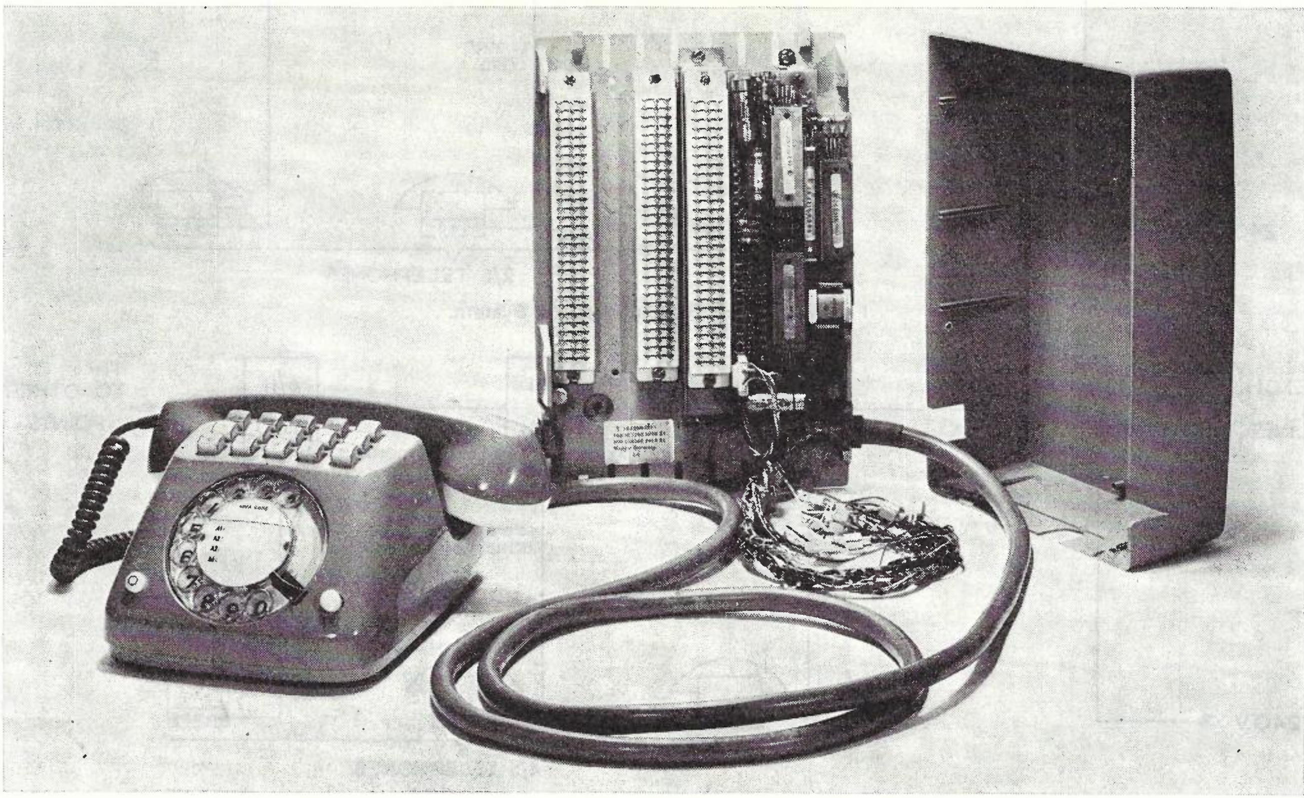


Fig. 4 — Telephone and Terminal Connecting Unit, 4/11 System.

ment will not be provided with monitoring facilities and these two keys are inoperative. The exchange keys are fitted with lamps to indicate the line condition. The second row has five locking keys which provide signalling and connection on intercom calls.

All keys are mechanically interconnected with each other and the gravity switch so that:

The operation of an exchange key following the operation of an intercom key releases the latter.

The operation of a second intercom key releases the first.

Replacing the handset releases all keys.

The 4/11 instrument shown in Fig. 4 is similar to the 2/6 but has one additional row of intercom keys, two extra exchange keys, but no monitor keys.

In addition to the keys at the top of the instrument, both types have two non-locking keys at the base. The right hand key may be used for recall or enquiry calls on P.M.B.X. and P.A.B.X. lines. The left hand key is used to hold exchange lines.

Transmission

The transmission circuit of these instruments is based on the standard German FE.61 telephone. Unlike the Australian 800 series telephone, the circuit does not have automatic regulation to compensate for line feed current variation. Consequently, on lines less than 200 ohms it has been necessary to build out the line resistance with a 180 ohm resistor in series with each side of the line to prevent excessive transmitter current and send level.

Compared with the 801 telephone under identical line and feed bridge conditions the effective send reference equivalent is 1.9 dB better and the receive reference equivalent 2.4 dB worse. However, in future contracts a higher grade receiver capsule will be supplied and this will give an improvement of 2 dB to the receive

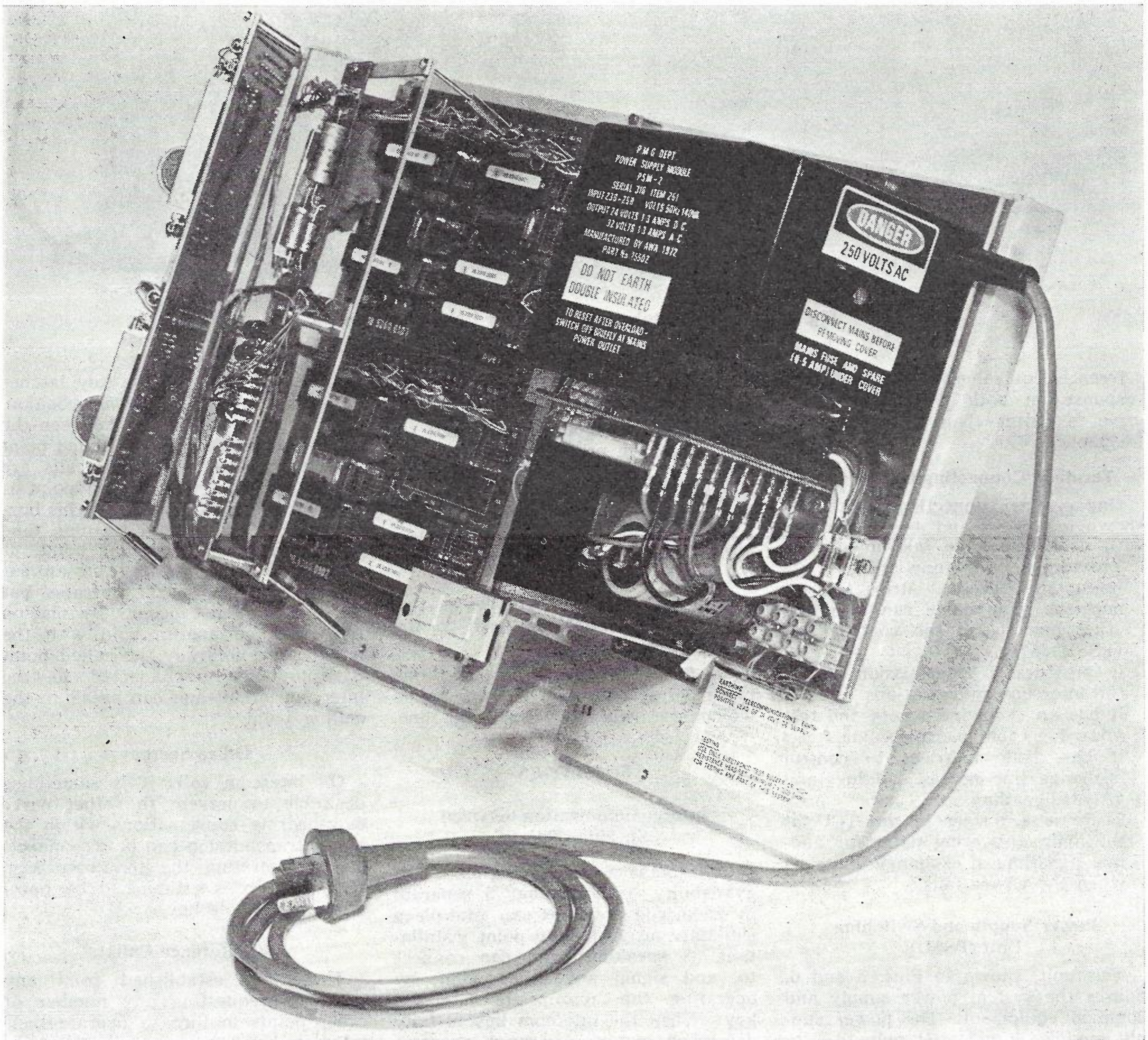


Fig. 5 — Power Supply and Switching Unit for 2/6 System, with Circuit Gates Open.

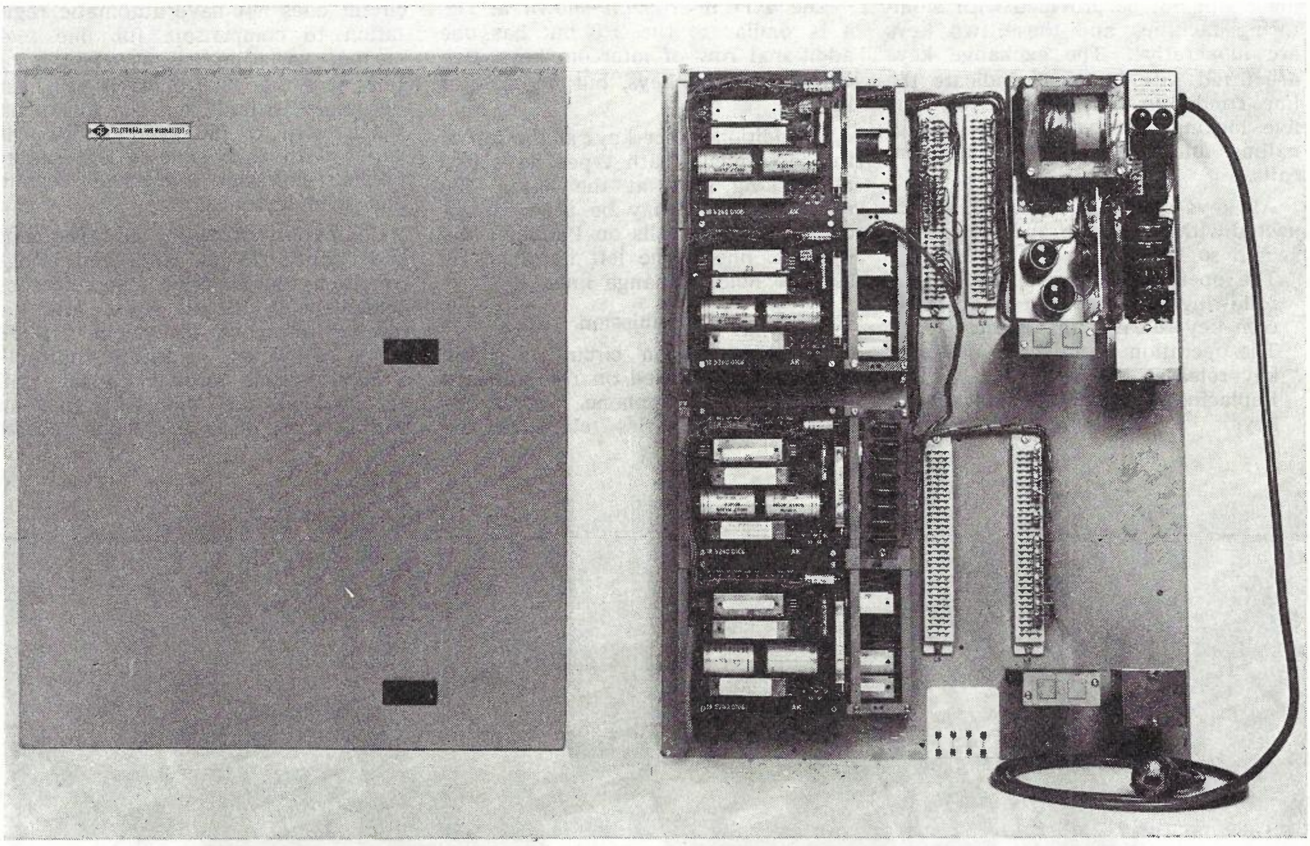


Fig. 6 — Power Supply and Switching Unit, 4/11 System.

reference equivalent. The frequency response on both transmit and receive is flatter than the 800 series telephone.

Terminal Connecting Unit (TCU)

One terminal connecting unit (TCU) shown in Figs. 3 and 4 is associated with each telephone instrument and it provides 5 basic functions:

It contains terminal strips to connect the main cable run from the other points and the control unit (PSSU).

It provides a transmission bridge for intercom conversations.

It has an exchange access and test relay for each exchange line.

It has diode matrices to control exchange line access, holding, and visual signalling.

There is a buzzer in the TCU at the main answering point for audible signalling of exchange line calls when the power fails.

Power Supply and Switching Unit (PSSU)

This unit, shown in Figs. 5 and 6, houses the system power supply and common equipment. The power supply module provides 24 volts d.c. to operate relays and semi-conductor circuits and 32 volts a.c. to operate buzzers and lamps.

The common equipment is built up in modules on printed circuit boards:

Exchange Access Modulex: Connects, guards and holds exchange lines.

Ring Detect Module: Detects the incoming exchange ring, and signals audibly and visually to the answering point.

Ring Flash Module: Provides a two pulse per second lamp flash to the answering point.

Hold Flash Module: Provides a one pulse per second lamp flash to points which are holding an exchange line.

FACILITIES

Intercommunication between Speaking Points

Calls between points are on a full availability basis so that 5 separate intercom conversations can take place simultaneously on a 10 point installation. A speaking point can connect to, and signal any other point, by operating the appropriate intercom key. When the intercom key is fully depressed a.c. ring current operates the buzzer at the called point. After pressure is removed, the key latches in the operated intercom position. Connection is established between the two points as soon as the called point lifts his handset. Intercom calls are not secret, but if the called point is busy on another intercom call his buzzer sounds and a busy warning tone is sent back to the calling point. If the called point is busy on an exchange call his buzzer operates but intrusion will not occur. By placing the exchange line in hold with the non-locking hold key the called point is automatically connected to the intercom circuit and can speak to the calling point.

Office Secrecy

On intercom calls it is sometimes desirable to prevent the other party over-hearing conversations within the office; transmission can be disconnected by operating the terminate key. Reconnection is established by operation of the hold key.

Conference Calls

These are established from any point by requesting any number of other points in turn to operate their intercom key associated with the point setting up the conference.

Direct Signalling

By pressing the intercom key and using a simple code signal an executive may summon a member of his staff without lifting the handset.

Exchange Line Connections

Busy exchange lines are indicated by a steady lamp glow in the line key at all points. Any unbarred speaking point may gain access to an exchange line by lifting the handset and operating an unilluminated non-locking line key. Busy lines are electrically guarded and accidental intrusion by a second point is not possible.

Incoming calls are indicated by the operation of the instrument buzzer at the answering point in synchronism with the exchange ring.

The calling line is identified by the fast flashing lamp in the line key. A steady lamp glow at all other points prevents them seizing the incoming call.

Calls are normally answered at the answering point by momentarily operating the non-locking exchange line key, which in turn causes the line lamp to cease flashing and instead give a busy indication (steady glow) at the answering point as well as the other speaking points.

Holding Exchange Lines

Exchange lines may be held manually by operating a separate non-locking hold key, or automatically when another exchange line or intercom key is depressed. The hold condition is indicated by a slowly flashing line lamp. Manual hold allows the subscriber engaged on an exchange call to hold the line so that he may:

Answer an intercom call from another point.

Prevent the exchange line party overhearing a local office conversation.

Reconnection to a held exchange line is by momentarily operating the line key.

Automatic Hold allows the subscriber engaged on an exchange call to:

(a) Transfer the call to another speaking point. Operation of the intercom key automatically connects the exchange line into hold and allows the point transferring the call to advise a second point to take over the exchange line. The second point operates the nominated exchange line key which releases his intercom connection and connects him to the exchange line. When the line is connected the lamp at the first point ceases to flash and glows steadily, indicating to the first point that he may replace his handset or initiate another call.

(b) Alternately answer and hold more than one exchange line. A subscriber engaged on an exchange line may originate or receive calls on other exchange lines. Operation of another line key connects the preceding line into hold. Thus operation of any line key held or free will effect connection to this line and automatic holding of the previously connected line.

Terminating Exchange Calls

Any point busy on a number of exchange line calls can release each one individually with the non-locking terminate key. This key releases the line actually connected to the instrument and not others in hold.

Power Fail

Normally one exchange line is provided with a power fail relay which on release connects the exchange line to a pre-determined answering point. Incoming ring signals operate a power fail buzzer in the terminal connecting unit.

Optional Facilities

Several optional features can be provided:

(a) Visual indication of incoming exchange ring at points other than the answering point.

(b) In conjunction with (a), a changeover switch at the main answering point switches the audible exchange ring to an alternative answering point.

(c) Speaking points may be barred access to one or more exchange lines or they may be given restricted access. The restricted point can request another point to make an exchange call and transfer the call back to him.

(d) There is provision in the PSSU's to fit a printed circuit module (one per exchange line) which after a period of 10-20 seconds causes the audible and visual exchange ring signals to be duplicated between the normal answering points and any other nominated speaking point.

DESIGN FEATURES

The design of these systems has introduced some new components and has expanded existing installation and maintenance techniques.

Terminal Strips

Two different types of terminal strip are used; both have 30 rows of 3 multiple tags, two of which are insulation crushing and the other is a receptacle to take quick connect tags. In addition to these tags one type has a side socket in multiple with the tags for accepting a printed circuit assembly.

Reed Relays

Reed relays are used in conjunction with semiconductor circuitry for control and line switching.

Buzzer

A single flat reed relay is clipped to the base of the telephone to provide audible signalling on exchange and intercom calls. The coil is operated from 32 volts a.c. and the unwired reeds respond to the 50 Hz. In conjunction with the telephone base which acts as a sounding board the vibrating reeds emit an audible buzz.

Lamps

A significant fault factor in any intercom design are the indicating lamps. A blown 20 cent lamp means a $9 visit by a technician. Lamp life is improved by pre-heating all the line lamps to an indiscernable dull red glow to reduce the thermal shock to the filament when lamps are switched on and off. Half and full glow are achieved by switching diodes into the lamp circuit to provide half cycle or full cycle rectification from the 32 volts 50 Hz supply.

Power Supply Regulation

The power supply is regulated using a series switching pass transistor. Unlike a linear regulator which works continuously in the active region of the regulating transistor, the series switching type works in either the cut-off or saturation regions and therefore dissipation is considerably less than for linear regulated supplies.

AUSTRALIAN PRODUCTION

When the tender was accepted it was agreed that the Australian agents would produce as much of the system in Australia as would be economically feasible.

Power Supply

The first Australian contribution was to modify the German power supply input connection so that it complied with Australian standards.

Development of an Australian supply was started in April 1971. It was decided that this new supply should incorporate the double insulation technique as laid down by the Standards Association of Australia. This technique includes a second layer of insulation which provides a second line of defence in the event of a breakdown of the normal functional insulation.

The production samples were approved in June 1972 and up to the end of August 1972, 1000 modules were produced. This new power supply is shown mounted on the PSSU in Fig. 5. As interest has been shown outside the A.P.O. it now seems that this power supply may have application in other areas where earth protection is unsuitable.

External Extensions

Sales of the 2/6 and 4/11 system have been restricted by the lack of external extension equipment. The next item for Australian manufacture will be the design and development of external extension equipment to allow connection of one or two 800 series telephones over two wires from distant locations.

MAINTENANCE EXPERIENCE

At each installation a service record sheet is provided for field staff to record faults found during installation and at subsequent service calls. A review of 122 of these sheets showed that in the first six months after installation, 38% of these installations had no service calls, 31% had one, 17% had two, and the remaining 14% had between 3 and 8 visits. The most prevalent faults were open transmission bridge coils, sticking relay contacts and springsets out of adjustment. As a result of this feedback from the field, the manufacturers will correct specific faults.

EQUIPMENT INSTALLED

To date 490 4/11 and 290 2/6 systems have been installed with an average ratio eight points per 4/11 and five points per 2/6 system.

TECHNICAL NEWS ITEM

POCKET CALCULATOR IS SMALLER THAN CIGARETTE PACK

An electronic calculator that weighs only 2.5 oz (just over 70 g) and takes up less space than a packet of 20 average-sized cigarettes can perform all functions of a conventional desk unit.

Described by its British manufacturer as the first instrument of its kind that can be carried comfortably in a suit pocket or lady's handbag, the calculator measures only 2 in wide by 5.5 in long (50 mm by 140 mm).

The keyboard, which normally controls the overall thickness of pocket devices, is of special design and only 4 mm deep. Contacts are gold-plated and keys arranged in such a way that it is virtually impossible to hit two simultaneously.

Power is supplied by three tiny mercury cells normally used in hearing aids. They are cheap, easy to replace and have an average life of about three months. A special circuit design reduces power consumption to only about 20 mW.

The illuminated display has a capacity of eight digits enabling the machine to add, subtract, multiply and divide almost simultaneously. The decimal point can be fully floating. A 'constant key' speeds multiplication or division by a constant number simplifying, for example, the calculation of discounts or of currency conversions.

Main function of the device is to enable travelling businessmen and engineers to check estimates, convert currencies and units of measurement, and make complex calculations of all kinds while attending a conference, travelling by train, boat or aeroplane, or on the shopfloor or building site etc.

DANGEROUS GASES IN THE A.P.O. UNDERGROUND NETWORK

J. P. KILLEEN

INTRODUCTION

The hazards of asphyxiation, poisoning, fire, and explosion from the build-up of gases in confined spaces have for long been appreciated. Recorded incidents of the leakage of dangerous gases into telecommunication underground networks date back some 70 years or more. In the early days of underground construction, working precautions were developed by the A.P.O. to protect staff and property from the resultant hazards of gas leaks. About 1937, this was followed up by the introduction of a chemical type gas detector which would indicate the presence of carbon monoxide, one of the constituents of the reticulated gas more commonly known as "coal gas". The working precautions and test procedures for detecting the presence of gas were developed to meet the A.P.O. construction methods which differed somewhat to many overseas practices in that manholes were generally much shallower in depth and more generous in the size of surface openings.

During this period gas was manufactured in all the State capital cities and a number of provincial towns and cities which were located mainly in the eastern States. Distribution of the gas was restricted to local areas of manufacture where the pipelines to consumers were only a few miles long and operated at relatively low pressures. Any hazard which could arise from a leak in reticulated gas systems was therefore restricted to clearly defined areas, well known to all staff.

More recently the problem has assumed new dimensions. The A.P.O. underground network has been greatly expanded in both rural and urban areas, manholes have increased in size and depth and shaft entries are becoming necessary to meet the greater depth of duct routes in some congested areas. Significant changes have occurred in gas reticulation and distribution; many country towns and cities have converted from manufactured gas to tempered liquefied petroleum gas and, since 1969 natural gas has been phased into several major cities and towns of Victoria, Queensland, South Australia and Western Australia, while by 1975-76 it will be reticulated extensively to many of the major populated areas of New South Wales. At the same time there has been a substantial increase in the number of fluid fuel storage and distribution points. These factors have considerably increased the risk of leakage and the subsequent build-up of dangerous mixtures in the network, which if not controlled, could develop into hazardous situations which could affect the safety of staff and property.

THE IMPACT OF NATURAL GAS

Main Pipelines

The discoveries of natural gas have in general been remote from the major populated areas of the continent and welded steel pipelines operating at pressures up to 6,895 kPa (1,000 lbf/in^2) are used to convey the gas from its source, usually to a State capital city. These pipelines are very long, for example from Gidgealpa to Adelaide the pipeline is 772 km (480 miles) long, and the proposed pipeline to Sydney will convey the gas about 1 220 km (760 miles). Figs. 1 and 2 show the natural gas pipelines which supply gas reticulation systems. The pipelines usually follow direct routes and spurs from the main pipelines feed adjacent towns and cities. As the pipelines pass through many areas away from gas producing or gas consuming localities, gas may leak into the underground network in any adjacent rural or urban area.

Ring-Main and Reticulation Pipelines

The high pressure gas transmission pipelines terminate at a city or town gate where the pressure is reduced and the gas is then distributed in ring pipelines from 1,724 kPa (250 lbf/in^2) to 2,758 kPa (400 lbf/in^2).

For new construction, natural gas is then reticulated in welded steel

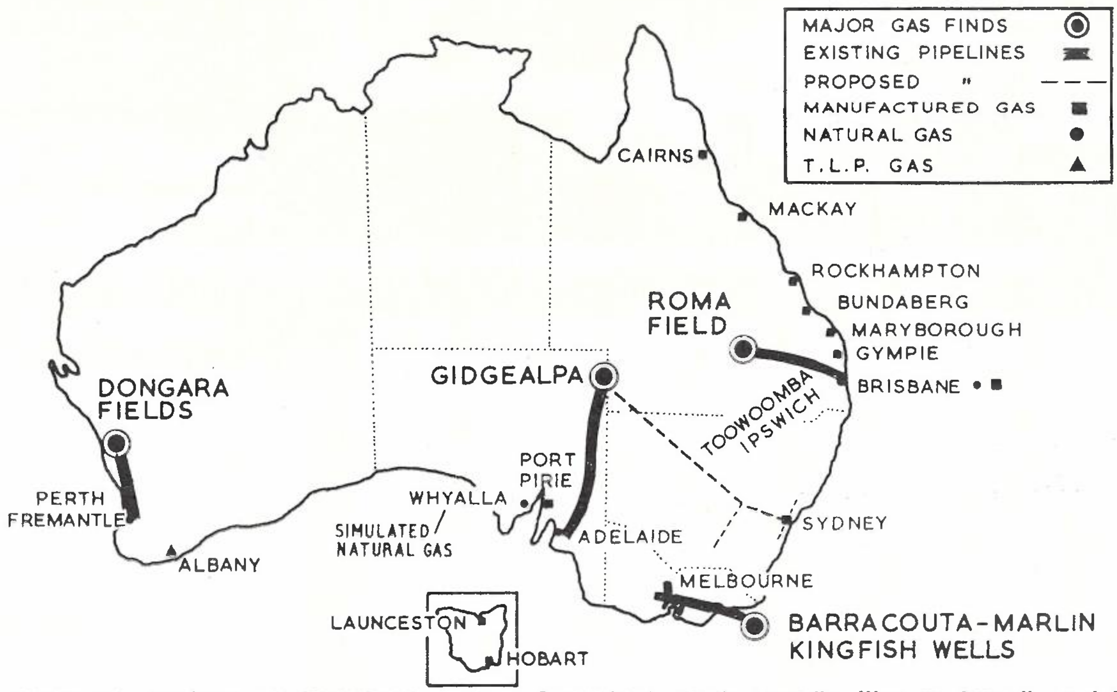


Fig. 1 — Natural Gas Pipelines and Reticulated Gases in Queensland, South Australia, Western Australia and Tasmania.

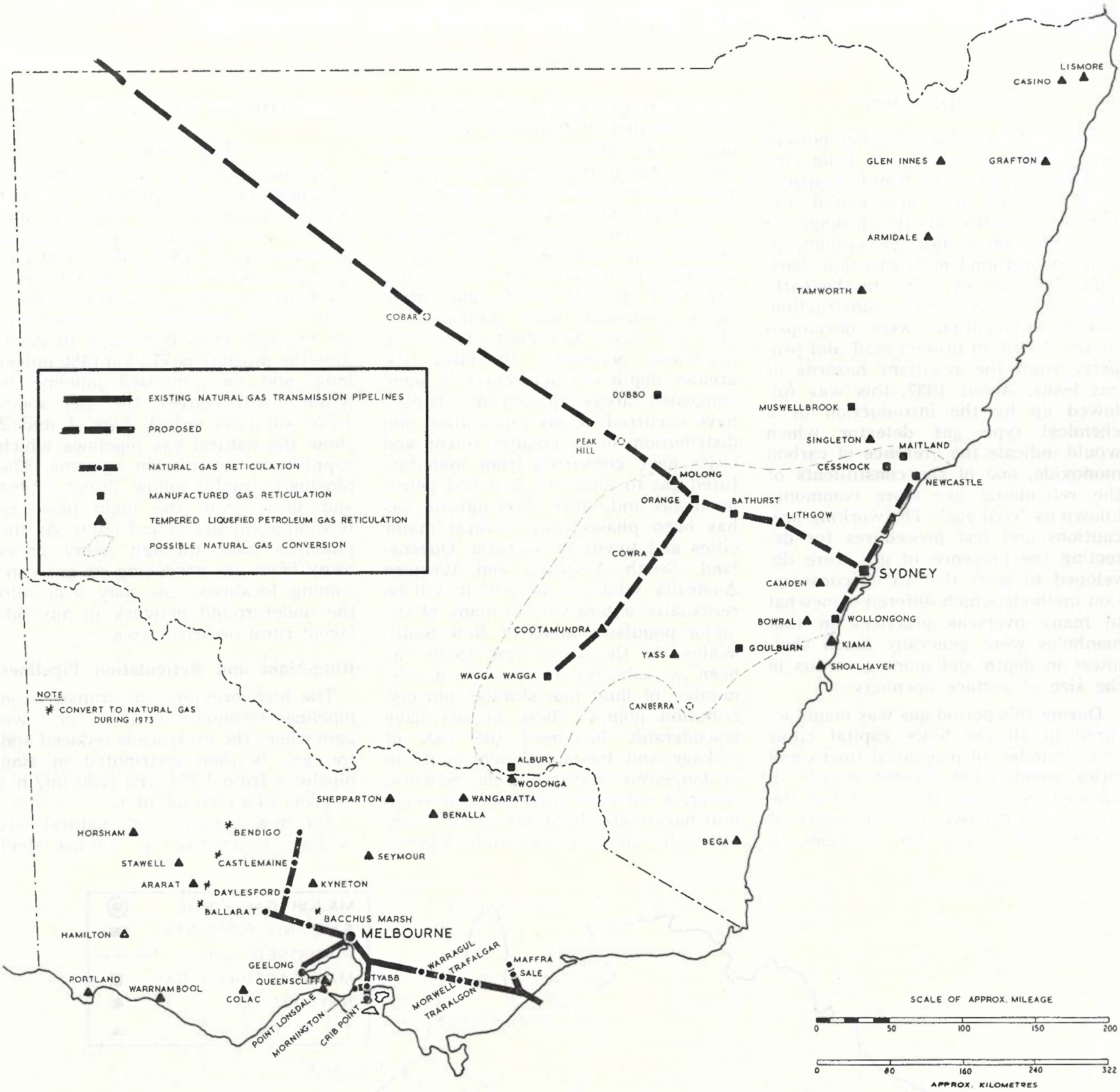


Fig. 2 — Natural Gas Pipelines and Reticulated Gases in New South Wales and Victoria.

pipes operating at pressures up to 448 kPa (65 lbf/in^2) where it is regulated to low pressure at consumers' premises. High pressure may also be used to supply large industrial or commercial establishments direct from the transmission or ring pipelines. This wide distribution of high pressure pipelines can create severe hazards if mechanical damage occurs and a number of incidents have already arisen where natural gas has leaked into the underground network.

Conversion of Existing Systems

Where natural gas is fed into existing gas reticulation systems the pressure is further reduced to the relatively low pressures previously used for the distribution of manufactured gas. Such conversions of existing gas reticulation systems from manufactured gas to natural gas can result in leakage from the older corroded pipes due to the dryness of natural gas. This can cause flaking away of rusted pipe, disintegration of caulked joints and in some cases cracking of previously moist clay beds surrounding corroded pipes. As distribution of natural gas in existing reticulation systems becomes more widespread, the hazards from leakage into the network will increase.

TYPES OF GASES

A variety of gases can enter the underground network. They include:—

Reticulated gases which in urban areas are distributed adjacent to the A.P.O. network. Figs. 1 and 2 show the areas where the various gases are reticulated.

Industrial gases from industrial and commercial sources as well as L.P. gas plumbing equipment used by A.P.O. staff.

Fluid fuels from industrial and bulk storage areas and service stations.

Gases from natural sources in the soil.

Reticulated Gases

Natural Gas: Natural gas consists mainly of methane with small quantities of other gases, some combustible such as ethane, propane and butane, and some inert, such as carbon dioxide and nitrogen. Natural gas is lighter than air (relative density 0.61) and will rise. Natural gas itself is non-poisonous, and it is relatively safe to breathe in concentrations of up to 25% in air. Above this concentration, the respiratory system becomes affected by lack of oxygen and unconsciousness may follow.

Manufactured Gas: Manufactured gases have varying compositions, depending on the manufacturing processes used. Common constituents are hydrogen, carbon monoxide, methane (and some higher hydrocarbons) as well as some inert gases. Manufactured gases are all lighter than air, with relative density ranging from 0.5 to 0.65 and the gases will therefore rise. The average carbon monoxide content of manufactured gas ranges from 12% - 25% in volume with some areas rising as high as 40% in volume. Exceptions are Sydney North Shore area and Newcastle, where manufactured gas with a low content carbon monoxide ranging from 2%-6% in volume is reticulated. Carbon monoxide is highly toxic and in areas where manufactured gas with a substantial carbon monoxide content is reticulated, a carbon monoxide gas detector must be used. The combustible gas detectors described later will not detect low concentrations of carbon monoxide.

Tempered Liquefied Petroleum Gas: Tempered liquefied petroleum gas (T.L.P.) is normally regarded as being a mixture of 25-26% propane in air, but, in areas where natural gas may be introduced, there may be another mixture known as Simulated Natural Gas (S.N. Gas) which consists of about 50% propane in air. Both of these mixtures are heavier than air, T.L.P. and S.N. gas having relative densities of 1.13 and 1.28 respectively. These gases will therefore accumulate in low areas, such as trenches, pits, manholes and basements. These gases being based on propane are, like natural gas, non-poisonous. T.L.P. gas being a mixture of one part of propane in three parts of air, contains sufficient oxygen for breathing, but S.N. gas being a mixture of one part of propane in one part of air, is asphyxiating as it contains insufficient oxygen to permit safe working.

Industrial Gases

Liquefied Petroleum Gas: Liquefied petroleum (L.P.) gas is usually commercial propane with a certain mixture of propylene, but it may consist of commercial butane with mixtures of various butenes. It is 1.52 times as heavy as air. Any gas which leaks tends to accumulate at low levels in manholes, building basements and trenches. L.P. gas is not toxic, but in high concentrations is asphyxiating.

Leaks may occur during A.P.O. operations due to loose connections or the use of a faulty hose in L.P. gas plumbing equipment during the course of work in a manhole. Such faulty equipment can result in a concentration of gas being left in a manhole. L.P. gas is also widely used in residential, industrial and commercial areas remote from areas of gas reticulation. Leaks from any of these users or from filling operations must be guarded against.

Fluid Fuels: Petrol vapour is the most common hazard. It can be toxic or asphyxiating but the main risk is from fire or explosion. The vapour is very dense being about 3 to 4 times heavier than air and it will accumulate in low areas.

The extensive growth of fluid fuel storage and distribution points has increased the risk of petrol entering the network. Leaks from ageing installations at service stations and industrial premises, and spillage or overflows when filling underground storage tanks can result in petrol being carried through ducts and manholes as the water level varies in the network. As petrol floats on the surface of standing water, vapour forms and accumulates in ducts and manholes thus creating a fire or explosion hazard.

Spillages from road tanker accidents are no longer freak occurrences. Incidents have occurred where fires and explosions have severely damaged a main cable route and repair operations have had to be delayed due to the extremely hazardous conditions from petrol within and around the network. It is important to remain constantly alert for information about such accidents and check the network in the vicinity. Even though the network may not have been directly affected, petrol or dangerous chemicals could well have entered during the accident clearance operations.

Other Gases: While reticulated gases, industrial gases (L.P. gas) and fluid fuels (petrol vapour) may be regarded as the more common hazards, other equally dangerous gases described in Table 1 can also enter the network.

DANGEROUS CHARACTERISTICS OF GAS

Three undesirable characteristics of gases and their resultant effect must be considered when formulating safety procedures and practices for gas detection. The gases may have some or all of these characteristics. They may be:

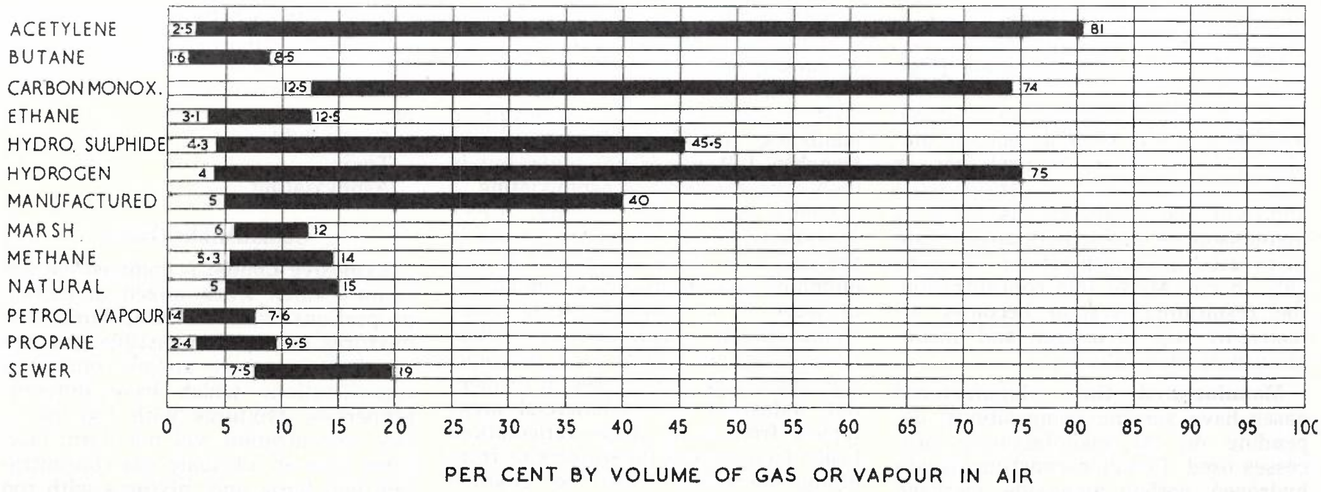
Combustible
Toxic
Asphyxiating

Combustible Gases

Explosive Limits: A combustible gas is one which when mixed in certain proportions with air will burn. For mixtures of any combustible gas and air there are three distinct ranges of concentrations which have different properties. Mixtures with too low a gas concentration will not burn, mixtures with an adequate gas concentration will burn, and mixtures with too high a gas concentration will not burn. Any mixture that will burn will explode if the burning occurs in a partially or fully enclosed structure. Therefore the concentrations, expressed in percentage by volume of gas in the gas-air mixture at the boundaries of the burning range are termed the Lower Explosive Limit (l.e.l.) and the Upper Explosive Limit (u.e.l.). The region between these two concentrations is the combustible or explosive range. Fig. 3 compares the limits of combustibility of the gases and vapours in air which may enter the network.

Gas-Air Mixtures: Mixtures which are too lean to burn do not constitute a fire hazard, although if a mixture should be close to the l.e.l. the possibility of changing conditions such as an increase in temperature or continuing leakage might change the composition sufficiently to make it combustible. Mixtures which are too rich to burn do not constitute a fire hazard under the then existing conditions, but since such mixtures are likely to be diluted with air, for example, by removal of manhole covers or during gas clearance operations, a hazardous situation develops as the mixture passes through the combustible range. Combustible mixtures of large volume in partially or wholly confined structures such as tunnels, ducts, manholes and exchange cable wells are particularly dangerous because if ignited, the force of the explosion may not only destroy the structure but endanger staff and damage equipment and property in the vicinity. The likelihood of severe destructive effects is increased in a structure capable of withstanding a higher pressure before failure occurs.

Sources of Ignition: In the underground network some typical sources of ignition are any type of flame or electrically produced sparks.



NOTE:—FOR EACH GAS THE LOWER FIGURE IS THE L.E.L. AND THE HIGHER FIGURE IS THE U.E.L.

Fig. 3 — Explosive Limits of Gases and Vapours in Air.

Toxic Gases

A toxic gas like carbon monoxide is harmful in very small quantities and has a cumulative effect when breathed over a long period. In higher concentrations it can have a very rapid effect. For example, it is unsafe to work in an atmosphere for more than 45 minutes if it contains 0.05% by volume of carbon monoxide (500 parts per million). The recognised Threshold Limit Value* in industry for carbon monoxide is 50 parts per million. Carbon monoxide is also a combustible gas but, from the data in Fig. 3, its l.e.l. is over 2,000 times its T.L.V.

As manufactured gas is phased out in many areas the risk from carbon monoxide poisoning will be substantially reduced. Considerable emphasis has always been placed on the risk of carbon monoxide entering the network from the exhaust fumes of stationary vehicles or mechanical plant adjacent to open manholes. Provided the normal precautions of operating plant on the lee side of underground openings is followed, no hazard can arise from this source. Where operational conditions preclude this arrangement, forced draught ventilation will avoid any hazard. Tests overseas have proved that carbon monoxide produced by vehicles under heavy traffic conditions cannot 'spill' into manholes, because while carbon monoxide with a relative density of 0.97 is only slightly lighter than air, the emitted exhaust fumes are hot and therefore rise.

Asphyxiating Gases

Asphyxiating Gases are harmless in themselves but do not support life. If their concentration is large they reduce the quantity of oxygen reaching the lungs and so cause suffocation. They can act quickly, for example, carbon dioxide because of its high density can collect in high concentrations at the bottom of a shaft and under these conditions can cause very rapid loss of consciousness.

Some asphyxiating gases, notably carbon dioxide, are not combustible and the detection devices contemplated for general issue in the A.P.O. do not detect it. Adequate continuous ventilation is required in any situation where dangerous concentrations of carbon dioxide could occur.

Most asphyxiating gases are combustible and concentrations lower than the l.e.l. contain adequate oxygen to avoid adverse effects.

* The Threshold Limit Value (T.L.V.) is a concentration exposure to which over an eight hour workday and a 40 hour week will not normally cause any adverse effects.

GAS ENTRY CONTROL METHODS

Limitation of the effect of entry of gas into an underground network requires adequate methods for:

- Reducing the quantity of gas that can enter the network.
- Detecting such entry of gas that does occur.
- Dispersing the gas that has entered.
- Reporting and recording the gas entry to effect permanent restoration of the fundamental cause.

This section considers entry control methods and later sections discuss the other aspects.

In the past, A.P.O. duct routes were not constructed to be gas tight. Gas or fluids leaking from underground pipes or storage areas nearby may therefore enter and accumulate through a considerable area of the network. Several measures are being implemented to control the entry of gas into the existing network, and modern developments in duct materials and jointing compounds provide a basis for new construction to be made virtually immune from gas entry.

Duct Sealing

Gas tight seals are being developed for installation in both occupied and unoccupied ducts entering cable chambers, tunnels and buildings where gas may be expected to be a hazard. Duct seals can provide a control method for gas and fluids throughout the network, for example to seal off a section or area of a route where marsh gas may be prevalent or an area of recurring gas leaks. Such areas need to be treated as hazardous at all times.

A bulkhead wall with sealed duct entries can be used to isolate an exchange from a tunnel or duct network. Similarly, a bulkhead wall may be utilised as the means to sectionalise a tunnel network (Fig. 4).

Fixed Ventilation

Grids or manhole covers with ventilating holes can provide natural ventilation in situations where gas may be expected to be a continuing hazard. Such situations would be in areas which are completely paved such as shopping or commercial centres. Similar forms of fixed ventilation may be required in certain exchange cable chambers.

The concept of exhausting the air conditioning system via cable entry chambers to prevent any accumulation of gas is being investigated for incorporation in the design of standard exchange buildings. For existing buildings forced ventilation may be necessary in areas regarded as potentially hazardous.

TABLE 1 — DANGEROUS GASES AND LIQUIDS WHICH MAY ENTER THE UNDERGROUND NETWORK

Type	Dangerous Element	Effect	How Detected	Possible Source
Reticulated Gases				
Natural gas	Methane	Asphyxiating and explosive	Combustible gas detector	Areas adjacent to natural gas high pressure pipelines and gas reticulation.
Tempered liquefied petroleum gas. Simulated natural gas.	Propane	Asphyxiating and explosive	Combustible gas detector	Areas of T.L.P. and S.N. gas reticulation.
Manufactured gas	Carbon monoxide, hydrogen, methane	Carbon monoxide is highly toxic and all elements are explosive	Combustible gas detector where carbon monoxide content is 10% or less. Carbon monoxide gas detector where carbon monoxide content is above 10%.	Areas of manufactured gas reticulation.
Soil Gases				
Hydrogen sulphide	Hydrogen sulphide	Toxic and explosive	Combustible gas detector. Smell like rotten eggs.	Fermentation of sewage
Sewer gas	Methane	Explosive	Combustible gas detector.	Sewered areas or in vicinity of sewer mains.
Marsh gas	Methane	Asphyxiating and explosive	Combustible gas detector.	Areas of coal, or oil shale deposits, extensive areas of made-up ground and decaying vegetation.
Carbon dioxide	Carbon dioxide	Asphyxiating	No detection equipment being supplied. Physical symptoms (headache, dizziness, air hunger) provide warning.	Decaying vegetation.
Industrial Gases				
Liquefied petroleum gas	Propane or butane	Asphyxiating and explosive	Combustible gas detector	Leaks from: LP gas plumbing equipment. Industrial bulk storage. Cylinders or tanks for household or commercial use.
Acetylene	Acetylene	Toxic and explosive	Combustible gas detector	Leaks from oxy acetylene welding equipment.
Carbon monoxide	Carbon monoxide	Toxic in very small quantities and explosive	Carbon monoxide gas detector	Exhaust gases from petrol or oil fuelled internal combustion engines operated adjacent to manholes.
Ammonia	Ammonia	Irritating	Smell	Vicinity of industrial plants. Refrigerants.
Sulphur dioxide	Sulphur dioxide	Irritating	Smell	Vicinity of industrial plants. Refrigerants.
Fluid Fuels				
Petrol	Fumes	Toxic and explosive	Combustible gas detector. Oil film on moist surfaces	Leaks from: Service stations or industrial premises. Overflows when filling underground tanks. Spillage from road tanker accidents.
Fuel Oils	Fumes	Irritating and explosive	Combustible gas detector	
Oxygen Deficiency				
Foul air	Lack of oxygen	Asphyxiating	No detection equipment being supplied. Physical symptoms (headache, dizziness, air hunger) provide warning.	Poor ventilation in deep manholes or manholes with shaft or tunnel entrances.

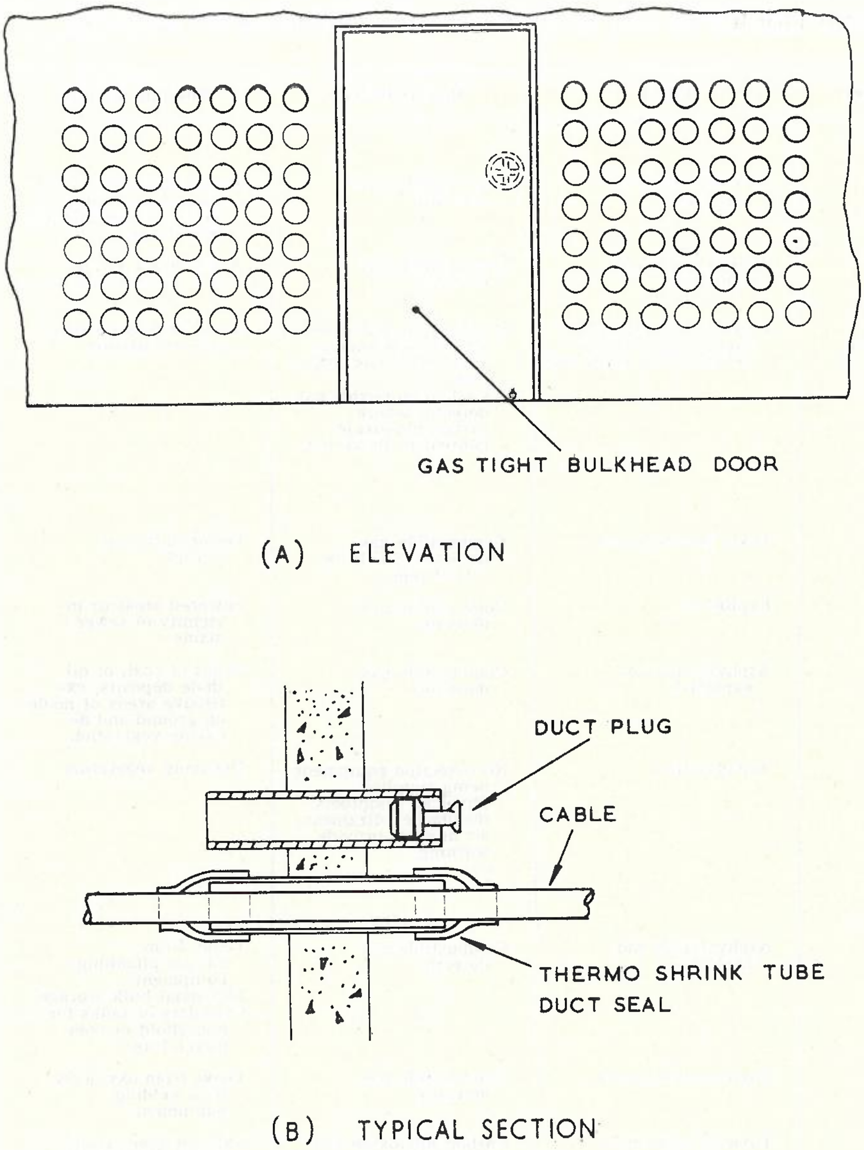


Fig. 4 — Bulkhead Wall.

DETECTION, DISPERSAL AND REPORTING METHODS

General

No matter how rigorous the methods of control of gas entry are, it will be necessary for staff in some areas to have personal issues of detection equipment and for staff in all other areas to have access to detection equipment. Gas dispersal equipment will need to be readily available and an effective reporting and recording procedure will be required.

Detection of Combustible Gases and Fluid Fuel Vapours

Electronic equipment to detect combustible gases or fluid fuel vapours has been developed overseas. Instruments based on this development are being made available to A.P.O. staff. Details of the principles and operation of the different forms of instrument are described later.

In areas where gas of any type is reticulated, one instrument as personal issue will be provided for staff required to work in underground structures, while in areas where gas is not reticulated one or more instruments will be provided for each Lines Supervisor's district depending on the size of the underground network.

Working precautions will include testing for gas before any underground structure is entered and before introducing any flame or spark producing device into underground structures. Where staff work for the major part of their time in underground structures they will be provided with a portable gas alarm which will continuously monitor the atmosphere. Combustible gas detectors will equip staff with facilities to ensure their own safety and will provide a means for daily sampling and monitoring of the network for gas over a wide area.

Combustible gas detectors are also suitable for use as gas alarms for buildings.

Carbon Monoxide Detection

As carbon monoxide is a combustible gas, the combustible gas detectors can detect it. However it is also highly toxic and gas concentrations below those detectable by the combustible gas detector could be dangerous.

A carbon monoxide detector which is a hand operated device which depends on a chemical reaction between sodium chlorpalladite (previously palladium chloride) and carbon monoxide will detect all toxic levels of carbon monoxide. Unfortunately the chemical has a limited life of one year. The detector has been in use in Australia for many years and must still be used in areas where manufactured gas with a carbon monoxide content over 10% by volume is reticulated.

In areas where manufactured gas has less than 10% carbon monoxide, any toxic concentration of carbon monoxide will be detectable by combustible gas detectors and there will be no need for carbon monoxide detectors to be used.

Asphyxiating Gas Detection

Asphyxiating gases can also be detected but the type of situation conducive to the accumulation of foul air or of concentrations of carbon dioxide are predictable and detection equipment will not be on general issue to A.P.O. staff.

Odorising of Gases

Some gases are deliberately odorised to aid in their detection, but in practice to depend on smell is a most unreliable method. Many combustible or toxic gases have no smell, and added odorants may be absorbed or changed in passing through soils or even through pipes. Many people have an impaired sense of smell and even a normal person becomes accustomed to a persistent odour and ceases to notice it after a time. While it cannot be denied that smell has on occasions been responsible for avoiding an accident, fires and explosions have occurred where no smell was detected even though gas was present.

Portable Ventilating Equipment

Portable forced draught ventilating equipment will be provided on a liberal scale to enable gas or foul air to be dispersed when it is detected in the network or to prevent it accumulating during working operations. Initially the ventilators are being incorporated with heaters and 240 volt alternator sets as a general purpose unit to provide for ventilation, heating and power, a common requirement for fault conditions. The 3.7 kW (5 h.p.) engine and the heater are both fuelled with L.P. gas. A 9 kg (20 lb.) cylinder of L.P. gas will provide sufficient fuel for a working day with the complete unit operating at maximum output.

The ventilator has a fixed output of 11.3m^3 (400 ft^3) of air per minute and will provide between 1 and 2 complete air changes per minute for average size manholes.

As asphyxiating gas detectors are not being used and as combustible gas detectors cannot detect foul air or concentrations of carbon dioxide, when tests in a shaft entry or deep manhole show that no combustible gas is present, such manholes should be ventilated for 2 minutes before they are entered. Continuous ventilation will then ensure that a supply of fresh air is maintained while staff are working.

Recording Gas Incidents

The introduction of a reporting and recording procedure for all gas incidents, from the detected presence of gas to more serious incidents causing fires and explosions will bring to notice areas which may be defined as significantly hazardous and requiring action for gas precautionary methods above the norm. It will also enable the overall gas hazard to be evaluated and determined at appropriate intervals and will provide a base against which the effectiveness of the various control methods can be gauged.

COMBUSTIBLE GAS DETECTORS

Combustible gas detection equipment suitable for use in the underground network are either portable detectors for use by staff to spot sample or continuously monitor an atmosphere before and while working in the network, or fixed detectors which continuously monitor the atmosphere in certain locations.

Principle of Operation

The same basic principle of operation applies to portable detectors or fixed installations. A sensitive filament operated at a controlled temperature is connected to one arm of a wheatstone bridge. Any combustible gas in a sample of the atmosphere when drawn or diffused into the combustion chamber of the instrument will burn and raise the temperature and therefore affect the electrical resistance of the sensitive filament. Detectors may be fitted with a meter indicating the degree of unbalance of the bridge and graduated to directly indicate the concentration of combustible gas as a percentage of the l.e.l., while those fitted with an audio or visual alarm, or both, will trigger the alarm at one or more selected points in the range from 10% up to 50% or more of the l.e.l.

The heat of combustion at the l.e.l. is approximately constant for a variety of combustible gases, Table 2 indicates typical values for some gases. The reading on the meter is therefore approximately correct for any combustible gas. However, gases are also affected by a number of variables such as temperature, amount of oxygen in the atmosphere under test and differing factors of safety in instrument calibration. Therefore to be completely safe in the operational situation, any reading on the meter is to be treated as a dangerous concentration of gas.

Portable Detectors

Spot Sampling Detectors: These detectors can be used to sample the atmosphere in an underground structure by:

- Hand aspiration, where a sample is drawn through a sampling hose into the combustion chamber of the instrument only while the rubber bulb is operated by hand.
- Electric pump sampling, where a sample is drawn at a constant rate into the combustion chamber of the instrument while it is switched on.
- Diffusion, where the detecting filament is fitted in a sampling probe at the end of a cable and the probe is placed in the atmosphere under test.

Hand aspiration types are cheaper and can meet the requirements where staff may work intermittently in underground structures for short periods, where an area of the network is being surveyed for the presence of gas or for tracing the location of a leak.

Electric pump sampling types have advantages in that they are more convenient to use especially where a number of tests have to be made, for example, before entering and at intervals while at work in an underground structure. As the electric pump samples at a constant rate, the meter gives a more stable reading at low percentages of the l.e.l. and provides advantages in detecting rich mixtures above the u.e.l. where the operator must look for a momentary full scale reading before the meter needle falls back to zero.

Diffusion types have several drawbacks for spot sampling and are not being used in the A.P.O.

TABLE 2 — COMBUSTION PROPERTIES OF GASES

Gas	Lower Explosive Limit (percent)	Calorific Value of 1 m^3 of Gas (kJ)	Calorific Value of 1 m^3 of gas-air Mixture at Lower Explosive Limit (kJ)
Butane	1.6	127,296	2,037
Carbon Monoxide	12.5	14,817	1,852
Ethane	3.12	67,090	2,093
Hydrogen Sulphide	4.3	47,857	2,057
Methane	5.3	37,941	2,010
Petrol Vapour	1.4	152,328	2,132
Propane	2.37	96,950	2,297

Continuous Monitoring Detectors: These detectors will continuously monitor an atmosphere where staff are working and give an early indication of a hazardous situation developing. They are usually powered by a nickel cadmium battery with a capacity to operate for at least a working day before recharging. Diffusion type detector heads are best for these instruments and may be located remotely on a short length of cable.

A continuous monitoring portable gas alarm with fail safe features such as an alarm test before use and alarm to give warning that the power supply needs recharging; with an audio and visual alarm pre-set to trigger at say 10% - 20% of the l.e.l.; with a plug-in battery pack with capacity for 40 hours operation; and with a meter to enable gas to be detected below the pre-set alarm level, is regarded as the best safety equipment for staff who work for the major part of their time in underground structures.

Factor of Safety: To ensure safety in the operational situation, any positive reading even below 10% of the l.e.l. is to be regarded as dangerous and requiring immediate action. Such action can enable the source of the gas leak to be traced and the gas cleared from the network before a serious situation can develop.

Fixed Detection Equipment

This equipment is designed for permanent installation where immediate warning of a build-up of gas is necessary due to the serious consequences which might result from a fire or explosion. Typical locations where this protection is desirable are cable tunnels or cable entry chambers at telephone exchanges where gas can enter due to difficulty in providing effective duct seals. For fixed installations, two basic methods can be used for continuously monitoring an atmosphere, by diffusion or by sample drawing.

Diffusion Sampling: In diffusion sampling, the flameproof detector heads containing the filament are located at points where the atmosphere is to be monitored and a control unit is situated in a non-hazardous area. A basic installation suitable for an exchange cable chamber may consist of one or two detector heads located adjacent to the points of duct entry with the control unit situated adjacent to the test desk. For larger installations control units to differentiate between detecting locations may be necessary. The detector heads may be located at varying distances up to a radius of about 1.5 km (0.81 mile) from the control units. Positioning of the diffusion detector heads is important and factors such as the direction of natural air currents and whether the most likely gas to be guarded against is lighter or heavier than air must be considered.

Sample Drawing: The sample drawing system can provide for single point or multi-point sampling. The atmosphere for test is drawn through remotely situated filter points along small bore tubes to the control unit situated at a central point in a safe location. The control unit has a gas detection chamber and an automatic sample point selector where the atmosphere from each sampling tube is tested in sequence on a fixed time cycle. In multi-point sampling, as the cycle of tests proceeds, a panel of lights indicates the point under test and if gas is detected an alarm is operated and a panel light indicates the point from which the combustible gas sample is received. Flowmeters are provided to give an alarm if any significant change occurs in the sampling flow rate. Depending on the type of system and its components more that 16 sampling points can be provided located up to about 1.8 km (1.12 mile) from the control unit.

Alarm Levels: Fixed installations are generally operated with a two stage alarm set at 20% and 40% of the l.e.l. Various facilities can also be incorporated such as the operation of recorders and control of ventilation equipment when the alarm is activated.

CONCLUSION

Gases and fluids can leak into the underground network at any time and in any place from a variety of sources. This leakage is difficult to prevent and constitutes a serious hazard to life and property but it can be controlled. Hazardous situations can be detected and removed by a number of methods such as duct sealing, ventilation, fixed gas detection installations and constant sampling and monitoring of the atmosphere with portable detectors over a wide area in the network.

Portable gas detection and monitoring equipment will equip staff with adequate facilities to detect the presence of combustible or toxic gas before they enter the network, and during work operations they will be continuously safeguarded.

ACKNOWLEDGEMENT

The author acknowledges the substantial contribution made by officers of the Chemistry and Metallurgy Section, Engineering Planning and Research Division, during the testing and evaluation of combustible gas detection equipment, and the staff of State Administrations in carrying out field investigations.

PRESENTATIONS TO THE FORMER EDITOR-IN-CHIEF AND GENERAL SECRETARY

Friday, the 13th to some people conjures up visions of black magic, superstition and jinxes. But there was no air of pessimism at the October the 13th evening function which the Council of Control of the Telecommunication Society of Australia held recently in Melbourne to express appreciation of the services of two of its retiring office-holders. Former General Secretary Mr. Ron Kitchenn and former Editor-in-Chief Mr. Vern White, whose retirements were reported in recent issues of the Journal, were guests of honour at the function attended by some thirty other guests.

The Chairman of the Council of Control Mr. Neil Macdonald made the presentations to Ron and Vern, and Mr. Norm Cameron, Chairman of the Victorian State Committee of the Society, presented Ron with his Certificate of Life Membership. This honour is reserved for those members of the Society who make an outstanding contribution to its progress, and in this regard Ron is a most deserving conferee. Mr. Vern White was conferred as a Life Member in 1961.

Amongst the guests at the function were some well known identities of the past who served the Society and the Journal in its early days.

It was good to see Mr. Syd. Witt looking fit and well. Present day members may be unaware of just how important a role Mr. Witt played in the early formation of the Society. He was a committee Member dating from 1913, and in 1932 he was elected first President of the reformed Postal Electrical Society, and again held that position in 1942. He was active on the Council of the Society throughout the period. Present day members in the Research Subdivision should be grateful to Mr. Witt for undertaking the establishment of the Research Laboratories in 1923.

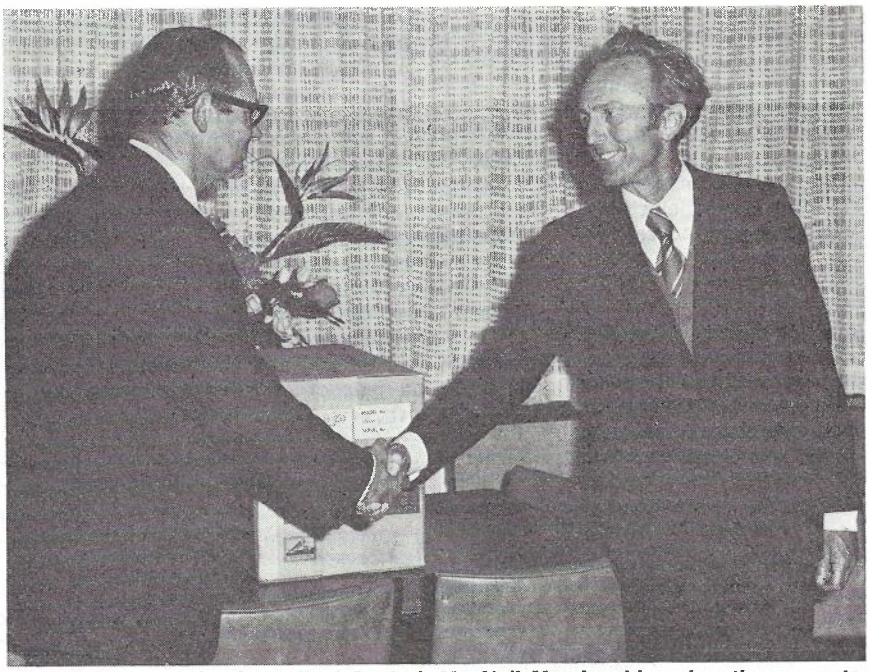
Another stalwart of the early days of the Society and attending the function was Mr. Frank McCarter, who was President of the Society in 1938 and a committee member from 1938 until 1952.

The Society is also indebted to Mr. Clyde Griffiths for his interest in the Society over several decades. Commencing as a committee member in 1934, he was active in this role until 1947. Following the reconstitution of the Society on a Commonwealth wide basis in 1960, Mr. Griffiths presided over the Council of Control for varying periods in 1961-62 and 1966-68. He also served on the Board of Editors from 1944 to 1955.

Also deserving of mention are Mr. Jack Vickers and Mr. Clarrie Brown who were committeemen of the Postal Electrical Society from 1957 to 1960.

Space limitations prevent us from extending this list of well-known names beyond those who have retired from their departmental careers. Judging from the keen interchange of views between present council members and editors and their predecessors, the evening was a memorable one for those attending.

The present Secretary of the Council of Control, Mr. Noel Ross, discusses the Life Member Certificate with former Secretary Ron Kitchenn.



The Chairman of the Council of Control, Mr. Neil Macdonald, makes the presentation to the former Editor-in-Chief Mr. Vern White.

PRINCIPLES OF TRUNKING AND SWITCHING IN AUTOMATIC TELEPHONE EXCHANGES

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

Editorial Note: This article is a chapter from a monograph on the principles of telephony to be published by the Telecommunications Society of Australia. It is a longer article than is preferred for the Journal, but is published in full in this issue because the material will be of interest to practically all readers of the Journal, irrespective of their field specialisation.

INTRODUCTION

The article outlines the underlying principles of the switching and trunking arrangements of automatic telephone exchanges. The topic is treated under the following headings:

The Elements of an Exchange
- **The Crosspoint Concept in Switching Systems**
  - General
  - Mechanical Switches as Crosspoint Arrays
    - Uniselector
    - Bi-motional Selector
  - Relay Type Crosspoint Arrays
    - Relays
    - Crossbar Switches
  - Electronic Switches as Crosspoint Arrays

The Exchange as a Collection of Crosspoint Arrays
- The Small Crossbar Exchange
- Large Exchanges
  - Preselection
    - Full Availability
    - Graded Access
    - Link Trunking
  - Group Selection
    - Two Stages
    - Three or More Stages
    - Entraide
  - Final Selection
- Optimum Size of Crosspoint Arrays

ELEMENTS OF AN EXCHANGE

A terminal exchange is one which has subscribers' lines and junctions connected to it, and is required to establish three kinds of call:

(i) A call between two subscribers both connected to that exchange (a local, or internal call).

(ii) A call originated by a subscriber connected to this exchange and directed to a subscriber at another exchange and which is therefore connected to a junction to that exchange, or to a tandem exchange (an outgoing call).

(iii) A call originated elsewhere, requiring connection from the junction on which it enters the exchange to the called subscriber (an incoming call).

In most exchanges the path of a local call begins by sharing the same switching equipment as outgoing calls and finishes sharing switching equipment with incoming calls so that it is possible to regard a local call as a combination of an incoming and an outgoing call, linked together by a 'local junction'. There is usually some part of the exchange wiring which can be logically defined as the 'local junction', and in some cases there is actually a group of relays (relay set) providing signalling and other facilities at this point. Such a relay set is usually called a 'cord circuit' because it performs analogous functions to a similar group of relays on each pair of cords used to switch calls in a manual exchange.

By adopting this viewpoint it is necessary to consider only two types of call via a terminal exchange; outgoing and incoming.

Nearly all subscribers' lines are required both to make calls and receive them, and are therefore bothway circuits in respect to signalling and switching. Trunk or junction lines on the other hand are not necessarily required to provide for bothway switching, and the junctions between a pair of exchanges may be divided into two groups, one for each direction of switching, or used as a single group of bothway junctions. The choice between these alternatives is a matter of economics, which generally favour bothway junctions if the total number required is small.

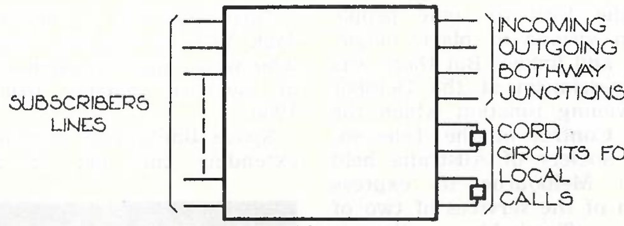


Fig. 1.

Since every connection required in a terminal exchange is between a subscriber at one end and a junction or cord circuit termination at the other, the switching task can be specified in the form shown in Fig. 1.

This shows the exchange as a switching unit with two sets of terminations. One set terminates subscribers' lines, while the other terminates junctions and cord circuits, and the machine is required to make connections as desired between a specified subscriber's terminal and a specified junction or cord circuit. The request for switching may arise from either end and the control of the machine must be bi-directional. The illustration says nothing about the internal structure of the machine which, in a large exchange, usually requires the operation of several switches to establish one connection.

The requirement of switching in either direction causes difficulties with some types of switches and, because of this, exchanges are sometimes organised as two more or less independent units as shown in Fig. 2.

In this case there are two independent switching units, one for each direction of calling. They are each one way devices, and therefore may be simpler, in addition to which it is possible to take advantage of dif-

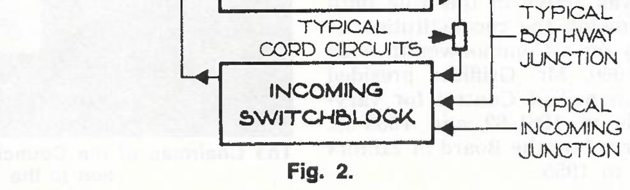


Fig. 2.

*Mr. Freeman is Supervising Engineer, Fundamental Planning, N.S.W. See Vol. 18, No. 3, page 287.

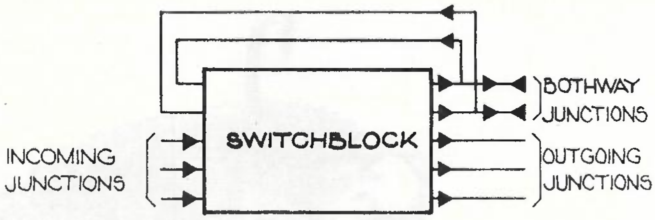


Fig. 3

ferences in the nature of the switching task in each direction.

For an incoming call, a specific incoming junction must be connected to a specific subscriber, and no other, so that the input and output points are both defined. For an outgoing call it is sufficient to select any free junction of the group to the desired distant exchange, since they are all capable of being used to complete the call. The process of switching to a specific line is called 'individual' or 'final' selection, while the process of switching to one line out of a group is called 'group' selection. As might be expected, group selection is generally a simpler task than final selection, and therefore the outgoing switching machine in Fig. 2 may be less complicated and expensive than the incoming one.

On the other hand, subscribers' lines, and bothway junctions must appear on both machines and be provided with directional switching. In many exchanges there is a mixture of the two techniques of Figs. 1 & 2 and this will be discussed later when specific types of exchange are described.

A tandem exchange is one to which only junctions are connected and there are two basic methods of construction. Fig. 3 shows the method used when most trunks are unidirectional and requires a one way switching machine.

If a large proportion of the junctions are both way, the system shown in Fig. 4 is sometimes used. The left hand side of the switching machine provides terminations for junctions, while the right hand side terminations are linked together in pairs — analogous to the cord circuits shown in Figs. 1 and 2. Any call must be switched from the junction on which it is incoming to one side of a link, and then from the other side of the link back to the junction to which it must be switched. The advantages and disadvantages of the two alternatives depend very much on the details of the various types of switching equipment and control circuits.

The size of terminal and tandem exchanges varies over an enormous range; there are terminal exchange in country areas with fewer than 20 subscribers and two or three junctions, while in the large cities exchanges of 10,000 lines are common, and some are expected to grow to over 40,000 subscribers and 10,000 junctions in the next 20 years. Similarly tandem exchanges range from sizes less than 100 trunks to a few of a planned size of 50,000 trunks. The variety of detailed requirements even between exchanges of similar size is so great that there is no possibility of standardised exchanges except in very small sizes, and the larger ones are custom built from convenient sized switching units used as 'building blocks'.

THE CROSSPOINT CONCEPT IN SWITCHING SYSTEMS

General

A considerable body of theory has been developed in respect of the methods of interconnecting switches to form a telephone exchange. Most of this theory ignores the physical details of the switches and describes them as arrays of crosspoints, and the complete assembly, shown as a block in Figs. 1 to 4 as a connecting network, or a speech path network.

A crosspoint is a device which will make or break a connection between two sets of wires. One such device is a relay with a number of springsets as shown in Fig. 5A.

This particular crosspoint has 3 wires in each set; and three springsets, but crosspoints may have more or fewer wires if required. In fact, some parts of crossbar control systems have crosspoints with over 100 wires.

The usual symbol for a crosspoint is two intersecting lines as shown in Fig. 5B, and if it is necessary to indicate that it is operated a diagonal cross as in Fig. 5C is used.

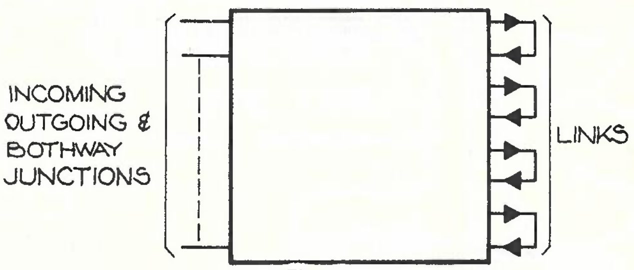


Fig. 4

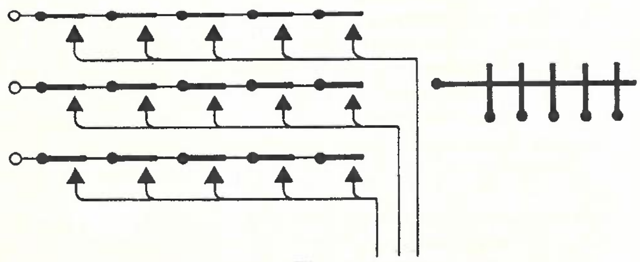


Fig. 6

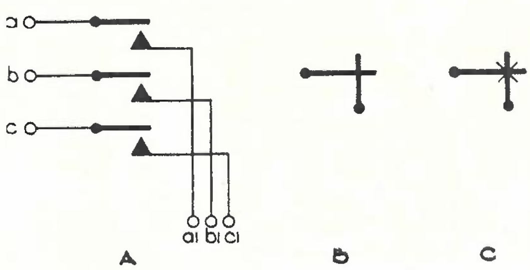


Fig. 5

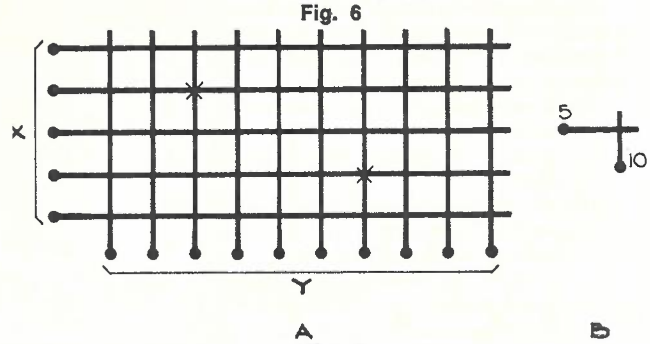


Fig. 7

Crosspoints are usually assembled to form 'rows', and arrays. Fig. 6 shows a row of five crosspoints, in relay contact form and in crosspoint symbols, while Fig. 7 shows a 5 x 10 array of crosspoints.

This array is made up of 50 crosspoints in a 10 x 5 array linking the 5 terminations marked X to the 10 terminals marked Y. Clearly, by operating the appropriate crosspoint it is possible to connect any particular X side termination to any particular Y side termination, and to set up a maximum of five such connections simultaneously. Crosses on the diagram show two possible connections. The symbol shown in Fig. 7B is frequently used to show this kind of rectangular array.

A crosspoint array of this kind can be constructed in many different ways, and the various forms can be classified into those using relay like crosspoints (including crossbar switches), those using mechanical switches, and those using active electronic devices.

Mechanical Switches As Crosspoint Arrays

Uniselectors: Mechanical devices are the most easily understood, and Fig. 8 is an illustration of one of the most widely used switches in a step-by-step exchange, which is known as a uniselector. Its construction and operation is more clearly shown in the exploded drawing in Fig. 9. The three main components are the wipers and wiper carriage, the bank contacts, and the drive mechanism.

The wipers are the movable contacts of the switch, and are mounted on the wiper carriage, forming an assembly which allows the wipers to rotate over the bank contacts. The bank consists of sets of fixed contacts located on a circular arc, so that by suitably positioning the wiper carriage, each wiper will be in contact with one of the bank contacts. In the illustration there are four sets of wipers, and the bank contains 25 rows of four contacts, so that the wipers and bank form a 25 position, 4 pole switch. The wipers are stepped sequentially from one bank position to the next by the drive mechanism, consisting of an electro-magnet operating on a ratchet and pawl. Because the bank contacts are located on an arc of 180°, each wiper has two arms, so that as one set of wipers is leaving the 25th contact, the opposite arms are entering the bank at the first contact.

There are several different types of uniselector, operating on this principle in use in the A.P.O., with minor

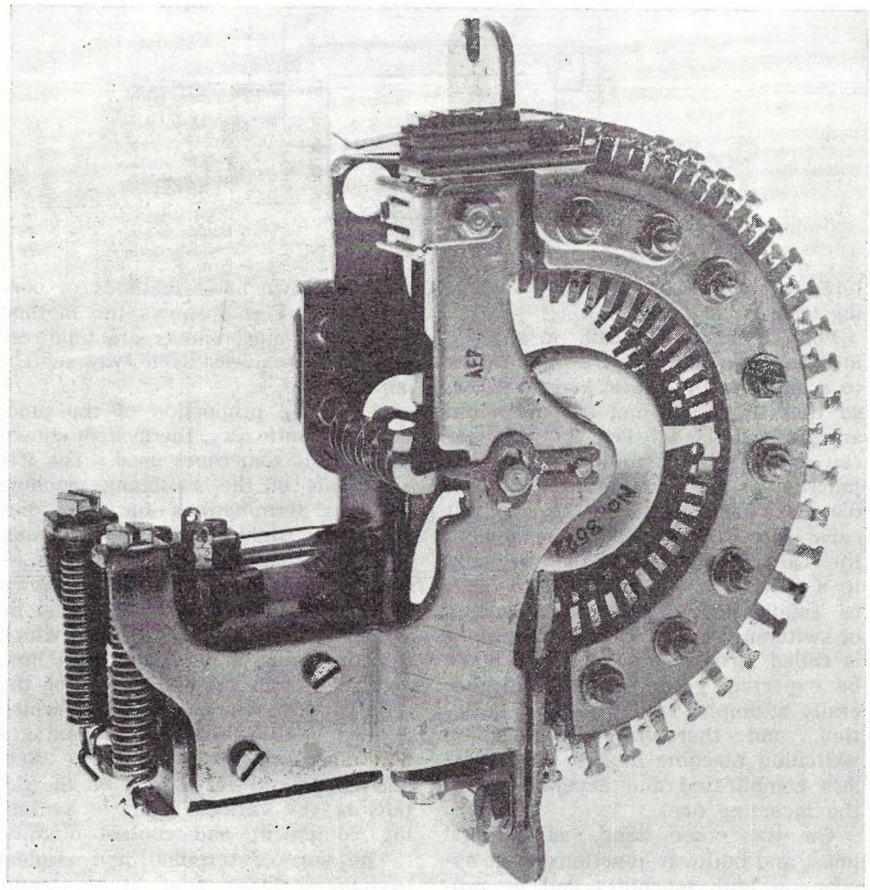


Fig. 8.

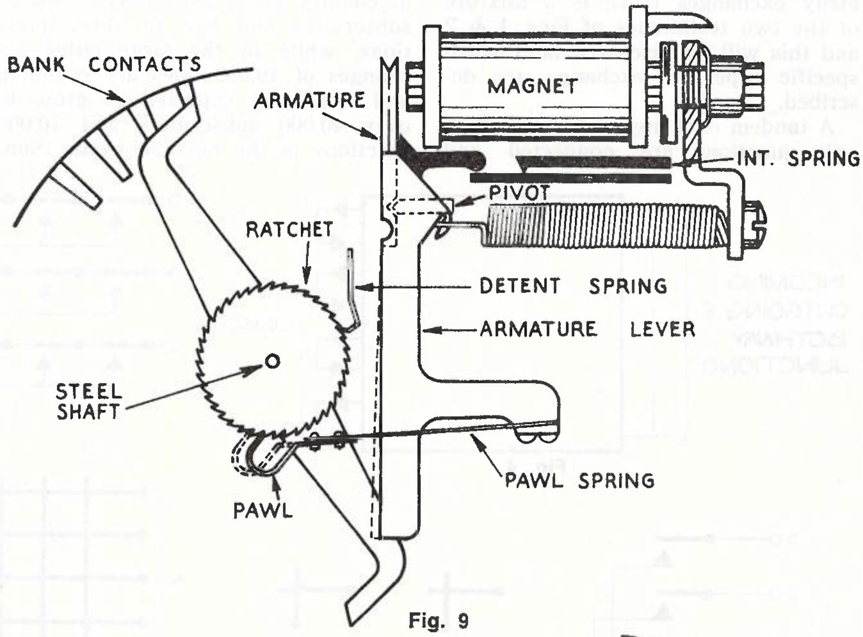


Fig. 9

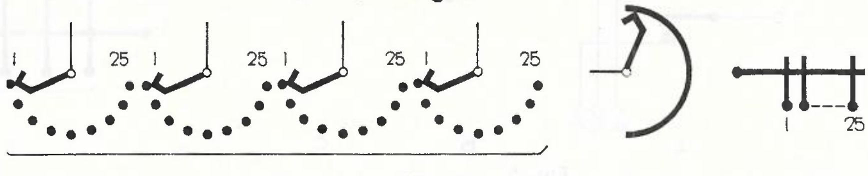


Fig. 10.

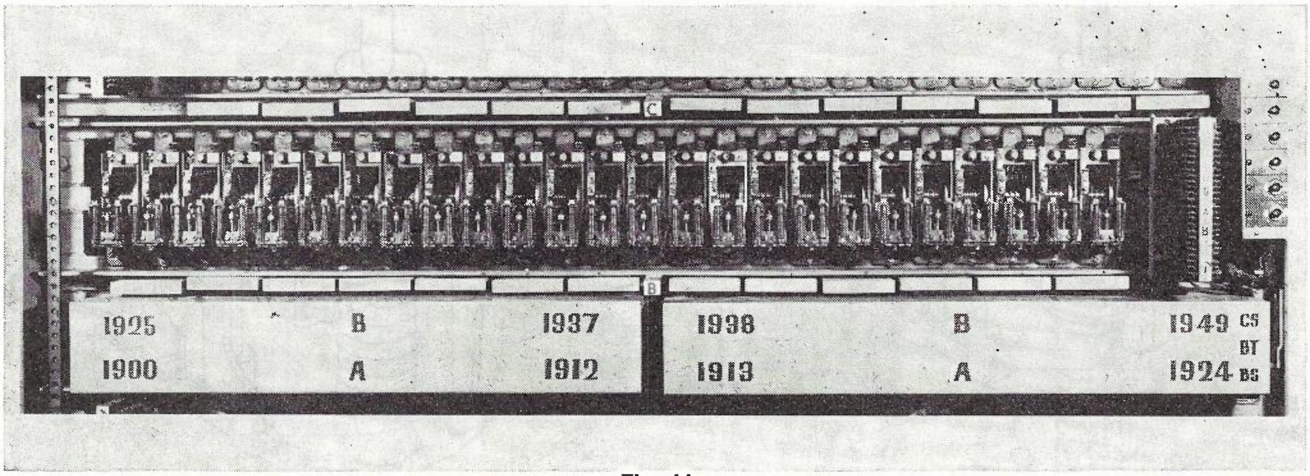


Fig. 11

variations in detail, and information about them is available in A.P.O. engineering instructions. The number of wipers may vary from 3 to 10.

This switch is usually represented in circuits by the symbol of Fig. 10A, in which every wiper and its corresponding bank contacts are shown, or in circuits where less detail is needed by the symbol of Fig. 10B. The switch performs the function of a row of 25 crosspoints, as described earlier, and can therefore be represented by the symbol of Fig. 10C.

If several switches of this kind have their bank contacts multipled together they then form a crosspoint array of the type shown in Fig. 7. For example, Fig. 11 is a photograph of a 'shelf' of 25 such switches with their outlets multipled to make a 25 x 25 crosspoint array.

The wiper carriage rotates through 180° to step over 25 positions, and each wiper has two arms 180° apart, so that as one arm leaves the bank at the 25th position, the opposite arm enters it at the 1st position. The switch can also be used as a 1 x 50 crosspoint array by using 'single ended' wipers. These wipers, have only one arm and contact the bank for only 180° of each revolution of the wiper carriage. By having two such wipers 180° apart, moving over 2 different arcs and joined together the switch effectively has 50 positions, as shown in Fig. 12.

For the first half revolution wiper 1 contacts outlets 1 to 25 of arc 1, while wiper 2 is free of the bank, while for the second half revolution wiper 2 contacts outlets 26 to 50 on arc 2 so that the pair of wipers can contact 50 outlets. To get 3 wire crosspoints, it would be necessary of course to provide a bank with 6 rows of contacts, and 3 pairs of single ended wipers.

Another way of getting 50 outlets which is of more general application is by means of 'wiper switching', and for this method, double ended wipers are used with an auxiliary 'wiper switching' relay to connect one or the other set of arcs as shown in Fig. 13.

This shows 4 arcs being used to provide a 1 x 50 2 wire crosspoints array but in practice 6 to 10 arcs would be used, giving 3, 4 or 5 wire crosspoints. One wiper switching relay is needed to select the desired sub-set of 25 outlets, under control of the logic circuitry of the selector. If enough arcs are available, additional wiper switching relays can be used to give more crosspoints per switch position and in one extreme case a 50 position, 16 arc uniselector has been used to give five, 3 wire crosspoints for each position so that the switch becomes a 1 x 250 crosspoint array.

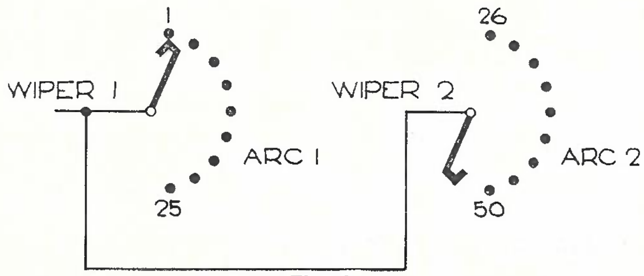


Fig. 12

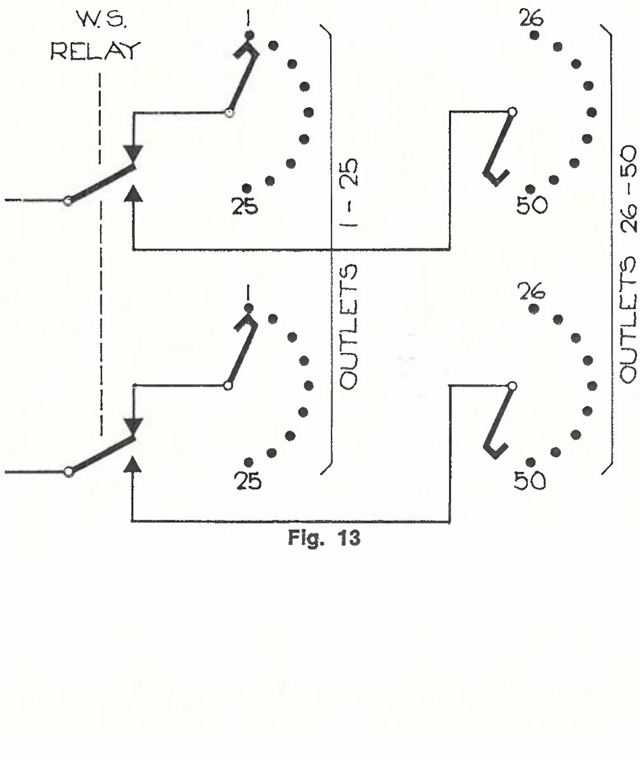


Fig. 13

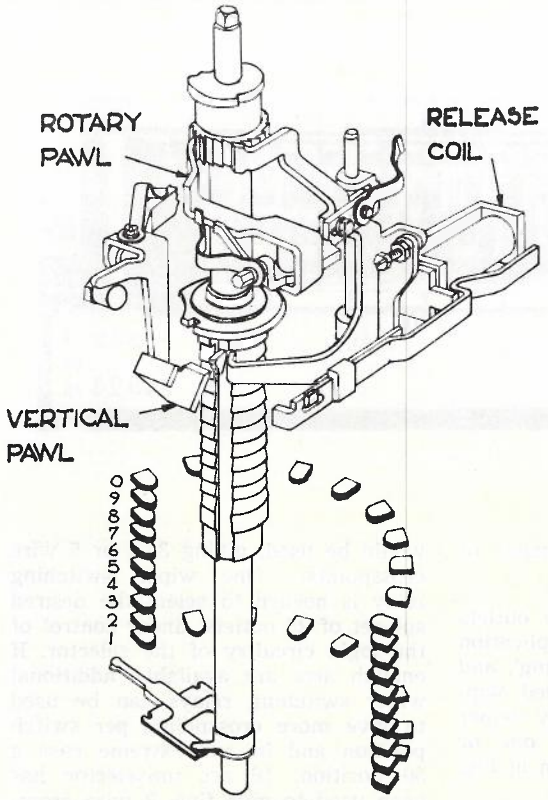


Fig. 14A

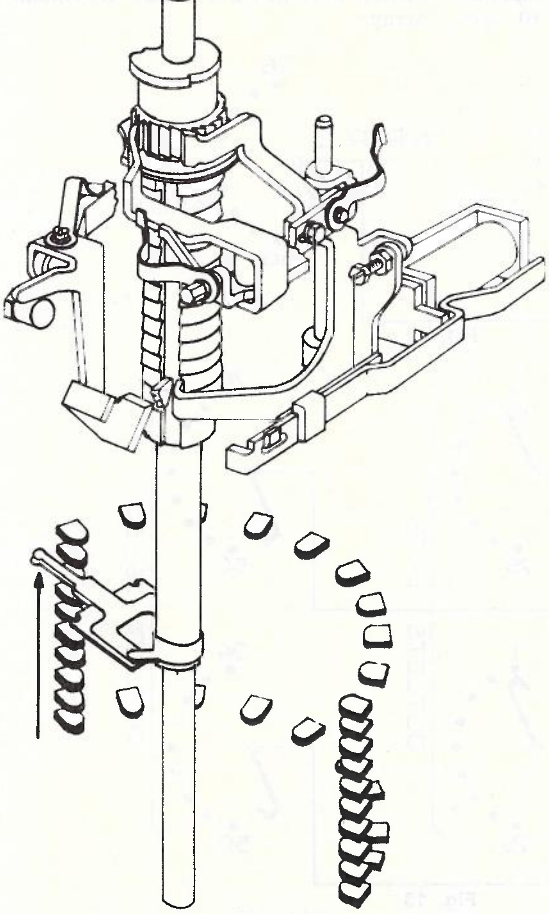


Fig. 14B

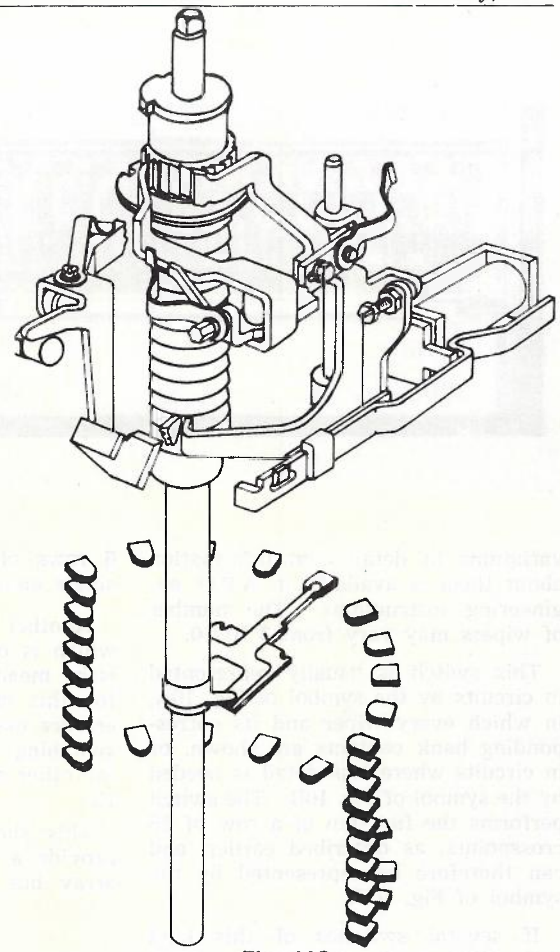


Fig. 14C

Bi-motional Selectors: Another very important mechanical switch, and the mainstay of step by step automatic telephony is the bi-motional selector. It is essentially a 100 position switch and as its name implies, the process of stepping to a particular position involves two separate actions. The wipers are carried on a shaft, which can move vertically to one of 10 positions, usually called levels and then rotate in a horizontal arc to one of 10 rotary positions at each level. Thus the 100 positions of the wiper tips are located on the inside surface of a sector of a cylinder. Figs. 14, a, b, c, & d which are simplified drawings of part of one type of group selector shows how this action allows each wiper to contact any one of 100 bank contacts. The stepping of the wiper carriage is achieved by two separate magnets operating ratchet and pawl drive mechanism. The magnets are known naturally as Vertical and Rotary Magnets while a third 'Release' magnet is used to release the switch.* The mechanisms are

*Not all bi-motional switches have a separate release magnet, and one in particular (2000 type equipment) uses the rotary magnet for release.

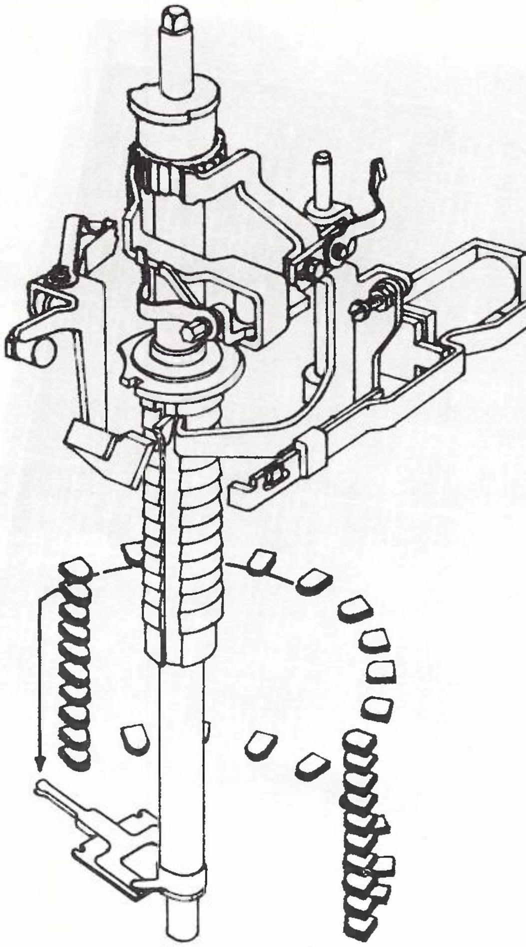


Fig. 14D

best understood by actually manipulating a switch, as it is very difficult to show the operation clearly in drawings; however, A.P.O. Engineering Instructions, and Training documents give adequate details of the operation and adjustment of the three main types of bi-motional selector in use in Australia.

The mechanism is also made to operate a variety of auxiliary springsets which provide indications to the switching circuit controlling the selector of the actions taking place. Typical springsets indicate that the switch has lifted vertically from its rest position (off normal springs), has stepped past the initial rotary position (rotary off normal), etc. In some circuits as much as half of the circuit logic is provided in this way.

In most modern bi-motional selectors wiper switching is used to make the 100 position switch provide 200 crosspoints. The mechanism compels these crosspoints to be treated as 10 sub-sets each of 20, and the switches are organised in stages corresponding closely to the numbering of the subscribers as will be shown later. A bi-motional selector is thus a highly specialised device which because it is designed to do one specific task is very efficient and economical for that task.

Relay Type Crosspoint Arrays

Relays: Relays can obviously be used to provide crosspoint arrays, simply by suitably connecting their contacts. Fig. 6, for example showed the contacts of 5 relays used to provide a 1 x 5 crosspoint array.

To perform as a selector, it is merely necessary to arrange to operate the relay corresponding to the desired crosspoint. A 4 x 5 crosspoint array could be constructed by multiplying the outlets of four such arrays. It would then be necessary to provide control circuits to ensure that the desired relays are operated and these could not include more than one in any horizontal row, nor more than one in any vertical row. When relays are used in this way, because the interconnections are systematic it is sometimes possible to adopt constructional techniques which reduce the labour involved in wiring.

Fig. 15 shows one view of an 8 x 8 crosspoint array made up of 16 reed relays, as used in the 10C processor controlled exchange. The relay coils, and one side of each reed insert are mounted on a printed circuit board which provides part of the wiring. The other ends of the reed inserts are wired together with a bare wire multiple.

Another construction of more conventional form is the RAM series of multicoil relays used extensively in LME crossbar control circuits and one such unit is illustrated in Fig. 16. It is made up of 10 relays mounted side by side on one mounting, with the fixed contacts of the relay springsets taking the form of contact strips so that the multiplying needed for a 1 x 10 crosspoint array is inherent in the construction. Several (say 5) such multicoil relays may be wired together to give a 5 x 10 array. Each crosspoint of an array using RAM relays can have up to 12 wires.

The above forms of crosspoints require one relay per crosspoint, but if a small number of wires per crosspoint is needed a technique analogous to wiper switching can be used to reduce the number of relay coils required. Fig. 17 illustrates the method, with 7 relays used to provide a 1 x 10 crosspoint array with 3 wires per crosspoint. The 5 relays R1 to R5 each have 6 springsets, corresponding to 2 crosspoints, while the two remaining relays A & B have 3 springsets each. By simultaneously operating one of the relays A & B and one of the relays R1 to R5, the three inlet wires can be entered to any of the 10 sets of 3 wire outlets, numbered 1A, 1B etc. to 5A, 5B. This technique appears in many disguises, and is given various names, but generally the relays corresponding to A & B are described as 'outlet switching' relays. The switching is usually but not necessarily restricted to doubling the number of crosspoints, and if enough contacts are available on the main relays three and four fold multiplication is possible.

Several such arrays can be multiplied together, to provide for example a 10 x 10 array. In such an array, only one out of relays A & B, and one out of relays R1 to 5 in one row must be operated at a time, and once such a pair is operated to close a crosspoint the other relays in that set will not be called on to operate until after the operated relays have released to break that connection.

Crossbar Switches: A crossbar switch is a relay contact type of crosspoint array in which advantage is taken of the fact that only a limited number of states and of changes of states are allowed in the array.

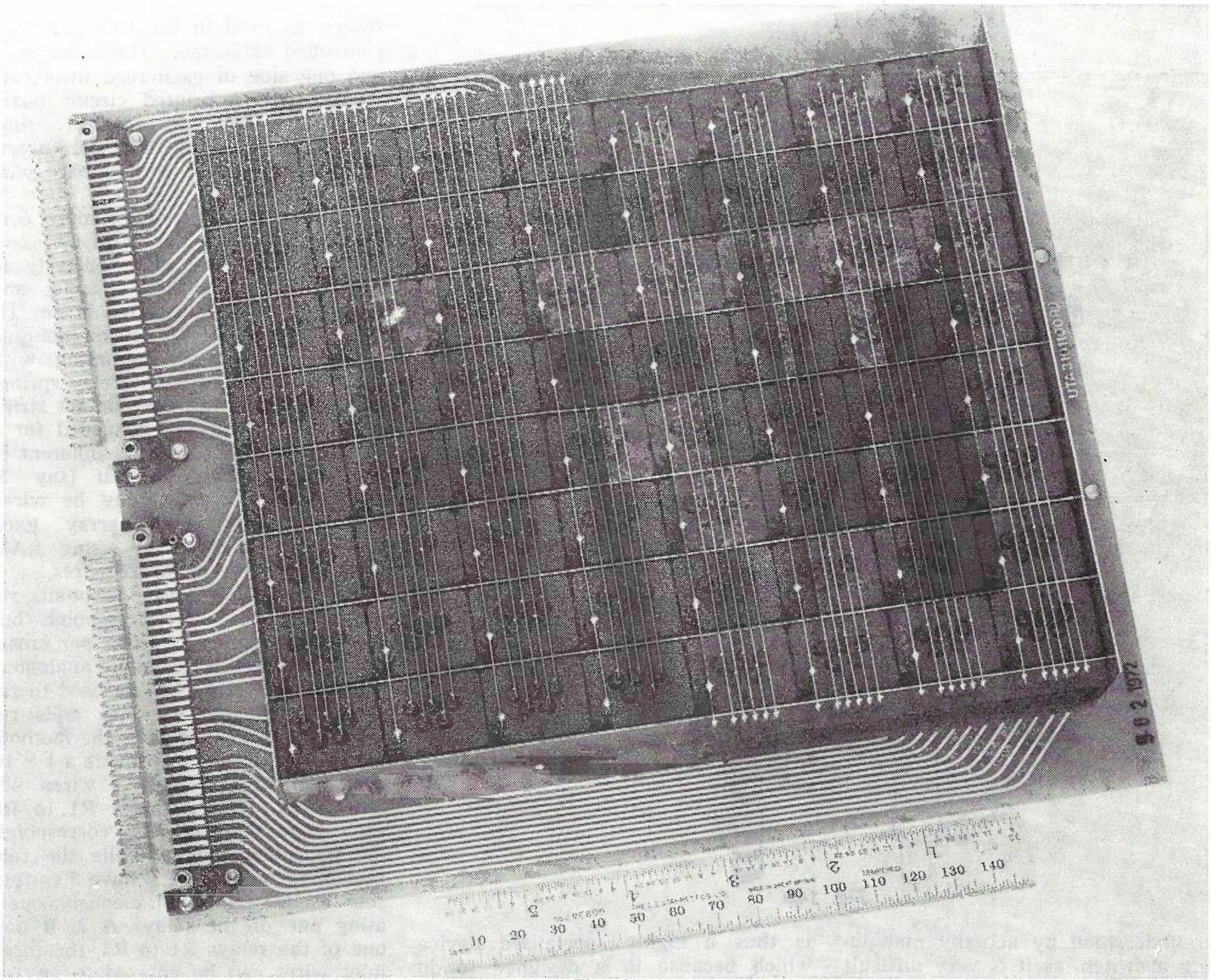


Fig. 15

This limitation allows the number of relay coils needed to control the contact sets to be greatly reduced.

One form of the LME crossbar switch has 100 contact sets; in a 10 x 10 array, and 20 operating magnets one for each horizontal row and one for each vertical column, as shown diagramatically in Fig. 18B. Each contact set can be defined by the horizontal and vertical magnets corresponding to the row and column, and thus the marked contact set is described as H3, V5.

The operation of the contact sets obeys the following rules:

(i) If a vertical magnet is not operated, all of the contact sets in that vertical row are open.

(ii) When a vertical magnet operates, any contact set(s) in that vertical row for which at that time the appropriate horizontal magnet is operated will be closed.

(iii) Once a vertical magnet has operated, the springsets which

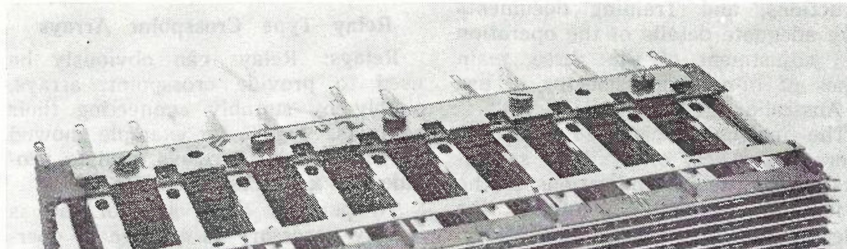


Fig. 16A

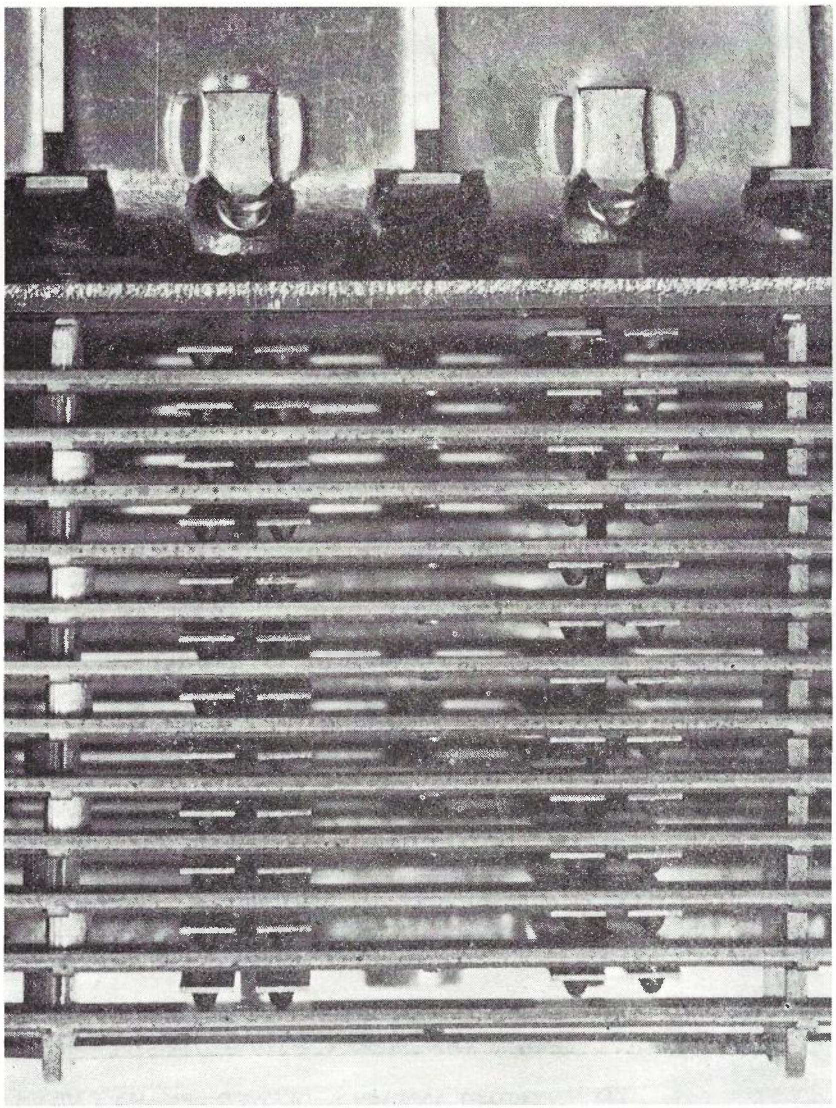


Fig. 16B

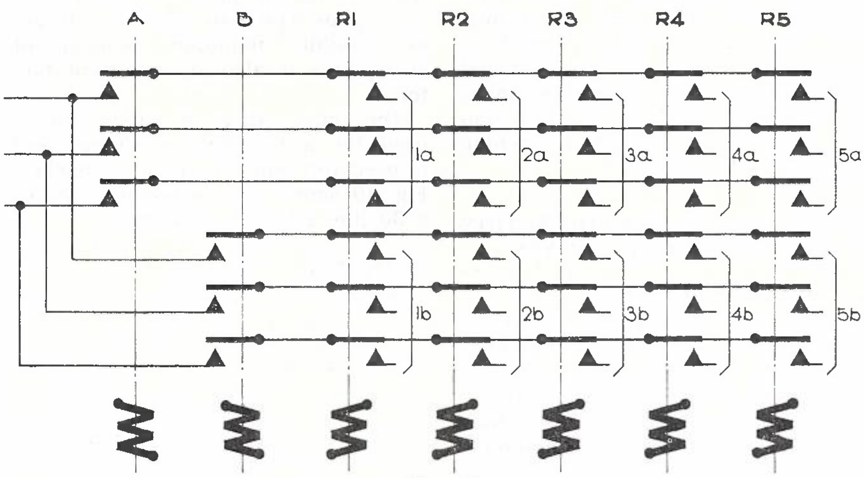


Fig. 17

it closed when operating, remain closed for as long as the vertical magnet remains operated, regardless of the subsequent state of the horizontal magnets.

(iv) Likewise, springsets in that vertical row which were not operated will remain un-operated regardless of the subsequent state of the horizontal magnets.

It can be seen that these rules allow each vertical column of the switch to be used as a 1 x 10 crosspoint array, independently of any other vertical. A crosspoint is closed by pre-operating the horizontal magnet and then operating the vertical magnet. Having done so, the state of that vertical set of crosspoints will remain unaltered as long as the vertical magnet is operated. Consequently the horizontal magnet can be released, and the switch is then ready to operate a crosspoint on any other vertical, (including those on this horizontal row). Thus each vertical, with the assistance of the horizontal magnets (which it shares with 9 other verticals) performs the same functions as 10 complete relays wired as a 1 x 10 crosspoint array.

Most LME crossbar switches have 120 spring contact sets, in 10 vertical columns of 12, with the two additional contact sets in each vertical row used for outlet doubling, so that it is necessary to operate two horizontal magnets to set a crosspoint, and each vertical becomes a 1 x 20 crosspoint array with a maximum of five wires per crosspoint.

Some of the important characteristics of a crossbar switch are:

(i) The cost per crosspoint is greater than for mechanical switches, but the electrical quality of the crosspoints is much higher and maintenance costs are extremely low. This applies to all crosspoint arrays using relay type contacts.

(ii) It takes only about 50 ms to operate a crosspoint, compared with a second or more for mechanical selectors. However, only one crosspoint can be set at a time, because the one setting mechanism is shared by all ten verticals.

(iii) The switch cannot easily be built with a large number of crosspoints. The largest switch in general use is the Pentaconta selector, with 28 horizontal magnets, giving 52 crosspoints per vertical.

(iv) In common with all relay contact type crosspoint arrays,

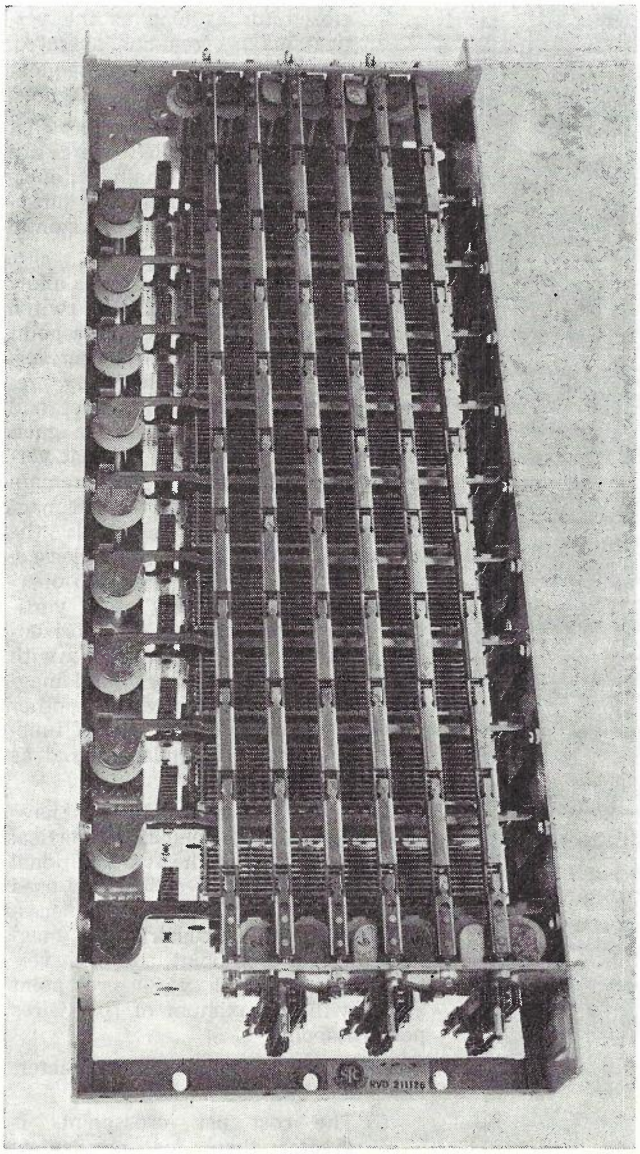
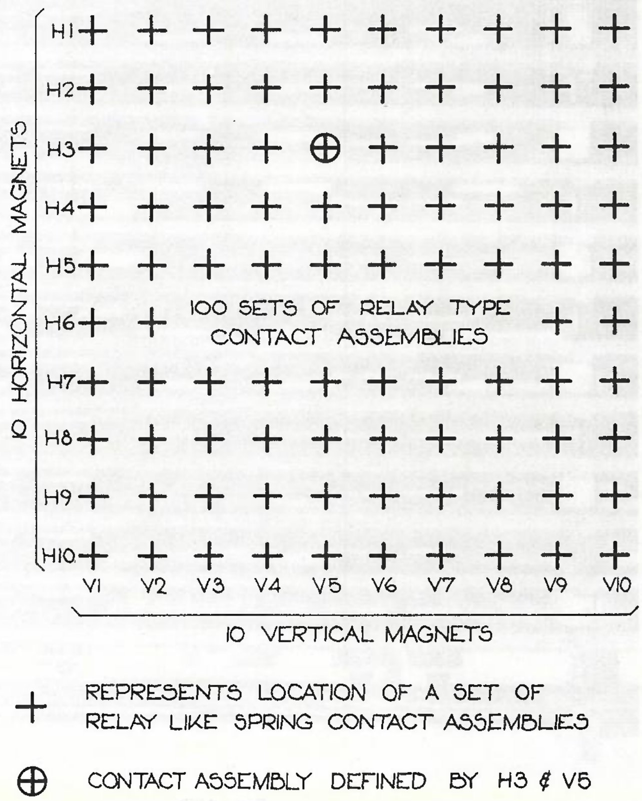


Fig. 18A



SYMBOLIC DIAGRAM OF A CROSSBAR SWITCH

Fig. 18B

there is no built in mechanical logic of the type incorporated in step by step selectors.

Electronic Switches As Crosspoint Arrays

The development of crosspoints using active electronic devices has been the subject of lengthy and very extensive investigations. Such devices as transistor switches are inherently capable of being used, but so far all attempts have either been inferior in performance to mechanical contacts, or so expensive as to be impracticable except in situations where they have some particular advantage. Some, for example have been used in warships, where extreme reliability under severe conditions of mechanical shock is imperative. They have potential applications in I.S.T. (Integrated Switching and Transmission) exchanges in which speech is switched in pulse code modulated form, and very wide frequency ranges are involved. Devices of this kind may well be part of the switching systems of the future.

THE EXCHANGE AS A COLLECTION OF CROSSPOINT ARRAYS

Small Exchanges

A large part of the cost of an exchange is made up of the cost of crosspoints; and the mechanisms directly associated with them; therefore switching configurations which minimise the number of crosspoints are likely to lead to economical exchanges. However, the cost of controlling the complex switching configurations which are necessary to get an absolute minimum number of crosspoints is also an important factor.

The simple array of Fig. 7 can be used for a telephone exchange and is used for small terminal exchanges. Fig. 19 shows the switching stage of a 30 line ARK511 exchange.

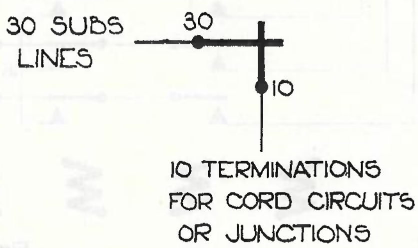


Fig. 19

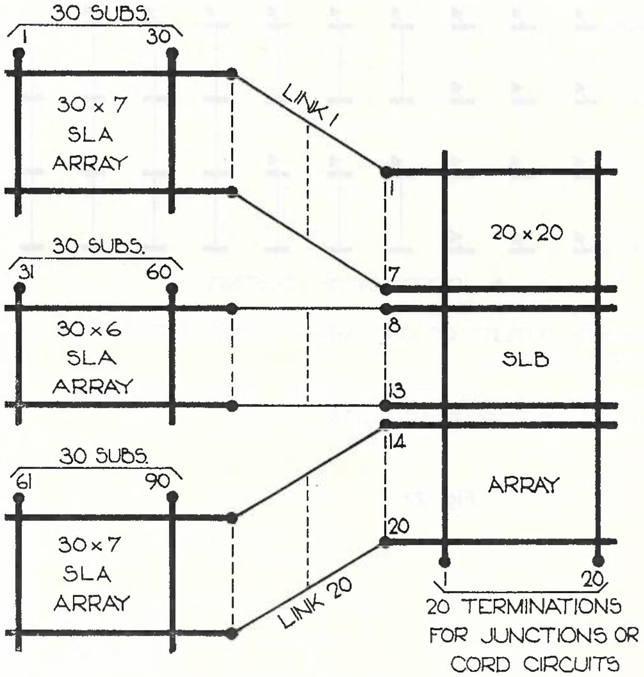


Fig. 20

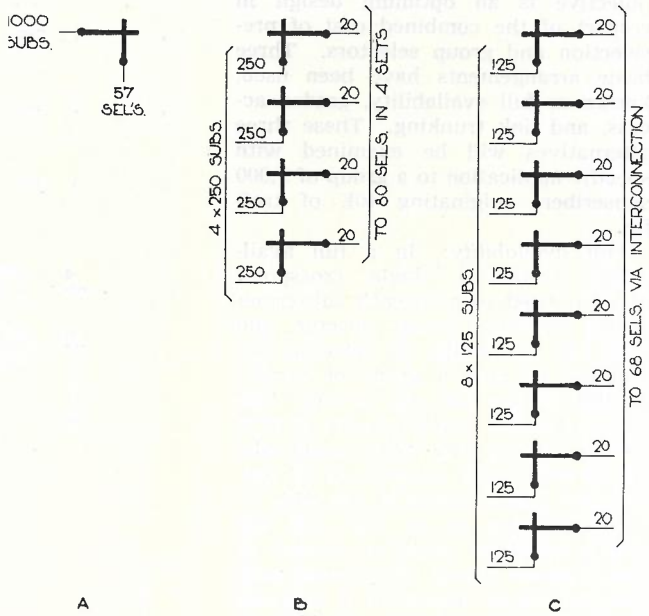


Fig. 21

This exchange is of the form shown in Fig. 1, and requires both way control of switching, but as it uses crossbar switches with marker control this is not very difficult. Moreover for exchanges of such small size most junctions are bothway. The ARK511 series of exchanges is built in sizes up to 90 lines, requiring a 90 x 15 crosspoint array, but it will be realised that the number of crosspoints is roughly proportional to the square of the number of lines, and it is necessary to use a different technique for larger exchanges.

A fairly simple exchange using two stages of switching is the 100 line ARK521 exchange, and Fig. 20 shows a method of interconnection which is only slightly different from that exchange and caters for 90 subscribers.

In this scheme there are 4 arrays of crosspoints arranged in two stages designated SLA and SLB. There are 3 SLA arrays each with 30 terminations for subscribers and 6 or 7 terminations which are connected to the SLB stage. The SLB stage array is of 20 x 20 crosspoints with one side connected to SLA switches and the other side to junctions or cord circuits.

An outgoing or incoming call between any subscriber and any junction can be established by operating one crosspoint in the appropriate SLA array, and one in the SLB array. Similarly a call between two subscribers via a cord circuit requires the operation of 4 crosspoints. This exchange has a total of 20 terminations for junctions or cord circuits and requires 1,000 crosspoints, compared with 90 x 20 — 1,800 required with a single array.

It has one limitation which does not apply to a single stage array in that only 6, or 7 simultaneous calls are possible within any group of 30 subscribers but subject to that limitation any idle subscriber can be connected to any idle junction or cord circuit. It is, of course, a more complex system to control than a single stage array, and the saving in number of crosspoints is purchased at the cost of a more expensive control system.

One important feature of this particular pattern of interconnection is that the individual arrays can be controlled independently. For example, a call from a particular junction to a subscriber in the 1-30 group can be connected over any of the links 1-7, and any idle link in that set can be chosen, without needing to consider the next step in switching the call.

On an outgoing call or the outgoing section of a local call the SLA stage is used to switch the subscriber to one of the links to the SLB, and the SLB stage switches that link to a specific outgoing junction or cord circuit. On an incoming call the SLB stage switches the incoming junction to one of the links to the desired SLA stage, and the SLA stage switches the link to the called subscriber's line. In this system three different kinds of switching function can be identified.

On an outgoing call, the SLA stage is a traffic concentrating device, or 'preselector'. In this application all the outlets are identical, and the function is to switch to *any* free outlet.

Secondly, on outgoing calls the SLB stage outlets form a number of different sets or groups, i.e., cord circuit inlets, and one or more sets of junctions, and this stage is required to switch to a free outlet within a specified group. This type of switching is called 'group selection'. Similarly on incoming calls the SLB stage has to select a link in the group of links giving access to a particular SLA array, and is again a group selector, but with inlets and outlets transposed.

The third type of selection operates in the SLA stage on incoming calls. In this case switching is required to a specific outlet and this is 'individual' or 'final selection'.

Large Exchanges

Preselection: In larger exchanges these different functions are performed in individual specialised units of equipment with more than one crosspoint array for each function and different sizes of crosspoint arrays and interconnection methods are needed for each purpose.

The simplest switching requirement is preselection for which the most important application is in connecting subscribers to group selectors in order to reduce the numbers of selectors required. This is only worth while if the saving in selectors is greater than the cost of preselection, and the objective is an optimum design in respect of the combined cost of preselection and group selectors. Three basic arrangements have been used, known as full availability, graded access, and link trunking. These three alternatives will be examined with specific application to a group of 1,000 subscribers originating 40E of traffic.

Full availability: In a full availability system a single crosspoint array is used to give each subscriber access to every group selector, and with full availability 57 selectors are required to give a grade of service of .002 or one lost call in 500. The interconnection would require a 57 x 1000 crosspoint array which might take the form of 1,000 switches of 57 outlets each and is shown in Fig. 21A.

Alternatively as in Fig. 21B the 1000 subscribers could be treated as four separate blocks of 250 each with full availability access to a separate block of group selectors. Each block would then require 20 group selectors for the same grade of service, or a total of 80, but the number of crosspoints is reduced to 4 x 20 x 250 or 20,000. Therefore, 23 extra selectors are needed, as the price of saving 37,000 preselector crosspoints. Given the cost of the selectors, and of the various alternative crosspoint arrays, a choice between them can be made on economic grounds.

Graded Access: In a graded access system, also known as an interconnected system, (*) the subscribers are again divided into a number of separate units, each having access to some of the group selectors but not as isolated blocks. For example, the subscribers could be divided into 8 units of 125, each unit having access to 20 of the selectors via a 125 x 20 crosspoint array, or 125 twenty position switches, but with some, or all of the selectors connected to more than one

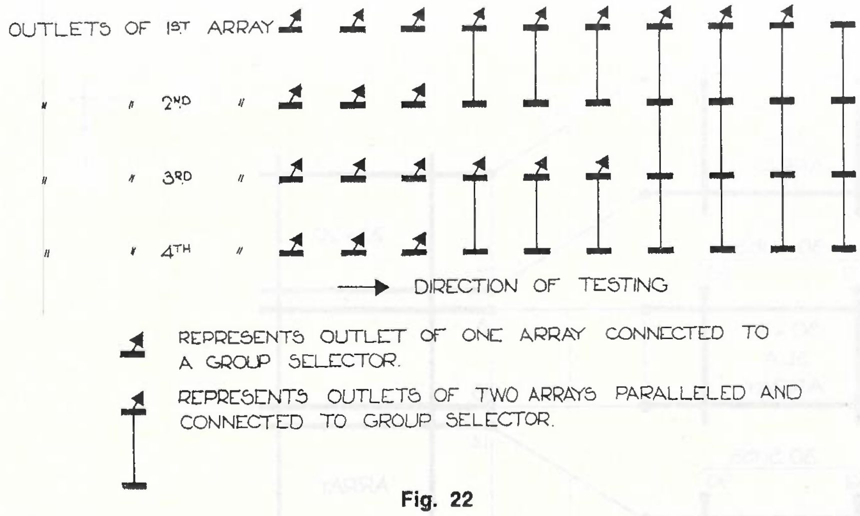


Fig. 22

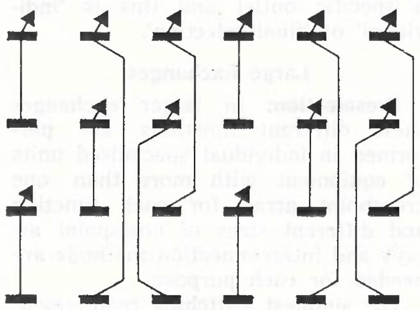


Fig. 23

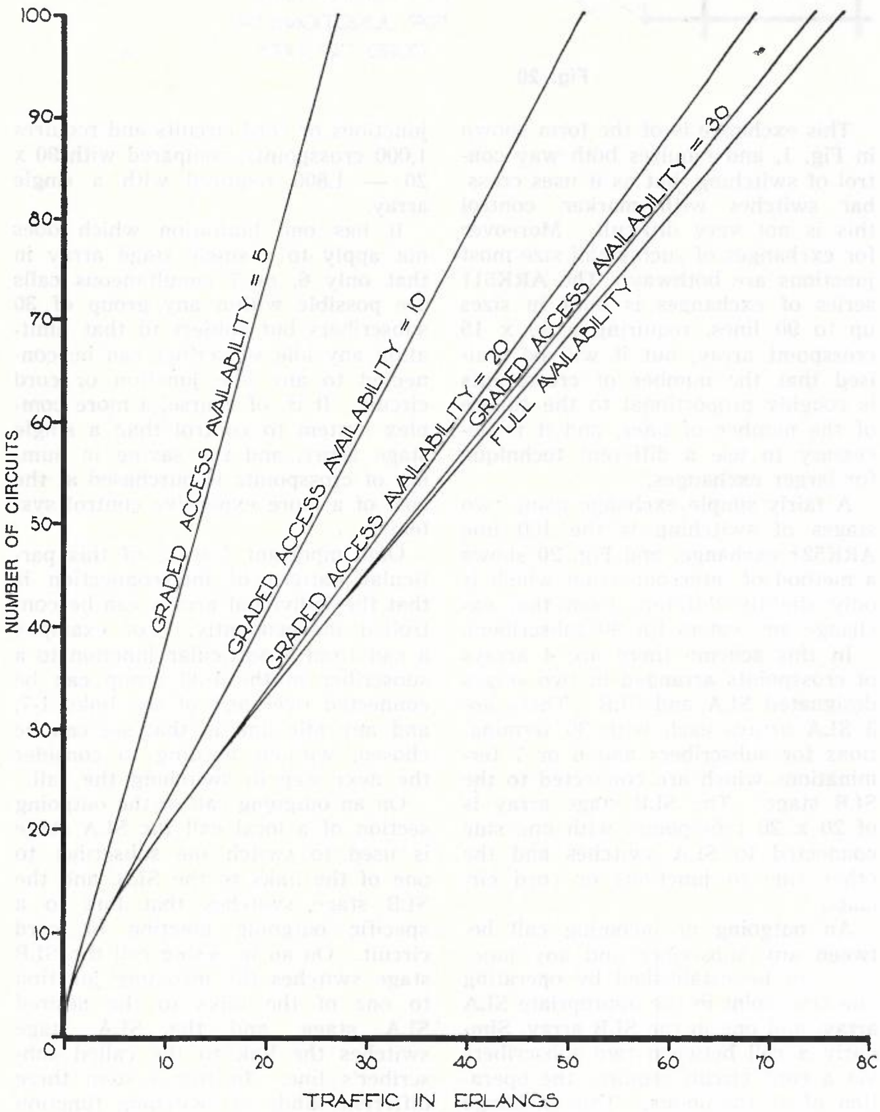


Fig. 24

* The expressions "grading" and "interconnection" are interchangeable, but it is more usual to call a sequential testing system a grading, and a random testing system interconnection.

array. If an efficient method of connecting the switch outlets to group selectors is used, 68 selectors will be required for .002 grade of service. In this case the number of crosspoints in the preselector array is again 20,000 as in the second full availability case but the number of group selectors has been reduced from 80 to 68.

Two main types of interconnection are in common use, depending on whether the switches test selectors in sequence or at random, both giving similar efficiency.

Fig. 22 shows an interconnection scheme for sequential testing, connecting 22 switches to the outlets of 4 arrays with 10 outlets each and the principle is that the earlier choices are accessible to only one group of subscribers, while the later choices are progressively shared by larger numbers of subscribers with the last choices accessible from all subscribers. The theoretical basis for this can be found in any text on telephone traffic engineering.

The method of interconnection used for switches with random selection is based on an entirely different principle. The grading is arranged so that, as far as possible every selector is reached from the same number of sources, and that the number of selectors shared by two groups should be the same for any pair of groups. These principles are illustrated by the small grading shown in Fig. 23.

In this example there are 4 groups of switches, each with 6 outlets, and with the outlets interconnected to 12 1st selectors. It can be determined by examination that each selector is reached from two groups of switches, and that every pair of groups shares access to 2 selectors. In this case the requirements are fully met, but in many practical cases it is only possible to partly satisfy them. This type of interconnection is known as a homogeneous interconnection.

More details on the method of computing the traffic capacity of gradings and of the design rules and procedures will be found in standard texts on traffic engineering. Fig. 24 shows the traffic capacity of a range of gradings, from which it can be seen that efficiency rises with availability, and an availability of at least 10 is needed for reasonable efficiency, while on the other hand the rate of increase of efficiency beyond an availability of 20 or 30 is relatively small.

Link trunking: Link trunking makes use of a different principle and requires at least two stages of switching, and a suitable configuration is shown in Fig. 25, where because of the number of interconnections between the two stages, only sufficient have been shown to indicate the pattern.

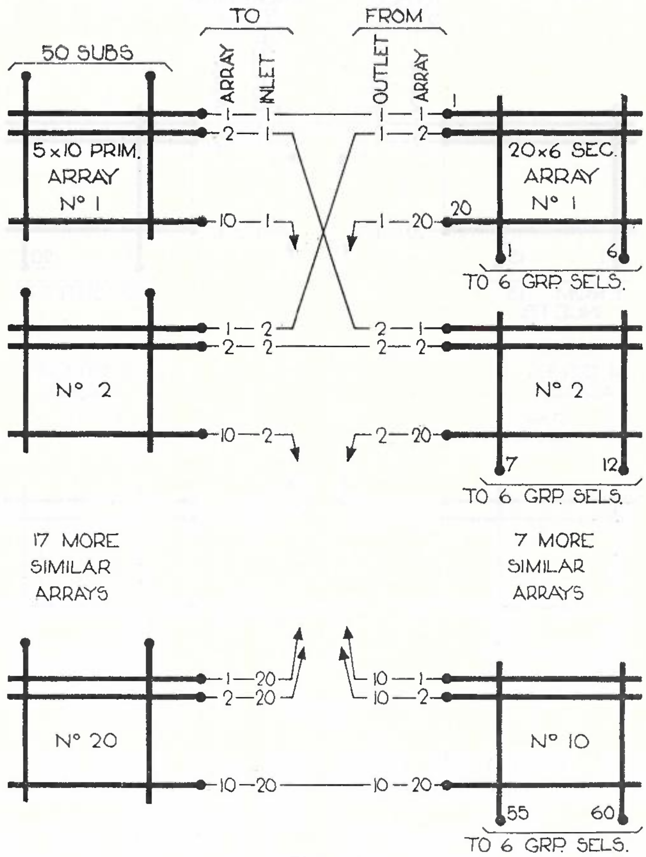


Fig. 25

The subscribers have been divided into sets of 50, and the access for the first set of 50 is shown in full detail. They are connected to a 50 x 10 crosspoint array or selection stage giving full availability access to 10 'links'. Each link connects one outlet to an inlet of a second crosspoint array each of which gives access to 6 1st selectors. Because each link is connected to a different secondary array, access is available to a total of 60 1st selectors.

However, although all selectors can be reached by any subscriber the system is not equivalent to a full availability system due to a phenomenon known as 'internal blocking'. In this particular configuration there is only one link from a particular primary array to a particular secondary array, and if this is in use for one call, any idle group selectors connected to that secondary array are inaccessible from that primary array. Consequently, congestion may occur even though there are idle selectors and the number of group selectors must therefore be increased to compensate. The calculation of the traffic capacity of link trunking systems is complicated and involves consideration of the state of the links and the outlets of the preselectors. However, a useful approximation of the performance of the system can be obtained by the following procedure.

If the first stage arrays have n(1) outlets and the second stage arrays have n(2) outlets, then the total number of outlets available from one inlet is n(1) x n(2). However, a proportion of the n(1) outlets will be occupied and if the traffic per link is 'a' erlangs, then the average number of occupied links is n(1) x a, and an average of a x n(1) x n(2) secondary stage outlets will be inaccessible due to internal blocking. Therefore the system may be expected to behave like a grading with availability (1-a) x n(1) x n(2). This approximation method is described as 'effective availability', and comparison with exact calculations shows that it is usually fairly close.

In the case under discussion, there is 2E of traffic from each primary group, and the traffic per link is 0.2E. Therefore the 'effective availability' is 0.8 x 10 x 6 = 48. This linked trunk system with 11,200 crosspoints is therefore as good as a single stage interconnected system with an avail-

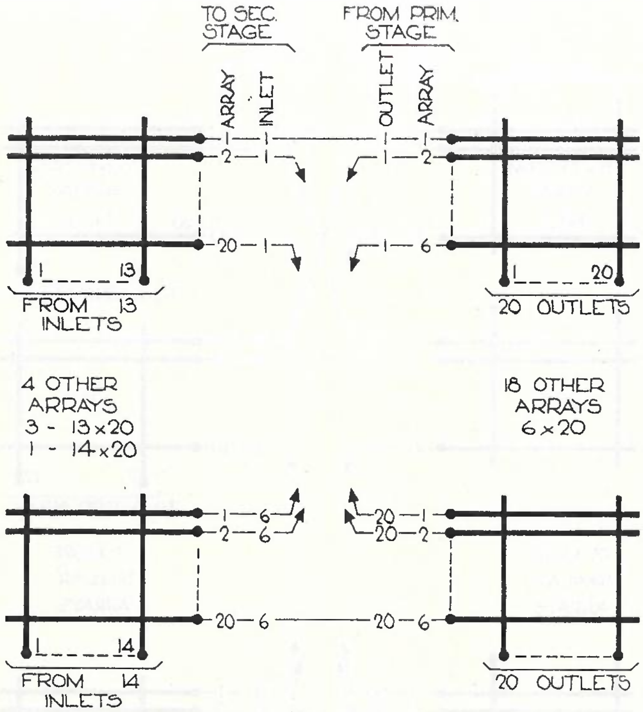


Fig. 26

ability of 48, which would require 48,000 crosspoints, more than 4 times as many.

In terms of crosspoint economy link trunking is the most powerful technique known, but it involves a more complex control problem. The choice of a path through the system involves examination of both the stages at once, and an outlet from the first stage must be chosen which is not only free, but which also leads to a secondary group which contains at least one idle outlet. This requirement of selecting a link satisfying two (or even more) conditions simultaneously is known as 'conditional selection'. If instead of this selection process, any free link is selected, the call effectively tests only the outlets of one secondary stage (6 in this case) and the efficiency is no higher than for a grading of this availability.

Link trunking and grading may be combined if desired, and in the case under consideration this would permit either a reduction in crosspoints to give an effective availability of as low as 20 or 30, or the interconnection of the outlets of a number of 1000 line blocks in a larger exchange.

Group Selection:

Two Stages: In Group Selection it is necessary to divide the outlets into a number of groups or routes, and with a single stage array this requires a rather large number of crosspoints per inlet. One common group selector formation in step by step system uses the previously described 200 outlet switch, with the outlets divided into 10 'levels', or routes of 20 outlets each.

The outlets for each route can be graded precisely as described for a pre-selector, giving satisfactory efficiency on the outgoing routes. In order to produce a switch with 200 outlets or crosspoints a fairly complex mechanical structure is required, but it is possible to incorporate into this structure a large amount of 'electromechanical logic', which helps to keep down the total cost of the step by step system.

For group selection the use of link trunking gives an even greater reduction of crosspoints than in the case of preselection. A widely used link trunked group selector is the GV stage of LME crossbar, illustrated in Fig. 26.

There are two stages in this selector with 13 x 20 and 14 x 20 arrays in the first (GVA) stage and 6 x 20 arrays in the second (GVB) stage, giving access to 400 outlets. However, because of internal congestion, the effective availability is a better guide to its capabilities. With typical traffic each inlet carries 0.6E and the average traffic per link is then (0.6 x 13⅓)/20 or 0.4E, giving, an effective availability of 400 x (1-0.4) or 240. The total number of crosspoints is 4000 for 80 inlets or 50 crosspoints per inlet which is about one fifth of the crosspoints needed in an equivalent single stage array. With an effective availability of 240 this configuration is roughly equivalent to a 10 x 20 outlet bi-motional group selector, and can be used as a group selector by suitably arranging the outlets into routes. The method of allotting outlets to routes is an important factor in minimising internal congestion, and this is best explained by considering how to allot 20 outlets to one route. The 20 outlets could be chosen all from one GVB array, or 10 from each of two GVB arrays, 5 from each of 4, 4 from each of 5, 2 from each of 10 or one from each of 20 GVB arrays. In each case the number of outlets accessible at a particular time will range between 20 and 0, depending on the state of the links, and in each case the long term average number of accessible outlets will be 12. However, the time distribution of the number of accessible links will be different for each case. The different cases are illustrated in Table 1. In case 1 with all outlets in the same array, for 60% of the time the only suitable link will be idle and all outlets accessible, but for the remaining 40% of the time this link will be in use and access to all outlets blocked, so that the grade of service cannot be better than 0.4. In case 2, access to all outlets will be blocked for only 16% of the time, and for a further 48% of the time only one link will be idle and access will be available to only 10 of the 20 outlets. This clearly gives a better chance of reaching an idle outlet and it would appear that case 6, where each link is capable of being used, and would only block one outlet of the route if it is busy, is likely to give least congestion. This can be proved rigorously, and a general rule for link trunked systems is that as far as possible, traffic 'streams' should be spread over as many links, and link combinations as possible.

In the same way if it is desired to allot 10 outlets to a route, they should be chosen from 10 GVB arrays, while if it is desired to allot 40, or 60, or 80, they should be chosen 2, 3 or 4 from each of the arrays.

The control of a link trunked group selector is a fairly complex problem, as it is necessary to find an idle outlet which can be reached via an idle link. This cannot be done without examining simultaneously and in a co-ordinated manner the outlets from both the first and second stage. It is *not* possible to select any idle outlet from the first stage blindly, without looking ahead to see what the consequence is of selecting that particular outlet. This is both the inevitable penalty of adopting link trunking and the source of its

TABLE 1

Allocation Method	No. of Circuits Blocked by Link Congestion	Probability
Case 1. All outlets on One GVB Array	0	.6
	20	.4
Case 2. Outlets spread Over two GVB Arrays	0	.36
	10	.48
	20	.16
Case 3. Outlets spread Over four GVB Arrays	0	.1296
	5	.3456
	10	.3456
	15	.1536
	20	.0256
Case 4. Outlets spread Over five GVB Arrays	0	.0778
	4	.2592
	8	.3456
	12	.2304
	16	.0768
	20	.0102
Case 5. Outlets spread Over ten GVB Arrays	0	.0060
	2	.0403
	4	.1209
	6	.2149
	8	.2508
	10	.2006
	12	.1115
	14	.0424
	16	.0106
	18	.0016
	20	.0001
Case 6. Outlets spread Over 20 GVB Arrays	<11	.8722
	11	.0710
	12	.0355
	13	.0145
	14	.0049
	15	.0013
	>15	.00031

strength. The question of control will be elaborated further in discussing detail design of exchanges, but it can be seen that the control cannot be vested in individual switches and that there is no such thing as a step by step linked trunked system.

The method of drawing out the interconnections of two stages in a link trunked system in detail is useful for illustrating the principles, but is too elaborate for most applications and impractical for showing more complex systems. The interconnection between stages of any link trunked system is always systematic, to give a maximum degree of uniformity, and therefore it need not be shown in detail. A very condensed method which is generally used is shown in Fig. 27. This shows both of the link trunked schemes so far discussed in skeleton form. The diagonal cross symbol indicates an interconnection between the two arrays of the form which has previously been shown in detail, while the two sets of arrays are each shown by a single symbol. The numbers indicate the size of the array, and the number of similar arrays. For example, in Fig. 27A, the first stage is made up of 20 arrays, each 50 x 10, so that there are 1000 subscribers and 200 links and the second stage is made of 10 arrays, of 20 x 6 which connect the 200 links to 6 outlets. Fig. 27B, likewise shows the make up of the group selector shown in more detail in Fig. 26.

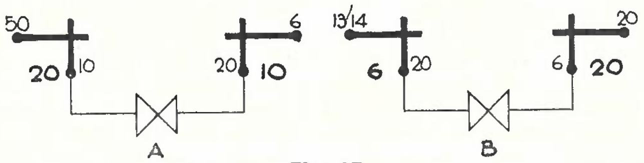


Fig. 27

The systems shown so far have only one link from each first stage array to each second stage array. In some circumstances it is possible, and desirable, to provide two or more links between each combination of arrays. For example, if a group selector required only 200 trunks to be terminated on its outlets, the selector shown in Fig. 26 would have half its outlets idle. If the spare outlets could be multipled with working outlets, in such a way that two different links could be used to reach each outlet, internal congestion would obviously be reduced. One systematic way to do this would be to parallel the outlets of the first and second GVB arrays and likewise the third and fourth, fifth and sixth, etc. The effect of this is to make the first two 6 x 20 GVB arrays into a single 12 x 20 array, with 2 links from every GVA array and similarly with the remaining arrays. There are now 200 outlets, instead of 400, but the internal congestion is lower. If each link carries 0.4E then the probability that both links are occupied, and that the relevant outlets are inaccessible is only $(0.4)^2$ or 0.16.

This particular configuration can be represented by Fig. 28. The fact

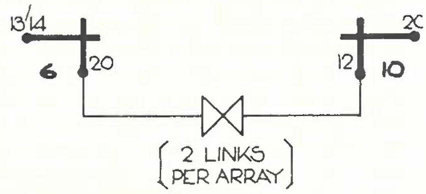


Fig. 28

that 2 links are provided between every pair of arrays can be deduced by calculation, or may be specified in the way shown.

Three or More Stages: In a 2 stage system there are two methods of controlling internal congestion. In the GV stage under discussion the number of links from each GVA array is greater than the number of inlets, thereby reducing the traffic per link and reducing internal congestion by expansion. The other technique is the use of multiple links, but can only be used where the number of outlets needed is small enough to allow it to be done. Expansion causes the number of second stage crosspoints to be increased in proportion and thus the GV stage has 50% expansion, and the total crosspoints in GVB are 50% greater than in GVA. Multipled links on the other hand cause a reduction in the total outlets, which cannot often be tolerated. There is therefore a practical limit to what can be achieved with only two link trunked stages and beyond this point it is necessary to use three stage systems.

A first attempt at a three stage system is shown in Fig. 29, based

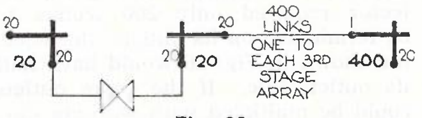


Fig. 29

on 20 outlet switches. The first two stages can be thought of as a conventional 2 stage system with 400 inlets and 400 outlets. The third stage is made up of 400 arrays each 1 x 20, giving access to 8000 outlets. Naturally, 400 inlets will not fully load 8000 outlets, and a number of similar units would have their outlets multipled.

Any inlet can reach any of the 400 links to the third stage, via one specific path, and therefore any one of the 8000 outlets. However, to reach a specified outlet it is necessary for a specific link between the 1st and second stages, and another specific link between the second and third stages to be idle. There is no expansion in the stages so the traffic per link is the same as the traffic per inlet, and as before this will be assumed to be 0.6E per circuit. The probability that the two links required to reach a specific outlet from a specific inlet are both idle will then be $(1-0.6)^2$ or 0.16, and the probability of blocking is 0.84, which is inconveniently large.

At the same time the number of outlets is too large for most applications, so the technique of multipled links can be used to create a more useful design. By multipling the outlets in fives, the total number of outlets will be reduced to 1600, each of which is accessible from a specified inlet over 5 different paths. The probability of blocking is now $(0.84)^5$ or 0.42, similar to that of the two stage selector previously described. The effective availability is 1600 (1-0.42) = 928, and is achieved with 60 crosspoints per inlet, compared with the 50 crosspoints per inlet of the two stage. As in this example, three stage link trunked Systems are often more economical in crosspoint usage for a given performance than two stage systems.

By selecting different combinations of expansion, and multipling of paths, it is possible to get a wide variety of different three stage systems, with differing degrees of internal blocking, and a probability of blocking between specified inlets and outlets as low as 0.1 can be achieved.

Fig. 30 shows the formation of the 400 inlet, 1600 outlet, 3 stage system

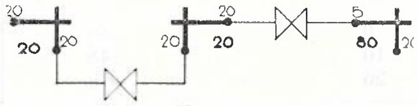


Fig. 30

being discussed. It is not possible to show in detail the method of interconnecting links as there are far too many. The principle, as usual, is to keep the maximum possible degree of independence between paths, and as there are 20 second stage arrays the 20 links from each 1st stage will be allotted one per second stage, thus ensuring that every second stage outlet is equally accessible from every inlet. The 400 stage outlets must be divided into sets of 5, each to one of the 80 third stages, and each set of 5 must be reached from 5 different links, which requires them to be fed from different second stage arrays. Again, in allotting outlets to routes, this must be done in such a way that the paths used for each outlet is different. In a practical system outlet allocation rules are specified in a manner which achieves the necessary result without requiring examination of the internal structure, and reduces this work to a routine.

It hardly needs pointing out that the control of a 3 stage link system is considerably more complex than a 2 stage system, and the adoption of a 3 stage system is never lightly undertaken. However, for some applications the cost of the control circuitry is recovered many times over in the resulting economics in the total system.

It is also possible to go beyond three stages, and crossbar systems with a 4 stage group selector system are in use, particularly for large trunk exchanges. Four stages is the practical limit with relay logic in the control circuits, and even this is only achieved by permitting some compromise with the ideal interconnection of stages. With computer techniques for the control circuits it is possible to control link systems with a large number of stages and such systems are coming into use. The extension beyond 3 stages follows the same basic principle, but there is a wider variety of possible configurations. In such a system the designer has under his control a number of parameters, the most important being:

(i) size(s)
(ii) traffic per link
(iii) number of stages
(iv) degree of multipling of paths

Entraide: A more elaborate configuration which is sometimes used for group selectors is known as 'entraide' and is characterised by links from one stage to an earlier one, used on an overflow basis to carry traffic which encounters internal congestion on the normal path. Fig. 31 shows

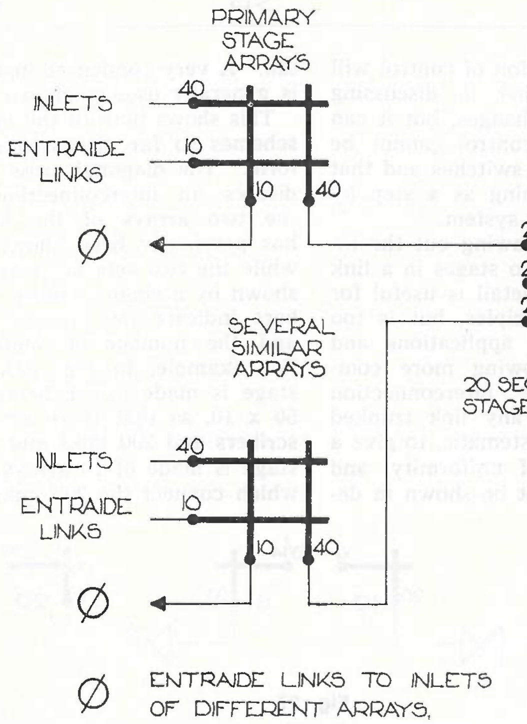


Fig. 31

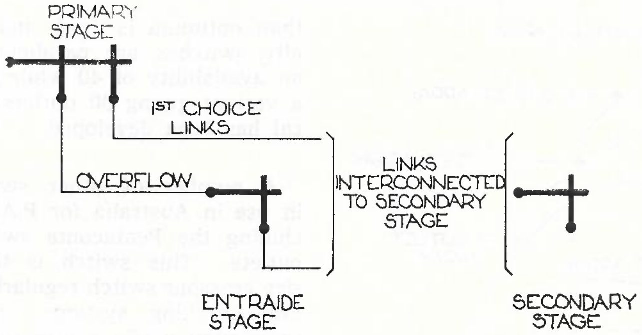


Fig. 32

the interconnection of the 'entraide' selector stage used in the Pentaconta system; and it can be seen that it includes a normal 2 stage link trunking configuration with 2 links from the first stage to every second stage. In this form it would give access to 1000 outlets, with about 25% probability of any second stage array being unavailable due to internal congestion. In addition to this there is an 'entraide' route of 10 outlets from the 1st stage, each of which connects to an inlet of a different 1st stage array, and therefore has further opportunities for reaching the desired outlet. The system can also be drawn in the form shown in Fig. 32, and in this form it is seen to be a combination of a 2 stage and a 3 stage system. The 3 stage system is only used if the links needed for 2 stage switching are occupied and therefore only a small amount of traffic is switched via 3 partial stages.

The main application of 'entraide' is to bridge the gap between the capacity of a 2 stage and a 3 stage system, and although it could also be used with a larger system, these have so much more flexibility in adjusting capacity and blocking by variation in link loading that there is no actual case where entraide is used with 3 stages in the basic system.

Final Selection: Final selection requires access to every outlet, and this is not possible with the large values of internal congestion usually found in link trunked systems. If a large enough number of multiple paths is provided the internal congestion of a 3 or more stage system on a call to any specific outlet can be made low enough (say .002) to allow the system to be used as a final selector. However, if such a system is examined it will be found that the links to the last array in the system act as independent groups and the system can be treated as a combination of a group selector and final selectors. This can be seen from Fig. 33 which shows the arrangement of the combined final selector/preselector stage used in ARB Telex exchanges.

There are 3 stages in the system designated SLA, SLB and SLC. The subscribers' lines are connected to 10 separate SLA arrays of 40 x 20, and since every call to a particular subscriber must use the array to which it is connected, the SLB and SLC stage can be regarded as a 2 stage group selector with access to 10 routes, each of 20 outlets. The control of this system is in fact divided into two stages, one of group selection using SLC and SLB, and an independent step of final selection using SLA. It can be appreciated that a link trunked final selection system must have at least 3 stages.

Optimum Size of Crosspoint Arrays

Economical use of crosspoints is the basic reason for using any link trunked system and there is therefore a need to compare the effectiveness of different configurations, and in particular to decide on an optimum size of crosspoint array. This can seldom be done by direct comparison as two configurations based on different sized arrays will seldom give identical facilities.

A method which is of more general application, although at the same time rather less specific, can be derived by considering the multiplication of the number of effective paths achieved by a specific array.

In an n x n array, with traffic per inlet and per outlet of 'a' erlangs, the average number of effective outlets, i.e., those not blocked by internal congestion, is n(l-a), and the array, if used as an intermediate switching stage therefore multiplies the number of paths through the system by n(1-a), at a cost of (n/a) crosspoints per erlang. Now in comparing arrays, since the arrays act to multiply the paths, two arrays will give a multiplication of $(n(1-a))^2$ for twice as many crosspoints, and a reasonable figure of merit could be created by dividing the logarithm of the multiplying factor by the crosspoints per erlang, i.e., F.O.M. = (a/n) log (n(l-a))

It can be shown that this has a maximum for n = 2e and a = 0.5 and its value is 1/4e.

Therefore a normalised figure of merit, having a maximum value of 1 is:

F.O.M. = 4ea/n log (n(l-a))

There are more rigorous proofs that this does in fact represent the efficiency of crosspoint utilisation in the central stages of the type of multi stage systems under consideration. However, its applicability is confined to such situations.

Fig. 34 is a plot of contours of this figure of merit, against circuit loading and array size, and it can be seen that the peak at n = 5.44 and a = 0.5 is extremely broad. Crosspoint efficiency is only one aspect of switching system design and the equally important one of control circuit complexity tends to favour systems with fewer stages obtained by selecting larger values of n and lower values of a.

The earliest switching systems were developed before link trunking was a practical tool, and were confined to stage by stage control. For this type of interconnection, switches of at least 100 outlets are needed, and this requirement led to the development of designs in which the crosspoints were relatively inexpensive, and were positioned in a two co-ordinate structure. Much of the control logic took the form of mechanical devices, incorporated in the switch, for example, a vertical magnet which would respond directly to dialled impulses, and select a level. The crosspoint efficiency of a 100 outlet switch with 0.6E loading is seen from Fig. 34 to be about

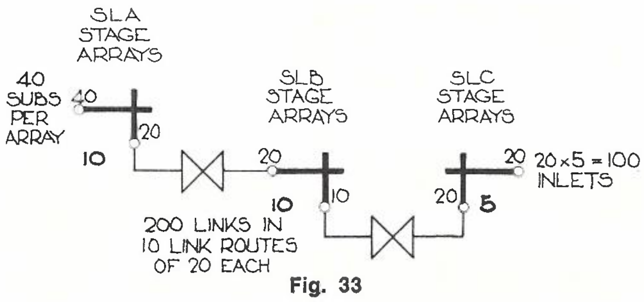


Fig. 33

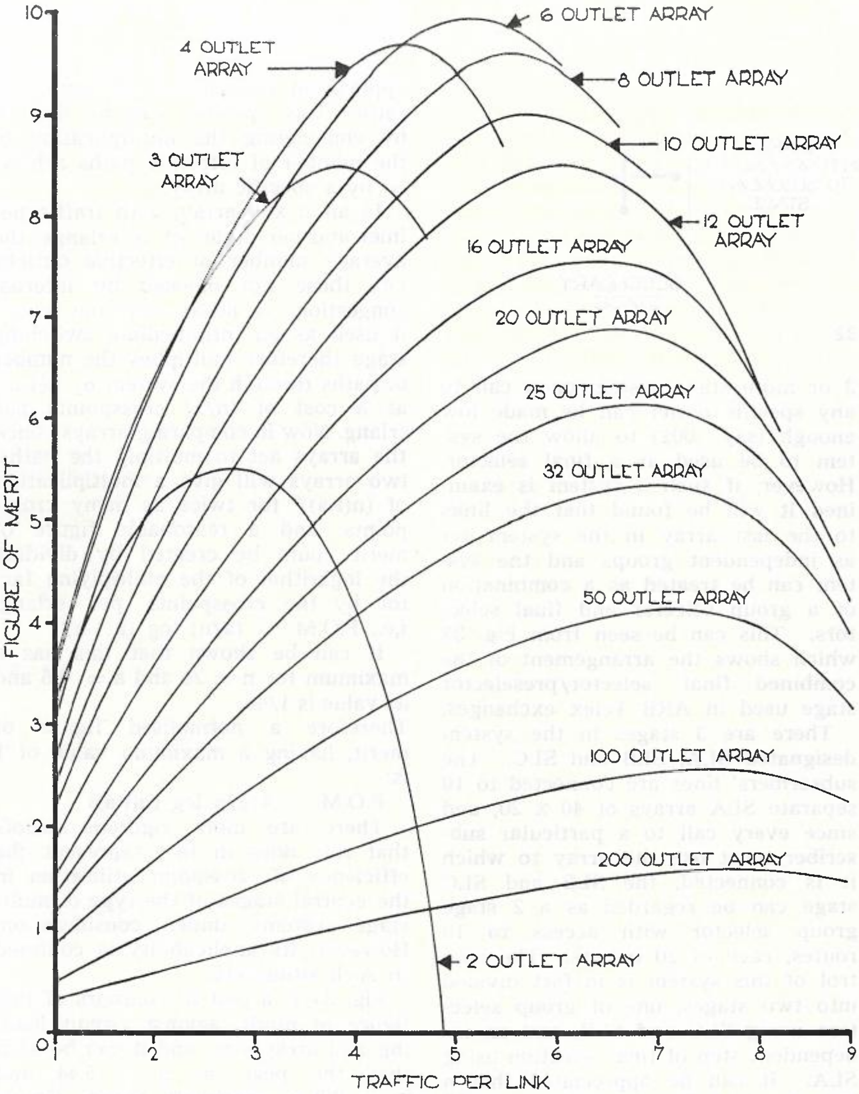


Fig. 34

25%, but nevertheless the low cost construction of the crosspoints themselves and the economy of single stage control enabled such systems to compete with crossbar for a long time.

The crossbar switch was invented in 1913 and its main characteristics are that the crosspoints are in the form of relay contacts, operated by a relay like mechanism. Originally it was envisaged that each switch would be used as a single selector of 100 outlets, replacing a Strowger group selector. It was demonstrated to be a more reliable mechanism, and to have superior crosspoints, but it was so costly in this form that it languished for some 25 years.

The development around 1940 of practical systems of link trunking, making efficient use of switches of smaller capacity, was necessary before crossbar could compete economically with systems using mechanically operated switches, but from this point crossbar fairly rapidly took over almost the whole field of automatic switching. In Australia the LME system was adopted as standard, using a switch which provides a 10 x 20 crosspoint array. It can be seen from Fig. 19 that the crosspoint efficiency of systems using this selector is very high, but in practice, to reduce the number of stages of selection a link loading around 0.4 which is lower than optimum is used, and occasionally switches are paralleled to give an availability of 40 while for CAX's a variant giving 30 outlets per vertical has been developed.

A number of other switches are in use in Australia for P.A.B.X.'s, including the Pentaconta switch of 52 outlets. This switch is the largest size crossbar switch regularly used for link trunking systems, and permit some very useful configurations, particularly in large exchanges, and at the same time is just enough for stage by stage control. As a point of fact, most Pentaconta P.A.B.X.'s use stage by stage trunking, which is more flexible in P.A.B.X. applications in sizes up to about 1000 lines. Most other crossbar switches are of 10 or 20 outlets, but when 10 outlet switches are used there is a considerable amount of paralleling to give a 20 outlet or larger unit. Two extreme cases are a 5 outlet unit (which is always multipled to give a larger size), and a 100 outlet switch developed by Bell, Antwerp, which is hardly ever used as a link trunking system.

Stored program control (S.P.C.) exchanges, usually called 'electronic exchanges' which are only in service in a few countries, but seem likely to take their place as the major type in a few years, use an array of reed relay crosspoints. In these systems there is less difficulty in controlling a link trunk system with a large number of stages, and there is a greater emphasis on efficiency of crosspoint usage. The most frequently used array is 8 x 8, which is very close to optimum, and is convenient for control by a computer using binary arithmetic.

However, because there is no common mechanism to impose constraints, it is possible to build the arrays from almost any convenient sub. units, and 4 x 4 sub. units are often used giving the possibility of assembling, such size arrays as 8 x 8, 12 x 12 or 16 x 8, as required. This also allows an array to be increased during the life of an exchange from 4 x 4 to 8 x 8, or from 8 x 8 to 16 x 16, and in a large exchange this procedure can give a much more orderly method of extension than is possible with crossbar switches of fixed size.

THE DARWIN-NHULUNBUY TROPOSPHERIC SCATTER SYSTEM — PART 2

*M. J. KIMBER, B.E. (Hons.), M.I.R.E.E. and V. W. LANGE, M.E., M.I.E.E.E.**

INTRODUCTION

Part 1 of this article in the previous issue of the Journal described the basic design considerations of the Darwin-Nhulunbuy system. This second part describes the equipment, power plant, accommodation, installation and maintenance aspects.

EQUIPMENT

The radio equipment for this system was manufactured by NEC in Japan and during its production it was examined and tested by an engineer from the APO.

The equipment types and their specifications are defined in Table 3 (see Part 1) and block diagrams of the system are shown in Figs. 7, 8 and 9. The basic equipment units which go to make up the system are as follows:

* Mr. Kimber is Engineer Class 3 and Mr. Lange is Engineer Class 2, Darwin-Mt. Isa Project, Darwin Area Management (Telecom) Branch, Northern Territory. See Vol. 22, No. 3, page 195.

(*a*) *Modulator (type MO-120-3B)*
120 frequency multiplexed circuits in the band 60 - 552 kHz and various sub-baseband circuits for supervisory and order wire purposes in the band 0 - 44 kHz, are fed into this unit which frequency modulates them on to a 70 MHz carrier. The modulator also incorporates pre-emphasis in accordance with CCIR recommendations.

(*b*) *Exciter (type TO-2G120-4A)*
The 70 MHz signal from the modulator is mixed in the exciter with a local oscillator signal in the band 2.4 to 2.7 GHz. The 2 GHz signal is generated by successive multiplications from a basic crystal frequency.

(*c*) *Power Amplifier (type PO-2G1K-5A)*
The power amplifier is the only unit in the system which uses a vacuum tube. The tube used in this particular instance is a four cavity klystron type LD4036. The klystron is fed with approximately 50 mW of RF power from the exciter and produces an output of 1 kW. The output of the klystron passes to the antenna via a band pass filter.

Since the klystron is a relatively narrow band device, tuning of each cavity is necessary when a new klystron is commissioned. Tuning requires the application of swept frequency techniques to optimise the amplitude characteristics of the tube. The replacement of a klystron therefore requires a considerable amount of test equipment — and is quite time consuming and consequently represents the most difficult aspect of maintenance operations in the field. The life of the klystron is guaranteed to be 8,000 hours and the cost of each tube is approximately $5000, so therefore it can be seen that

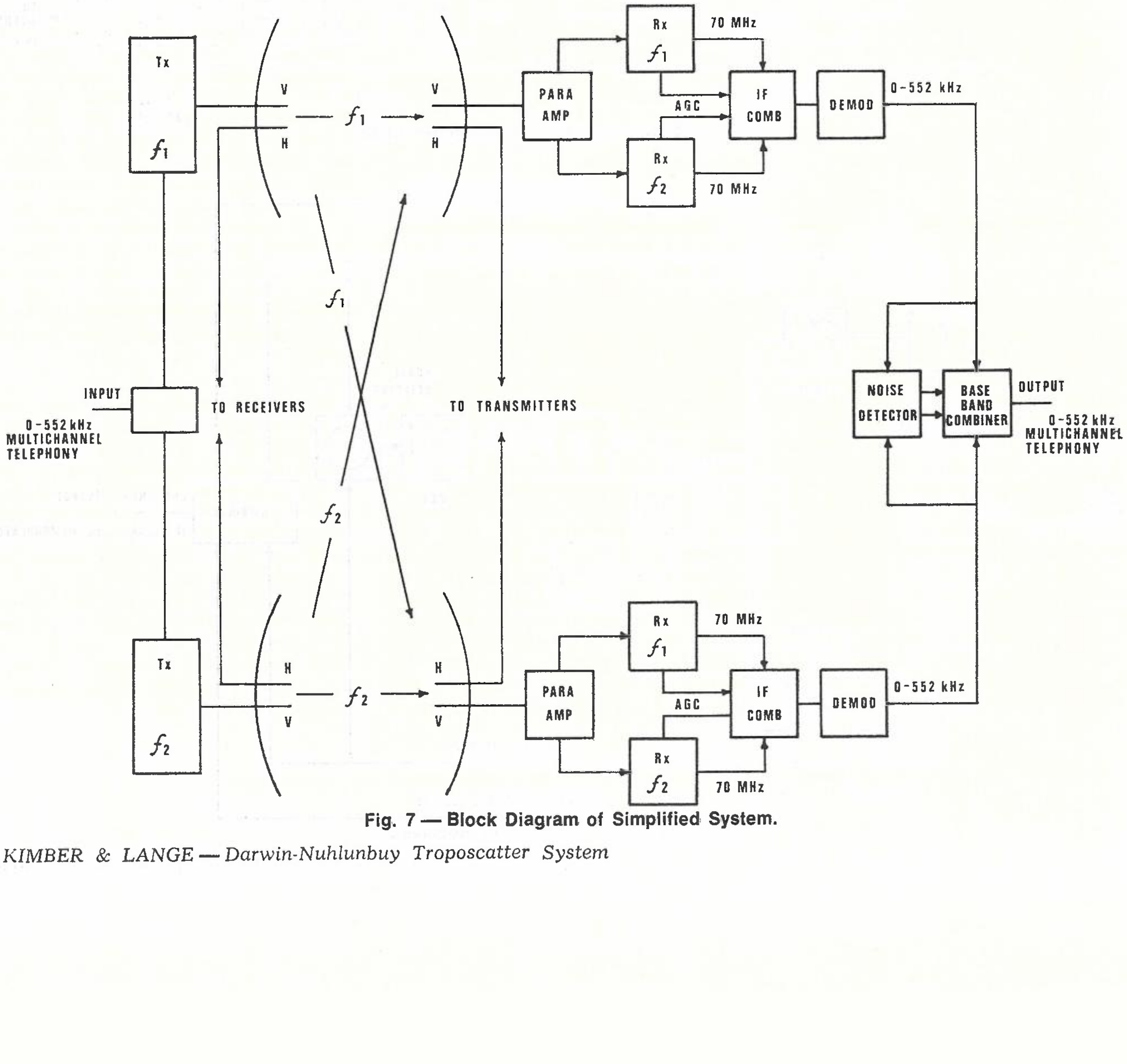


Fig. 7 — Block Diagram of Simplified System.

klystron replacements represent a significant portion of the operating costs of the system.

(*d*) *Low noise Amplifier (type RPO-2G120-4A)*

The low noise amplifier used in this system consists of a parametric amplifier followed by a transistor amplifier which, together give a noise factor of less than 2.5 dB and a gain greater than 22 dB. The parametric amplifier is pumped by an 18 GHz signal derived from a Gunn oscillator. This oscillator has an output power of +20 dBm. The low noise amplifier has a band width of 40 MHz and amplifies the two incoming RF channels which are 28 MHz apart.

(*e*) *Receiver (type RO-2GA120-4A)*

The receiver bay contains two down-converters, an IF combiner and a threshold extension demodulator. The down-converters mix the incoming RF signals with a local oscillator signal to produce two intermediate frequency signals of 70 MHz. These two IF signals are kept in phase by a phase detector which senses differences between the two signals and varies the phase of the local oscillator to maintain the correct phase relationship be-

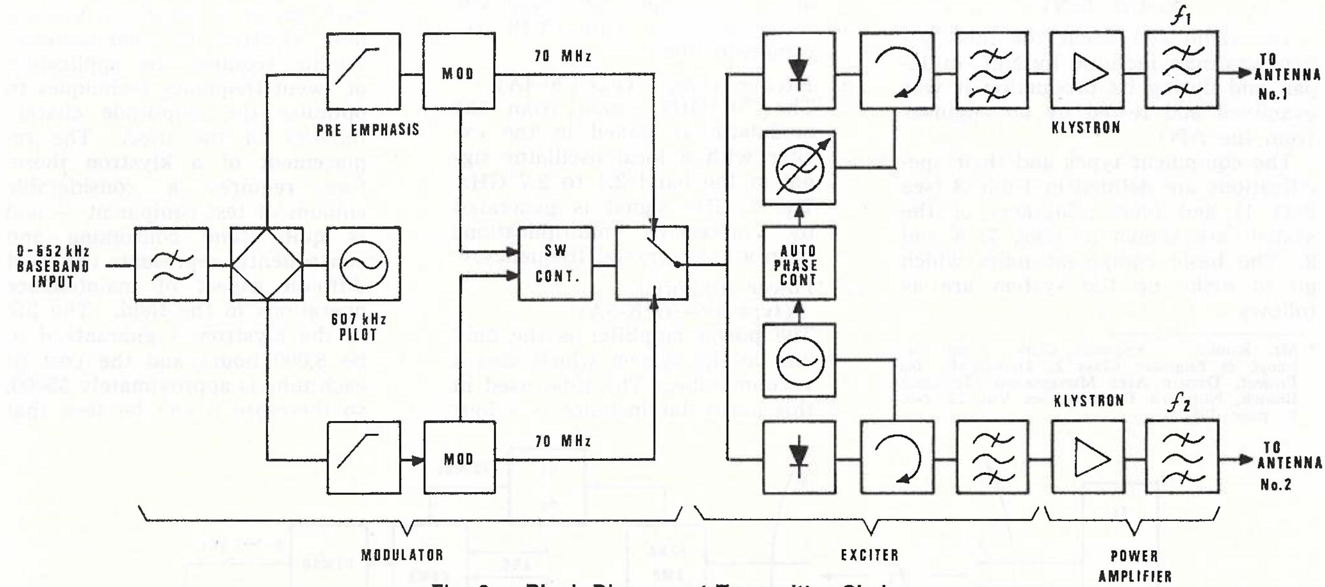


Fig. 8 — Block Diagram of Transmitter Chain.

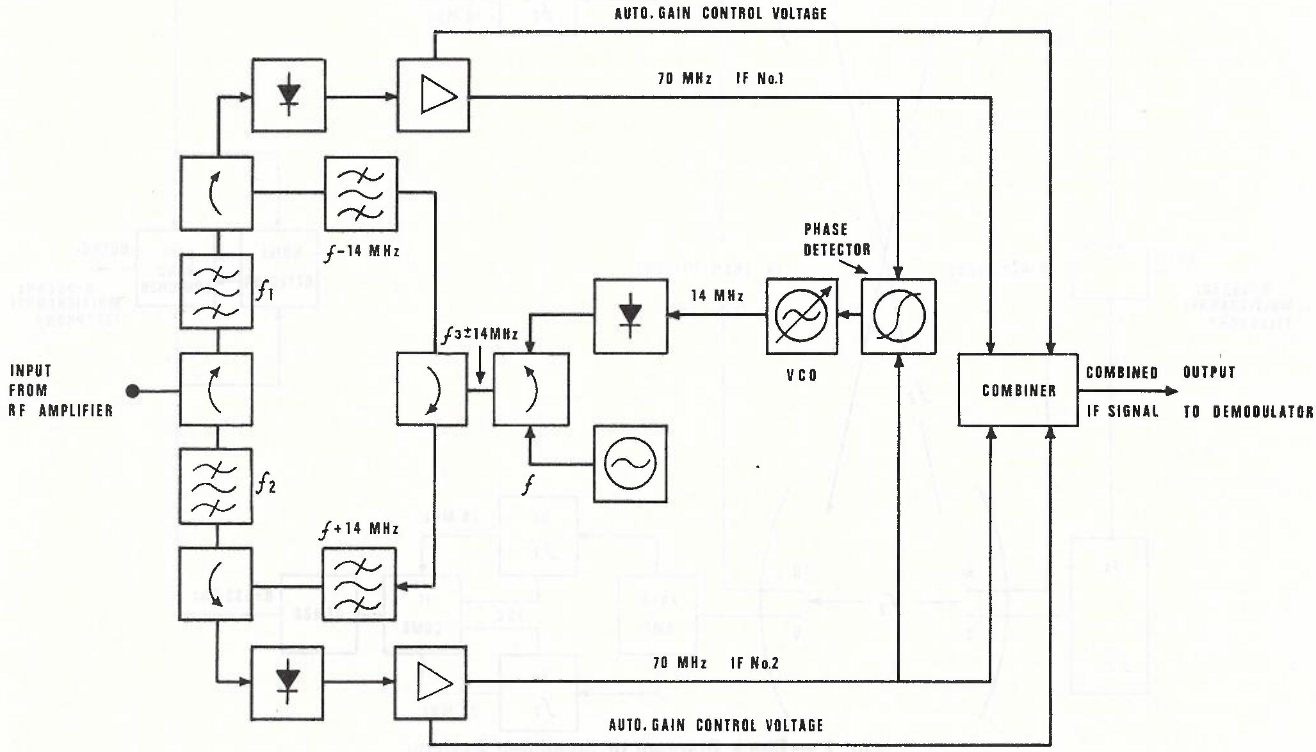


Fig. 9 — Block Diagram of Receiver.

tween the two signals. The phasing of the two signals is a necessary requirement for IF combining. The combination of the two signals is carried out in a non-linear adding circuit which derives its control voltages from the AGC circuits developed in each receiver. The output of the threshhold extension demodulator, which incorporates an appropriate de-emphasis network, is then fed to the baseband combiner.

(*f*) *Baseband Combiner* (*type CBO*-120-3*B*)
Baseband signals in the band 0 - 552 kHz from the two receiver chains are combined using ratio squaring techniques in the baseband combiner. Control voltages to determine the ratio of combination are derived from noise sensing circuits which measure, in effect, the top channel signal to noise ratio. The baseband combiner incorporates bypass and muting circuits to cope with failures within itself and high noise conditions on one of the receiver chains. The baseband combiner incorporates filters to remove the 607 kHz continuity pilot and to extract the sub-baseband circuits in the Band 0 - 44 kHz.

(*g*) *Supervisory Equipment* (*type NAR* 855, 856)
In order to satisfactorily monitor the system operation (see Equipment Maintenance section), it was necessary to provide supervisory equipment to indicate to the Darwin terminal the status of the system. In the first instance, the equipment provided 15 alarm indications from each station. However, this number proved to be inadequate for the maintenance policy to be adopted by the APO and modifications were made to the system to allow up to 28 alarms to be derived from the original supervisory equipment. The supervisory system extends alarms from the remote stations simply by identifying the particular station to the operator in Darwin who then interrogates that particular station.
All information is transmitted via a voice circuit derived from the sub-baseband system, which also provides omnibus and express order wires and wayside circuits which have been used to provide subscribers' services to the residents of Munmalary and Milingimbi.

(*h*) *Antennae*
The 10m and 12m antennae used on this system were made from sixteen panels bolted together to form a paraboloid on a galvanised steel structural frame. Each panel consists of an aluminium tube and angle frame covered with expanded aluminium mesh. A dual polarized horn is used as the illuminator which is supported at the focal point by 4 galvanized steel tubes. The specifications of each antenna are shown in Table 3.

Power Plant

It was decided to operate all the radio equipment from 3 phase 415-240 volts a.c. power because of the very high input power requirements of the power amplifiers which could not be accommodated by a battery installation. Some investigation was made into the provision of no-break plants but to supply up to 30 kVA from such plants in remote areas could have been troublesome, so the decision was made to provide primary a.c. power which was backed up by normally stationary diesel alternators.

Power Requirements

The A.C. input power of a typical repeater station is shown in Table 4.

The consumption of a terminal is approximately half that shown in Table 4 (11,029 VA).

Power Supplies

(*a*) *Darwin*
At the Darwin (Cox Peninsula) terminal, the station derives its a.c. input power from the essential bus provided for the Radio Australia receiving station. An emergency plant automatically starts to supply the whole receiver station and the Tropospheric Scatter terminal after a mains fail.

(*b*) *Munmalary*
At Munmalary the site is so remote that no commercial or private mains power is available and consequently provision had to be made to generate sufficient power locally. To cater for the power consumption as shown in Table 4, it was necessary to install 35kVA diesel generating plants. The power shelter layout is shown in Fig. 10.

This power generation installation had to be properly engineered to provide an extremely reliable supply. For this reason three diesel alternators were installed and incorporated a sequential start up procedure in the event of failure of one or two machines. The diesel engines (Lister HR6) were designed for continuous running and oil make-up tanks with float valve regulators were provided to obviate frequent oil changes and to allow the machines to run unattended for at least six weeks.

Fuel supplies for this site also presented considerable problems since the site was inaccessible for up to six months of the year during the wet season and so a 10,000 gallon overhead fuel storage facility had to be provided.

(*c*) *Milingimbi*
At Milingimbi Island, an agreement was reached with the local mission station that a.c. power would be available from their own supply and because of this a two mile underground cable was laid to connect the repeater station and the mission power house. To guard against failure of the primary supply, two 35kVA diesel emergency plants were installed. The diesels are arranged to start sequentially in the event of the failure of the first machine.

TABLE 4.—INPUT POWER FOR TYPICAL REPEATER

Bay/Unit	Number	Consumption/ Unit (V.A.)	Total (V.A.)
Parametric Amplifier	4	61	244
Receiver/Demodulator	4	96	384
Baseband Combiner	2	20	40
Modulator	2	46	92
Exciter	2	129	258
Power Amplifier	4	4,540	18,160
Dehydrator	1	20	20
Supervisory & Sub-baseband	1	20	20
Miscellaneous	—	—	400
Air Blower	1	3,024	3,024
Test Equipment (Intermittent)	—	—	1,000
Total			23,642

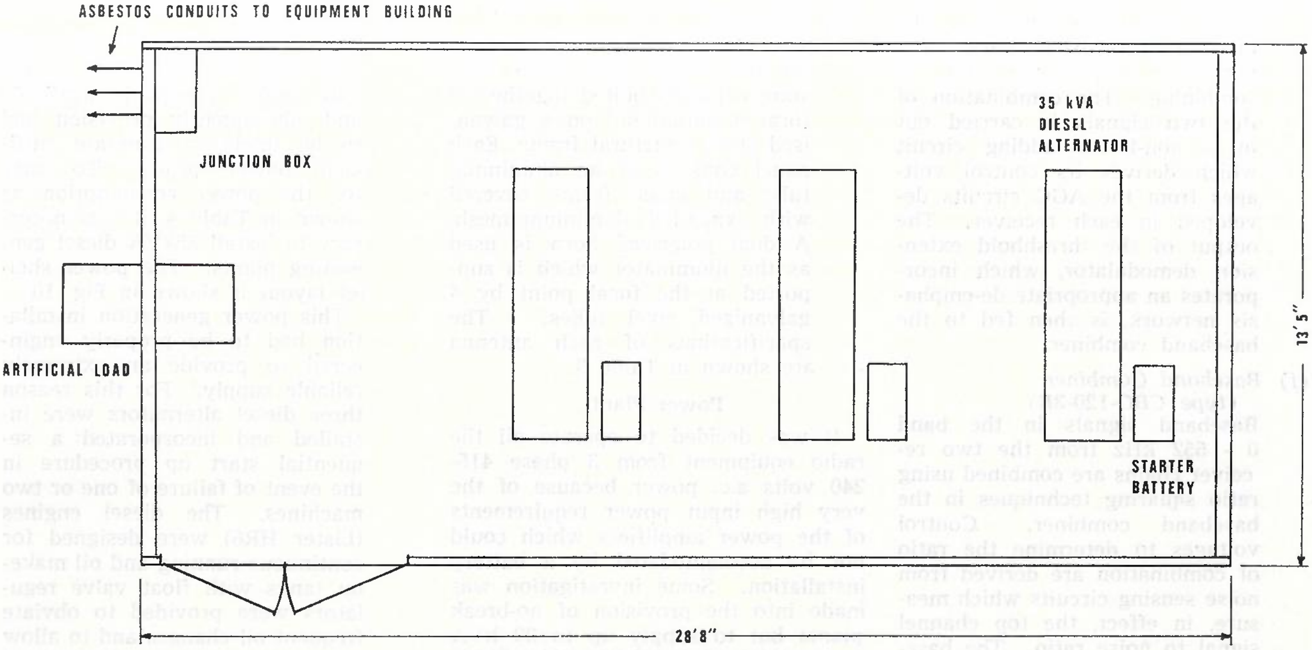


Fig. 10 — Power Shelter Layout.

Because of certain difficulties regarding the supply of power from the mission, these two diesel alternators have been required to run continuously since the system was first installed and consequently provision had to be made to allow them to run in this way. However, this state of affairs is temporary only and it is expected that the station will run on mains supply from March 1972.

(*d*) *Nhulunbuy*

At Nhulunbuy, commercial mains supply is available to the terminal station from an adjacent 22kV line. Unfortunately this line feeds power to a conveyor system, large compressors and primary crushing plants, most of which utilise direct-on-line starting which causes severe voltage fluctuations. In order to overcome these variations, which are too fast and too large to be controlled satisfactorily by an electronic or magnetic regulator, a 15kVA motor alternator set was installed. This motor alternator set acts as a buffer between the station load and the mains supply. The set consists of a

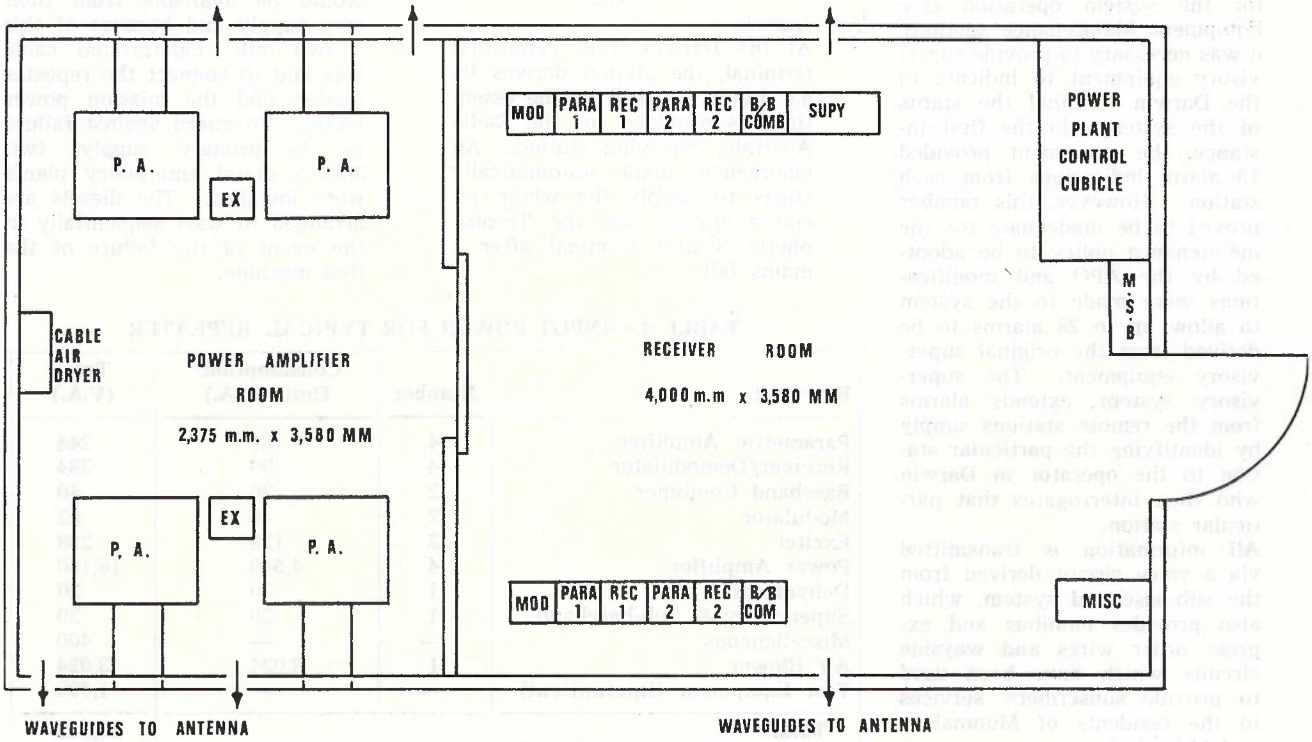


Fig. 11 — Equipment Shelter Layout.

25 h.p. induction motor driving a 15kVA alternator.

The motor alternator can be automatically or manually bypassed if a fault occurs in it and two automatic start diesel alternators are also provided in the event of mains failure. One of these two sets is in fact held as a replacement unit for any of the sets installed on the route. If a major fault occurs in a plant at either Munmalary or Milingimbi, facilities are available to transport the spare set by barge to either of those two sites.

POWER PLANT BUILDINGS

The power plant at all sites is housed in prefabricated sheds which were manufactured in Adelaide. These sheds are of open construction and allow free air circulation to cool the diesel alternators. This environment is unsuitable for the control cubicle and its related equipment so these units are installed within the dust free environment of the equipment building.

EQUIPMENT BUILDINGS

Because of the short lead time in the provision of the system, transportable steel framed buildings were chosen to house the equipment. These buildings are of a type which is in common use in South Australia to house large country automatic exchanges. The floor dimensions of these buildings are 21 ft. by 12 ft., and the layout of equipment at a typical repeater station is shown in Fig. 11.

The building design was extensively modified to suit tropical conditions and was painted with a highly reflective long life vinyl paint to reduce surface temperatures. The buildings were also insulated with fibre glass, but this insulation is not entirely necessary for the satisfactory operation of the buildings, since no attempt is made to aircondition them. The heat dissipation within the building is extremely high (approximately 8.6 kW) and so it is obvious that with the power supply available there is no possibility of using demand air conditioning. However, the equipment temperature must be maintained below 45°C which in the worst case allows an approximately 5°C temperature rise above ambient within the building. In order to achieve this relatively low temperature differential, large blowers have been installed to circulate air through the building. The volume of air required is 4000 cu. ft. per minute and this is obtained by using 19 in. axial duct fans.

In order to limit the amount of dust ingested during the dry season and water during the wet season, an extensive air filtration system is utilised. Firstly, the air passes over turbulence inducing louvres which precipitate most of the air-borne water. The remainder of this water and some dust is removed in a viscous filter which follows the louvres. This filter in turn is followed by an automatic advance roller filter using a fibre glass medium.

The buildings were manufactured in Brisbane and transported to Darwin where the majority of equipment was installed in them. Subsequently they were transported to each of the sites by road or barge as described in the installation section of this article.

INSTALLATION AND TESTING

Because of the remoteness and inaccessibility of the system, installation and testing provided not only the usual technical problems, but also rather unusual logistic problems. The general installation problem was tackled by carrying out as much work as possible in Darwin and then transporting completed items, usually in parts, to site and re-assembling them. All materials for Millingimbi and Nhulunbuy were brought in by barge while men were usually moved by charter aircraft. The installation pro-

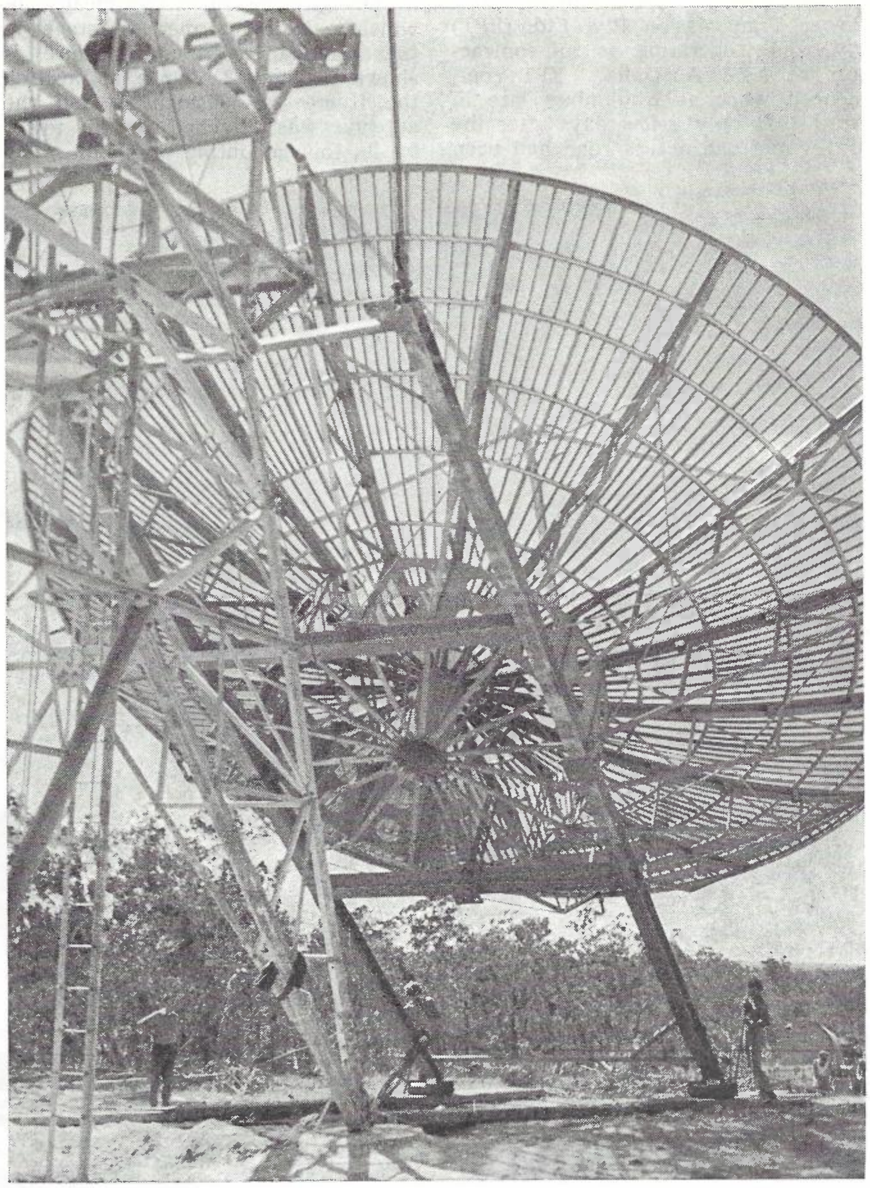


Fig. 12 — Lifting 12m Dish at Munmalary.

gramme was timed so that all heavy construction work was carried out during the period April to September 1971 so that Munmalary and Cox Peninsula were accessible by road. Because of the remoteness of all sites and the complete absence of any reliable and readily available communication system the APO provided a H.F. network utilising AWA SS 220 H.F. transceivers. This system was used extensively by both the APO and contractors and, without it, the project would not have been completed on schedule.

TOWERS AND ANTENNAE

The installation of towers, antennae, earthing system and all foundations was carried out by Electric Power Transmission Pty. Ltd. (EPT) of Sydney operating as sub-contractors to NEC Australia. EPT commenced work at Nhulunbuy late in April 1971 only a few days after the site works and access road had been completed. The installation of the towers presented no difficulties but the assembly of the parabolic dishes and their installation on the towers caused a number of technical problems. The surface accuracy of the reflector had to be within ± 5 mm so that great care had to be taken during assembly and installation. The antenna was checked by measuring the radial distances from the feed horn to points on equal chord distances from the parabola's centre. The problem of distortion during erection was overcome by utilising a heavy erection frame on which the dish was assembled and, after careful checking, lifted into position. A 30 ft. extension was added to the basic antenna support tower, and this enabled the frame plus antenna to be lifted into position by means of winches. An intermediate stage in the antenna erection procedure is shown in Fig. 12. Once in position the frame was dismantled and the antenna was attached to the tower by its four mounting points.

Since all sites are in areas with extremely high isoceraunic levels, extensive earth systems were designed by the APO and installed by EPT to bring earth resistances below 5 ohms. Installation by EPT took approximately one month per station and was completed by late August, 1971.

POWER INSTALLATION

This installation was carried out by APO staff and followed EPT across from Gove since it took approximately three weeks to erect the power shelter, install the plants and control cubicles and finally test the power installation.

EQUIPMENT INSTALLATION

The equipment shelters were handed to NEC for equipment installation in Darwin on April 18th, 1972. NEC and APO staff then completely installed and tested the equipment in each shelter. Once all shelters were completed and all equipment operated

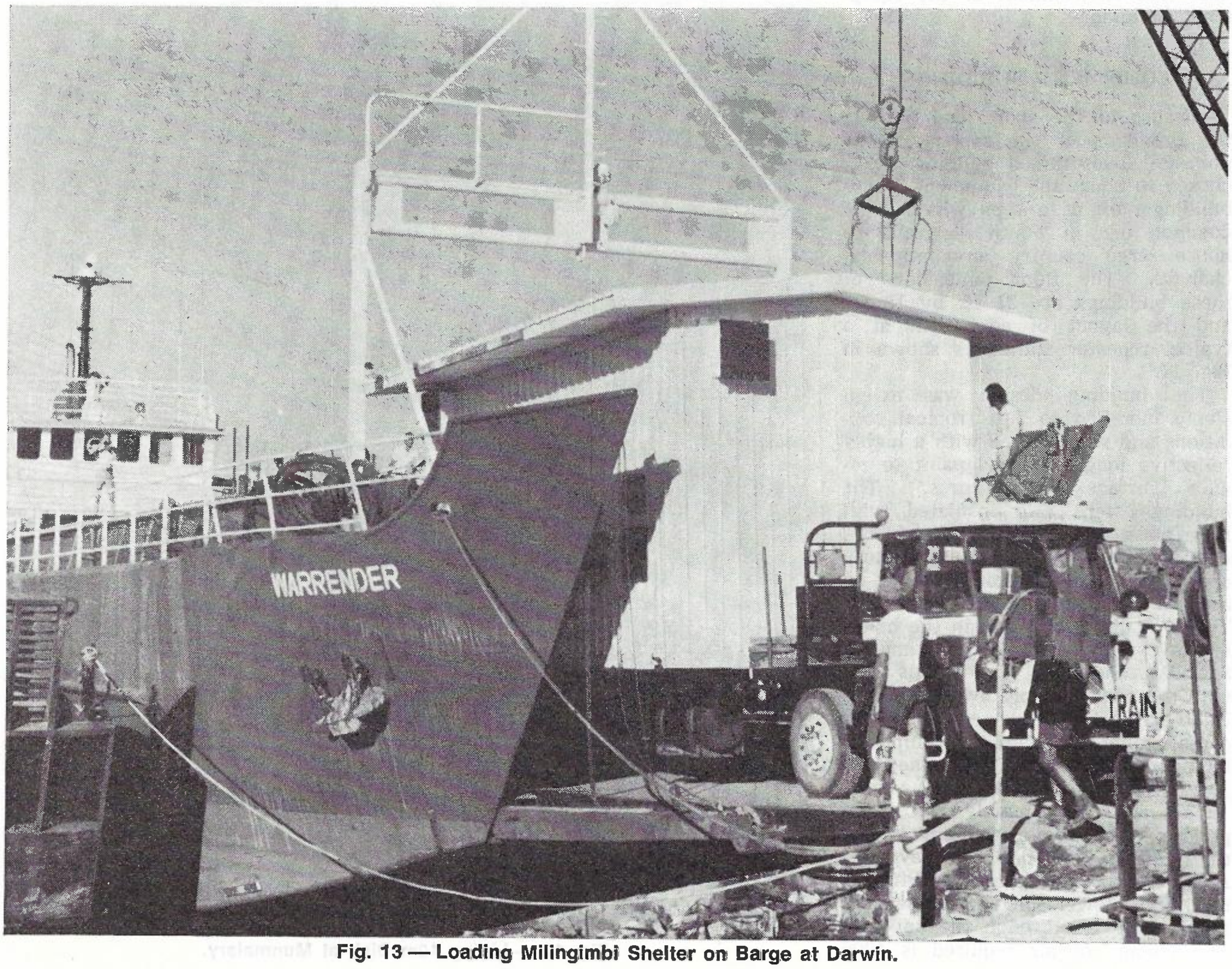


Fig. 13 — Loading Milingimbi Shelter on Barge at Darwin.

correctly, simulated hop tests were carried out by interconnecting transmitters and receivers via lossy cables. In this way all possible tests were carried out to ensure that the system would operate satisfactorily.

Since the shelters are not airconditioned, the performance of the equipment up to its guarantee limit of 45°C (113°F) was of vital concern. During factory tests NEC had heat cycled all panels but the APO insisted on an additional test to ensure that no interface problems arose during operating conditions. Consequently each shelter was heat cycled twice between ambient temperature and 45°C and kept at 45°C for 14 hours. During this temperature cycling the line-up levels of the equipment, its noise performance and all in built meter readings were monitored, also the base band was continuously scanned for spurious signals but none was found above the threshold noise level. After completely testing the system on a hop basis all panels were removed and repacked for transport to site.

Transporting of the shelter to site proved one of the major problems since by their sheer size and weight they are best handled by large cranes both during loading and unloading. The problem was finally overcome by shipping the shelters to Nhulunbuy and Milingimbi on trucks which drove from the barge to site and were unloaded by using four heavy duty jacks. The loading of truck and shelter onto a barge for transport to Milingimbi is shown in Fig. 13. The shelters for Munmalary and Cox Peninsula were shipped on low loader and also unloaded utilising the jacking technique. Cranes were used to load the shelters onto the low-loaders in Darwin (see Fig. 14). The trip to Munmalary proved to be the most difficult, since the road was narrow and obstructed by overhanging trees. It took five days to travel the last 100 miles to the site.

As each shelter was installed on its foundations APO staff installed the power control cubicles in them to provide continuous power. Again instation tests were carried out and no marked variations from the Darwin tests were found. Before hop tests could commence the 10 and 12 metre paraboloids had to be adjusted to obtain best received signal strength. The paraboloid could be panned in the azimuth for ±2.5° by means of two large azimuth adjusting screws, while in the vertical plane the beam was shifted by changing the position of the illuminator. The vertical adjustment was ±1.5°. Due to the variable nature of the received signal it was recorded for approximately 15 minutes and its average level used in determination of received signals level against angular position. It took four to six days per hop to adjust all four antennae.

Hop tests were carried out commencing September 1971 and, except for overall total signal to noise, the results were as expected.

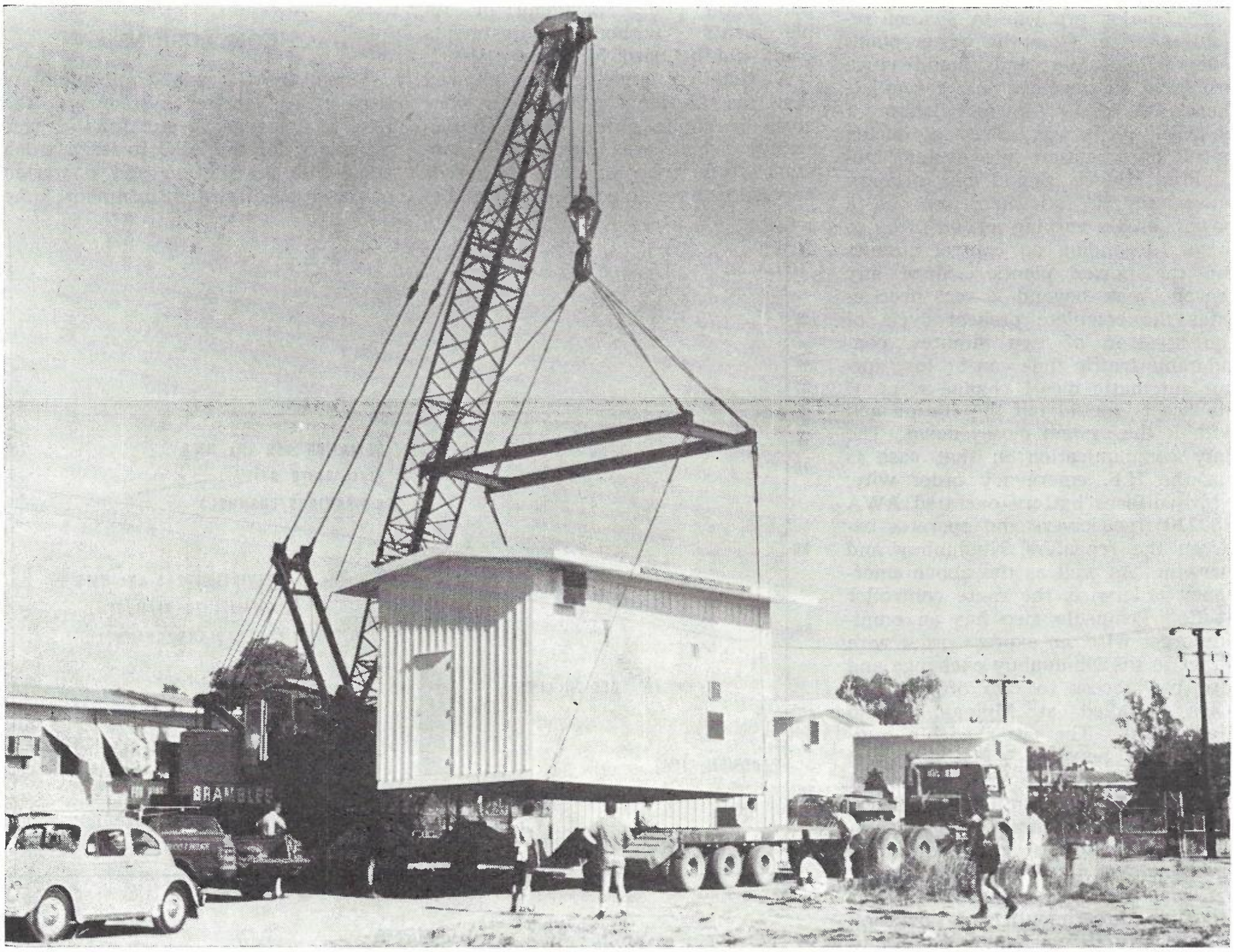


Fig. 14 — Loading Fully Equipped Shelter for Nhulunbuy at Darwin Depot.

SYSTEM MAINTENANCE

The problem of system maintenance had to be given special consideration since each maintenance trip involves the use of charter aircraft. Since it employs quadruple diversity the system has a high degree of redundancy, and will therefore continue to carry traffic, with perhaps slightly degraded noise performance, while the faulty unit is repaired.

To enable effective supervision of the system from its control station, 28 alarms per station are extended on the sub-baseband. These alarms enable the route controller to identify a group of panels constituting a 'maintenance unit' which is then despatched with the maintenance staff. Adjustments on site are restricted to klystron, all other panels being replaced on a plug-in basis, with repair being carried out in the depot-spare and repair facility established at Cox Peninsula Radio Australia receiver site.

The major problem to system reliability arises from the power plant. Due to locality and maintenance problems as well as power requirement (30 kVA) the installation of no-break plant was ruled out during initial investigation into system feasibility. Hence should our primary power supply fail there will be a power break varying of 0.5 sec. to 8 sec. depending on control circuits for the power plants. Since any power break beyond 2 sec. necessitates the complete preheat cycle of the klystron of two minutes, considerable traffic time can be lost during automatic diesel change-overs. If all diesels should fail the station and with it the system closes down. The only communication in that case is via the H.F. emergency order wire, which utilises battery operated AWA SS 220 transceivers and operates between the repeaters, Nhulunbuy and Darwin. As well as the above emergency orderwire, the route controller at Cox Peninsula also has an omnibus order wire, an express order wire direct to the Nhulunbuy exchange and also has access to two official services installed at Milingimbi and Munmalary. The latter enable communication between APO staff and the nearest available help in case of fire alarms or similar problems. While the remoteness and inaccessibility of stations are proving a problem, system performance, except for some power plant problems, over the first three months of operation has been gratifying with no equipment faults occurring.

Until the time of writing the only problem encountered during the operation of the system has been the frequent failure of the Gunn oscillator which is the 18 GHz pump source for the parametric amplifier. A total of eight of these units failed before the fault was traced to unsatisfactory mounts for the Gunn diode. This has been rectified and none of the modified units has failed. The overall signal to noise ratio for each hop just met the specification and since according to Unthank and Barton (Ref. 7) the tests were being carried out during the best time of the year, this caused considerable concern. Since hop tests were of necessity short (two days only) it was decided that no action could be taken until more data was available. Another factor brought out during these tests was that the 1 kW klystron was difficult to adjust and had to be adjusted to obtain minimum S/N on an internal R.F. loop using a 116 MHz frequency shifter. This meant that for future replacement, the departmental policy of 'plug in' replacements without adjustments could not be used for these units.

A detailed investigation showed that the klystron exhibited a very steep parabolic group delay characteristic which was sufficiently constant from tube to tube to allow correction by a fixed IF equaliser between modulator and exciter. This was suggested as a solution to NEC, but subsequent system modifications removed the necessity of group delay equalisers.

Overall system tests commenced late October 1971 and after approximately one week of noise recording it was obvious that the deviation per channel had to be reduced to reduce path intermodulation noise. In accordance with CCIR Report 446 (New Delhi 1970), the deviation per channel was optimised to achieve the best balance between thermal and path intermodulation noise. The deviation was reduced from 1 to 0.6 radian channel. This had the two-fold effect of improving system noise performance as is shown in Figs. 15 and 16, and secondly it largely eliminated the klystron intermodulation problem.

Overall system tests were completed on 20th December, 1971 and the system began carrying interim traffic, awaiting completion of the Nhulunbuy crossbar exchange on 24th December, 1971.

CONCLUSIONS

Since the Darwin to Nhulunbuy tropospheric scatter system was the first of its type in Australia it was necessary for the APO to learn much about the installation and operation of this type of system in a short time

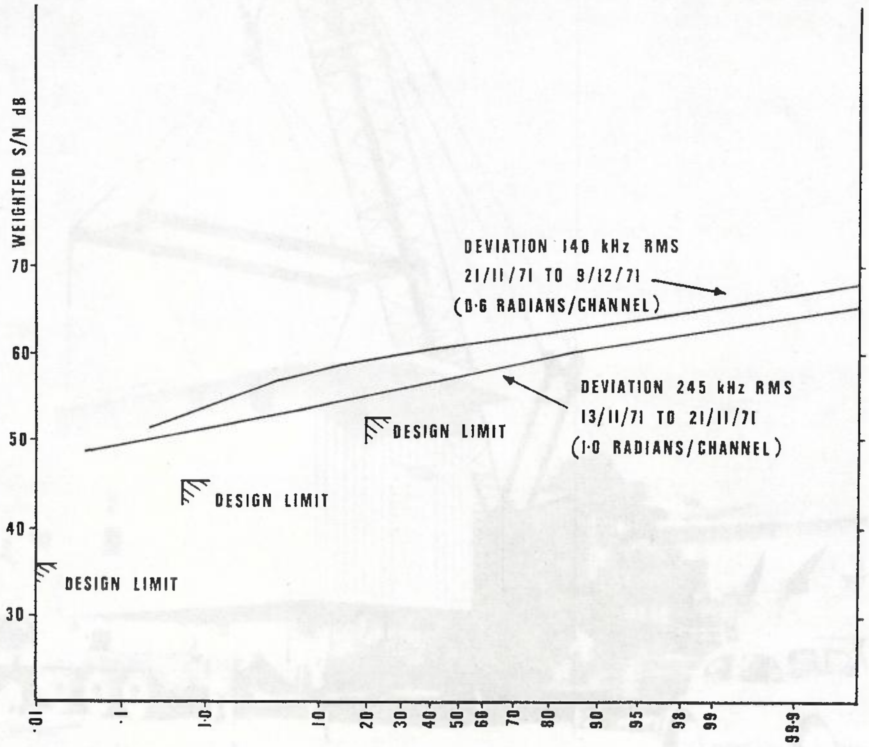


Fig. 15 — One Minute Mean Signal to Noise (Darwin to Nhulunbuy).

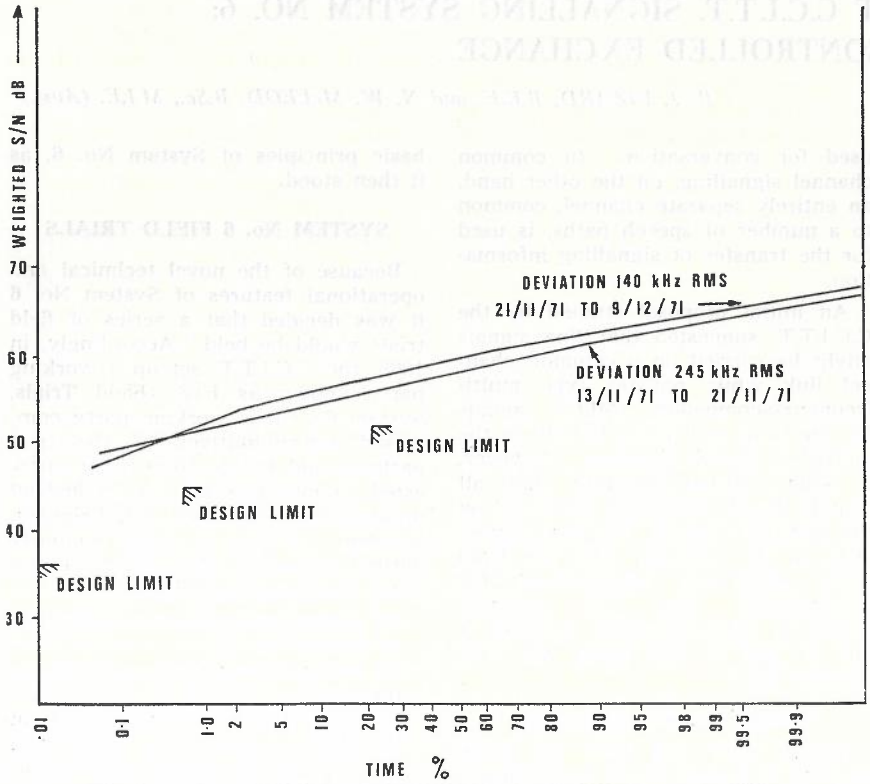


Fig. 16 — One Minute Mean Signal to Noise (Nhulunbuy to Darwin).

and with the assistance of its contractors was able to install a satisfactory and well engineered system. The system met its specifications and is continuing to operate satisfactorily despite the remoteness of the sites and the harsh conditions in which it operates.

ACKNOWLEDGMENTS

The authors, who controlled the installation of the system, are particularly grateful for the co-operation received from the engineers and technicians working with NEC, since it was through them that we learnt so much about tropospheric scatter systems and problems associated with the equipment. The authors are also grateful to the residents of Munmalary Station and Milingimbi Mission for the assistance afforded to the APO and its contractors during the installation of the project for without that assistance the installation would have been far more difficult.

NATIONAL FIELD TRIAL OF C.C.I.T.T. SIGNALLING SYSTEM NO. 6: PART 1 — A PROCESSOR CONTROLLED EXCHANGE

*R. J. VIZARD, B.E.E. and N. W. McLEOD, B.Sc., M.I.E. (Aust.)**

During 1968 the Australian Post Office commenced work directed towards a field trial of an inter-exchange signalling scheme known as C.C.I.T.T. System No. 6. System No. 6 is a common channel signalling scheme which uses a data link to convey all necessary signalling information for a group of circuits, and presupposes the use of stored-program controlled exchanges at each end of the data link. During the field trial, the Switching and Signalling Branch of the APO Research Laboratories designed, built and put into public service a model stored-program controlled crossbar exchange.

This article describes that exchange and the other equipment which was developed and gives an outline of the results of the field trial. A following article (Part 2) describes the various software (stored program) systems which were developed for use during the trial.

C.C.I.T.T. SIGNALLING SYSTEM No. 6

Preliminary development of this new system commenced in 1964 when the International Telephone and Telegraph Consultative Committee (C.C.I.T.T.) of the International Telecommunications Union decided that methods then available for international telephone signalling would become inadequate for future use, particularly as international subscriber dialling was introduced. A new system was required which should offer improvement in post dialling delay and provide a fast answer signal. As well, it should be suitable for use with all sizes of circuit groups or modes of transmission, in particular satellite circuits.

After consideration of various systems it was decided that common channel techniques held the most promise of an increase in speed of signalling. Readers will be to some extent familiar with conventional signalling techniques, where messages related to setting up, supervising or clearing down of telephone calls are sent over the individual speech path circuits used for each call. These messages may consist for example of a train of dial impulses or multi-frequency tones but in all cases are directly related for their transmission to the speech path used for conversation. In common channel signalling, on the other hand, an entirely separate channel, common to a number of speech paths, is used for the transfer of signalling information.

An initial proposal studied by the C.C.I.T.T. suggested that line signals might be carried on a common channel link while register type multi-frequency-compelled (MFC) signals for the same call would be left on the individual speech channels. However, it soon became apparent that all signals should preferably be routed on the common channel. The new system was to be radically different from those previously standardised for international use, for example C.C.I.T.T. multifrequency Systems 4 and 5, and it was given the title 'System No. 6'.

System No. 6 Specification

During 1967 and 1968 the basic features of System No. 6 were defined. Although designed principally for international use, the system was also intended to be applicable to national networks. The Australian Post Office, in association with the Overseas Telecommunications Commission (Australia), (OTC (Aust.)), played a part in the design and specification of the system. In October 1968 the C.C.I.T.T. formally approved a Specification for the new signalling system.

It is easy to understand the enthusiasm which attended this development. Here was a new system, the first to be defined by C.C.I.T.T. without constraints imposed by equipment already in service with, it was hoped, the potential to become a truly universal system suitable for all levels of national and international networks. The data transmission methods employed on the signalling link suited the new computer-controlled exchange types then being considered by many administrations. As well as satisfying known requirements, the new system had ample spare capacity to allow the introduction of new signals or messages that might be required for new functions such as network management or centralised accounting.

It is not intended in the present article to give a detailed description of various features of the No. 6 Specification. However, the interested reader is referred to the October 1969 issue of this journal in which an article by G. L. Crew (Ref. 1) describes the basic principles of System No. 6, as it then stood.

SYSTEM No. 6 FIELD TRIALS

Because of the novel technical and operational features of System No. 6 it was decided that a series of field trials would be held. Accordingly, in 1968, the C.C.I.T.T. set up a working party known as FT6 (Field Trials, System 6). This working party comprised representatives of the trial partners and people from other interested administrations or industrial organisations such as L. M. Ericsson, Sweden. It was to meet regularly during the period 1968-1972 and was given these responsibilities:

- To arrange and supervise field trials of System No. 6
- To devise test methods and analyse results
- To revise the No. 6 Specification in the light of field trial experience.

It is interesting to note that Working Party FT6 had quite definite limitations to its charter. While it could introduce system changes in order to provide operational facilities, it had no power to alter basic features of the No. 6 Specification. Indeed, the limited time available for administrations to prepare trial equipment made any major change impracticable. Within these limitations, however, a large number of detail changes were introduced progressively by Working Party FT6 in order to provide a proved and workable system.

Field Trial Phases

In order to allow a progressive and orderly exploration of the facilities offered by System No. 6, Working Party FT6 decided to break up the trial work into 3 distinct test phases. These were, in brief:

- *Phase A:* tests using messages passed over the signalling link.
- *Phase B:* simulated traffic on the signal link, and test calls through exchanges.
- *Phase C:* live (paid) traffic generated by subscribers or telephonists.

In each of these trial phases it was necessary for specially devised software systems to be provided at the test stations (see Part 2 of this article). In Phase A the basic adequacy of signal channels was established by transmission of a prearranged list of signals.

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The simulation methods devised for Phase B were of considerable interest. As far as No. 6 signal links and terminals are concerned, there need be no difference in the loading presented by simulated or real calls, both consisting merely of the signals nominated to be sent by the computers at either end of the link. The computers themselves provide a powerful means of analysis of the test results. The FT6 simulation method allowed considerable variation of factors such as signal traffic load or call types. Severe operational conditions were provided by injecting artificial errors on the No. 6 data links. The versatility and effectiveness of this simulation test method contributed greatly to the value of field trial results.

Simulated traffic was also used as an adjunct to live traffic tests (Phase C) in order to provide a substantial background loading of the signal links.

The progress of field trials was such that most partners had commenced Phase A tests by the end of 1970. Phase B testing commenced in mid 1971. Towards the end of 1972 several administrations had been able to enter Phase C testing and the work of the FT6 group was completed with the presentation of a final report and revised System No. 6 Specification to the C.C.I.T.T.

It is interesting to consider the scope of the work coordinated by Working Party FT6. A large number of field trial partnerships were established. The study was one of the broadest ever undertaken by the C.C.I.T.T., and has been quoted as an excellent example of international cooperation. The period of 8 years elapsing from early definition of System No. 6 to its first use in public service gives a measure of the task involved.

SYSTEM No. 6 NATIONAL TRIAL

Although primarily intended for use in international signalling, System No. 6 has been developed with national needs in mind also. The Australian Post Office was well aware of this potential application and in 1967 decided to take part in field trials. In partnership with the Overseas Telecommunications Commission (Australia), agreement was reached to set up field trial test stations at Windsor, Melbourne, and Paddington, Sydney, to be operated by the APO and OTC (Aust.) respectively.

The national field trial testing carried out by the two Australian trial partners has followed quite closely the test phases as defined in company with the other FT6 test partners. However, some difference in emphasis has been necessary. Of special interest to Australia is the ease of interworking between System No. 6 and our national MFC inter-register system. This has dictated an emphasis on live traffic testing with STD traffic between Melbourne and Sydney carried in Phase C of the trial.

Trial Facilities

The trial equipment provided by OTC (Aust.) and the APO differed considerably. After investigations, OTC (Aust.) purchased a complete

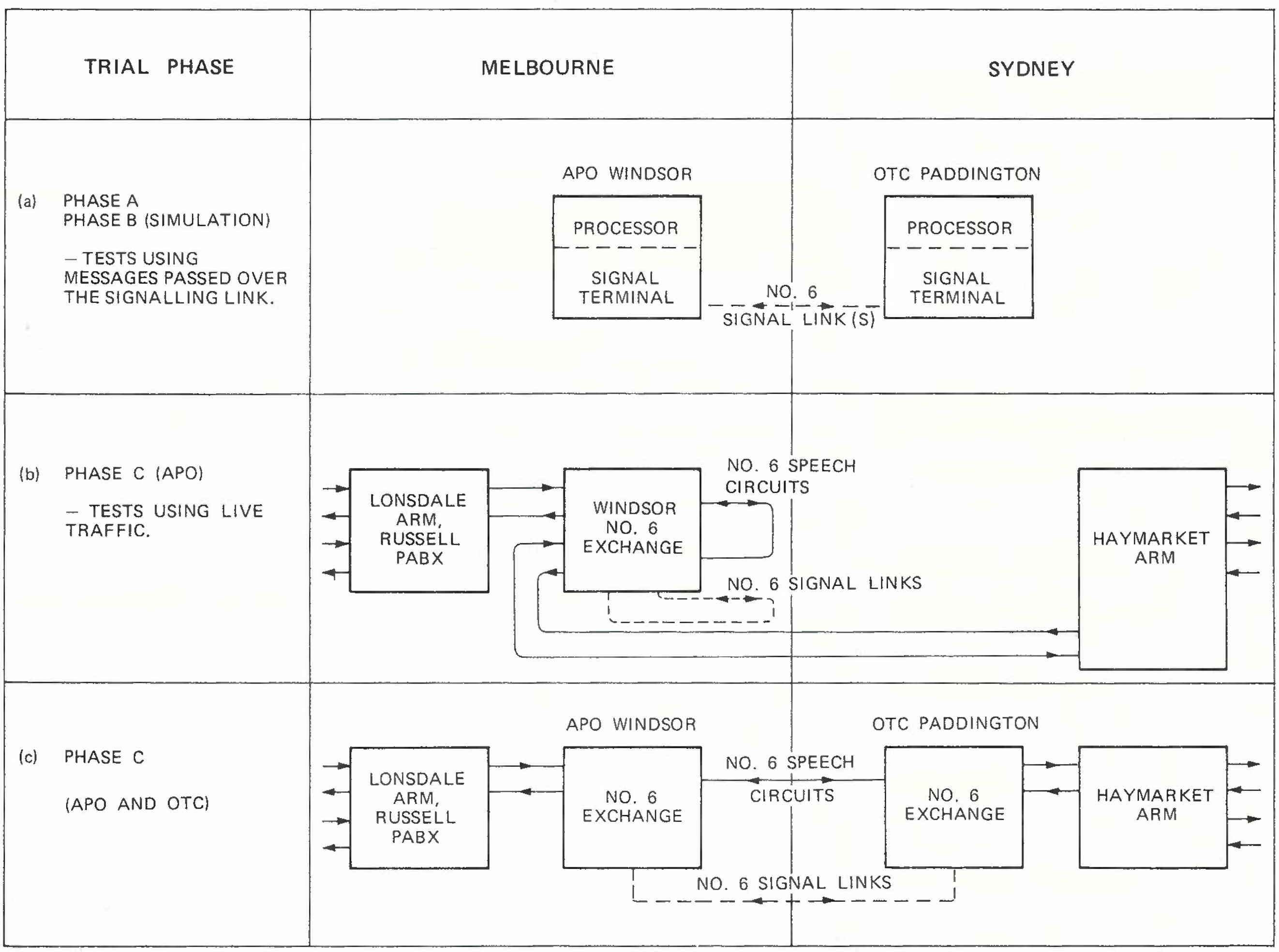

Fig. 1 — Exchange Equipment Arrangements for Different Phases of the National Trial.

trial exchange built to No. 6 Specifications by L. M. Ericsson (Sweden) Pty. Ltd. The APO saw an opportunity to combine several related areas of interest. Since it possessed a number of suitably experienced design staff within the Switching and Signalling Branch of the Research Laboratories, the APO was able to develop its own trial exchange — the No. 6 Exchange described later in this article.

These independent approaches caused very little difficulty in trial tests, due largely to the detailed system definitions contained in the No. 6 Specification.

National Trial Progress

Fig. 1 shows how the trial exchanges have been used in each test phase. The Phase A and B (simulation) tests did not need exchange switching equipment and were commenced in October 1970 and August 1971. Simulation testing continued in 1972.

In October 1972 the arrangement Fig. 1 (b) was used in Phase C tests (STD working). Later OTC (Aust.) was free from obligations imposed by field trials with their international partners and the arrangement shown in Fig. 1 (c) was used in December 1972.

From an Australian point of view, the field trials were very successful. In April 1972 OTC (Aust.) took part in something of a 'first' when the first switched System No. 6 test calls were carried between Sydney and Columbus, Ohio, the Bell Laboratories test exchange. Later, the APO Windsor exchange became the first stored-program controlled exchange to be placed into public service in Australia, and the first No. 6 exchange to handle subscriber-dialled traffic.

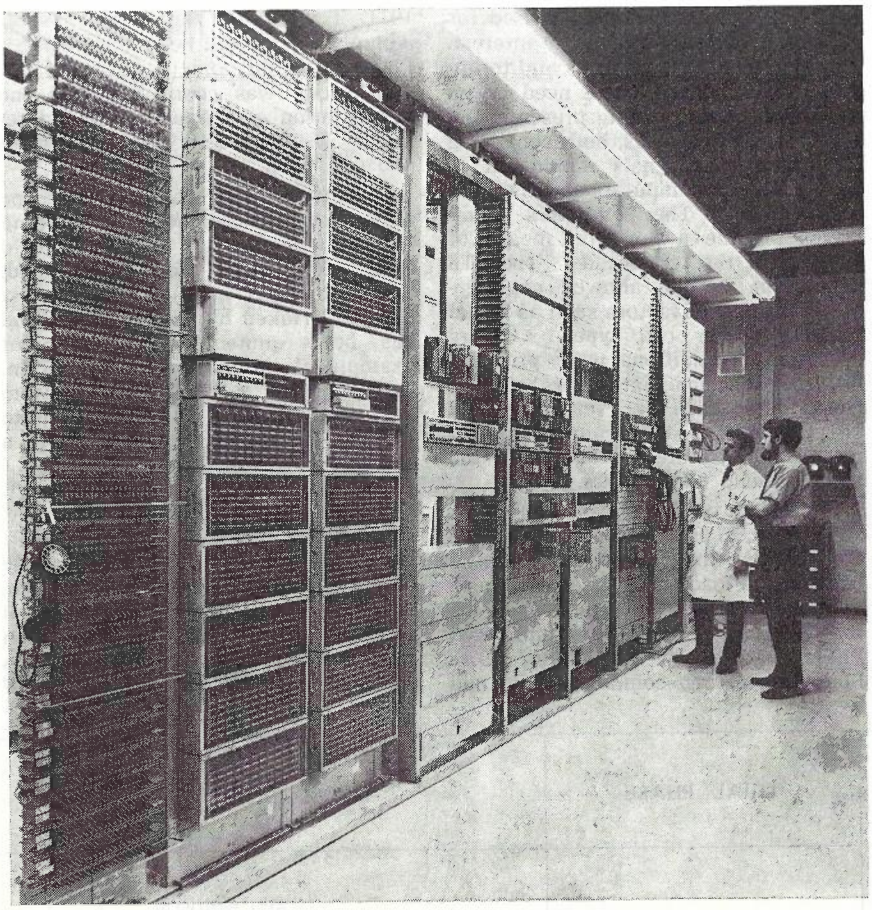

Fig. 2 — APO No. 6 Exchange Switching Equipment.

THE APO No. 6 EXCHANGE

The exchange comprises basically:
- Switching equipment, based on 100 lines of ARM crossbar switching equipment.
- Signal terminals, for the No. 6 Links.
- The processor (or computer) with its stored programs for control of the exchange.

The No. 6 trial therefore provided the APO with the opportunity to gain expertise in a number of new fields, the chief of these being:
- Operation of System No. 6, and its interworking with Australian systems (the national trial as described above).
- The addition of solid-state electronics to relay-type exchange equipment,
- And, most importantly, the design of complex software (processor program) systems for control of exchange equipment.

The latter topic is a considerable subject on its own and is treated separately in Part 2 of this article. It may be observed simply however that the software design and testing of a modern processor controlled exchange presents a problem every bit as complicated and time consuming as that of hardware (equipment) design.

No. 6 Exchange Switching Equipment

As mentioned, the exchange uses 100 lines of ARM switching equipment. This standard equipment has been extensively modified for electronic control. The crossbar switches and the associated electro-mechanical control circuits (marker) that select a path through the crossbar switch have been kept. Semiconductor control and interface circuitry replace many other electro-mechanical functions. Digit analysis, signalling and overall control and supervision functions have been allocated to software in the processor. The APO No. 6 exchange is therefore a mixture of a number of different technologies, electro-mechanical, electronic (integrated circuits), and processor control.

The telephone exchange switching equipment is shown in Fig. 2. The first two racks of equipment contain the crossbar speechpath switches. The remaining racks contain the equipment associated with the individual incoming and outgoing speech circuits and the processor access interface equipment.

Fig. 3 shows a simplified trunking diagram of the equipment. Lines connected to Russell PABX or Lonsdale ARM Trunk exchange use conventional loop (decadic pulse) or multi-frequency-compelled (MFC) signalling. When an incoming call is detected, the processor arranges connection of a dial pulse receiver (DPR) or code receiver (KM) to the appropriate line.

Information dialled by the subscriber is passed to the processor which then directs the switching equipment to connect the line to the required outlet. In the case of a call to Sydney, mes-

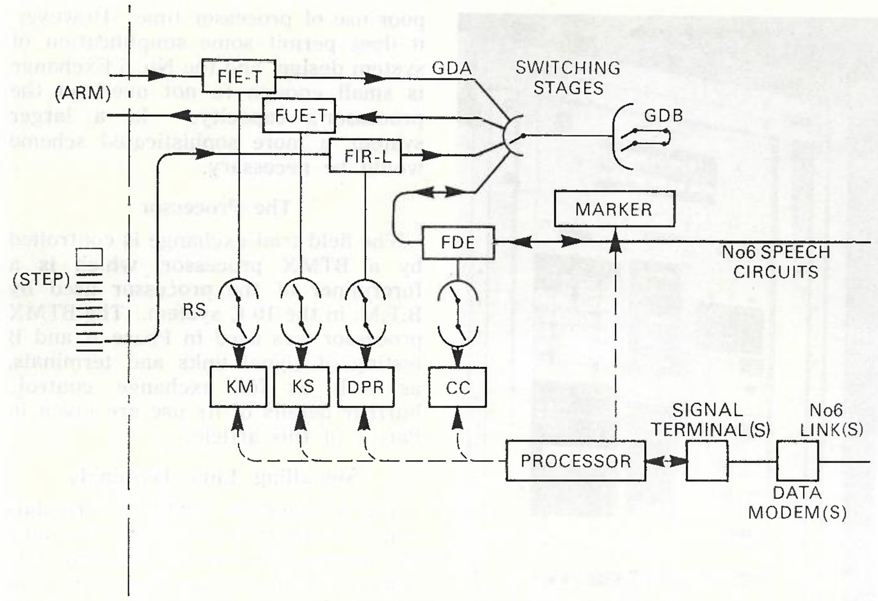

Fig. 3 — Trunking Diagram of APO No. 6 Exchange.

FIE-T : Incoming electronic line relay set for MFC and T-Pulse signalling.
FUE-T: Outgoing electronic line relay set for MFC and T-Pulse signalling.
FIR-L : Incoming line relay set for loop disconnect signalling.
KM : MFC code receiver.
KS : MFC code sender.
DPR : Dial pulse receiver.
CC : Continuity check transceiver for No. 6 speech circuits.

sages are sent on the No. 6 signal link to allow setting up of the call at the other No. 6 exchange. A tone transceiver (CC) carries out a continuity check on the selected No. 6 speech circuit to ensure that satisfactory transmission conditions exist.

For a call set up in the opposite direction, incoming signal messages on the No. 6 link result in connection of a No. 6 speech circuit to an outgoing line to Lonsdale ARM.

The functions of the No. 6 exchange equipment can therefore be summarised as providing a facility for signal translation, while at the same time switching calls to the both-way system No. 6 speech circuits.

Processor Control Technique

The technique of control of the No. 6 Exchange is based on the principles shown in Fig. 4 (Ref. 2). The exchange is made up of a number of groups of controlled equipment, each group consisting of a number of units. The groups are closely related to interface equipment which provides access to the processor. Software operations in the processor generate instructions and addresses which are passed to the Instruction Highway, which is connected to all interface equipment. Depending on the group address on the highway, the appropriate group interface will respond, and pass the instruction to the unit (or units) of that group, dependent on the unit address included with the instruction.

There are generally two types of instructions sent on the highway, drive or scan. The former will cause some function, such as a relay operation to take place in the unit. Otherwise a scan instruction will cause the unit to send data back through the interface via the Data Highway to the input of the processor. This data might display for example the current state of an incoming line.

The processor used in the No. 6 exchange operates on a sixteen-bit word. Hence the Instruction and Data Highways are based on 16 bits, which are sent in parallel on twisted pair lines. Special integrated circuits have been designed in the Research Laboratories for driving and terminating the twisted-pair lines, and custom-built by A.W.A. in Sydney.

A 16-bit instruction word to the exchange is split into 3 fields:

G — Group Address — to indicate which group of circuits is being addressed,
U — Unit Address — to indicate which unit in this group is being addressed,
F — Function Code — to indicate the function to be performed by this unit.

This instruction has the following format:

Bits:	1, 2, 3, 4	5, 6, . . . 11
	Group Add.	Unit Add.
		12, 13, 14, 15, 16
		Function Code

This format allows a total of 16 groups, 128 units per group, and 32 functions, which is ample for the No. 6 Exchange equipment.

Information for the processor is collected from the No. 6 Exchange by scanning every circuit on a repetitive basis. It is important that the processor becomes aware of new data without too much time delay. Hence, some circuits are scanned every 15 ms, even though the circuit condition may only change occasionally. This type of scanning, in general, makes

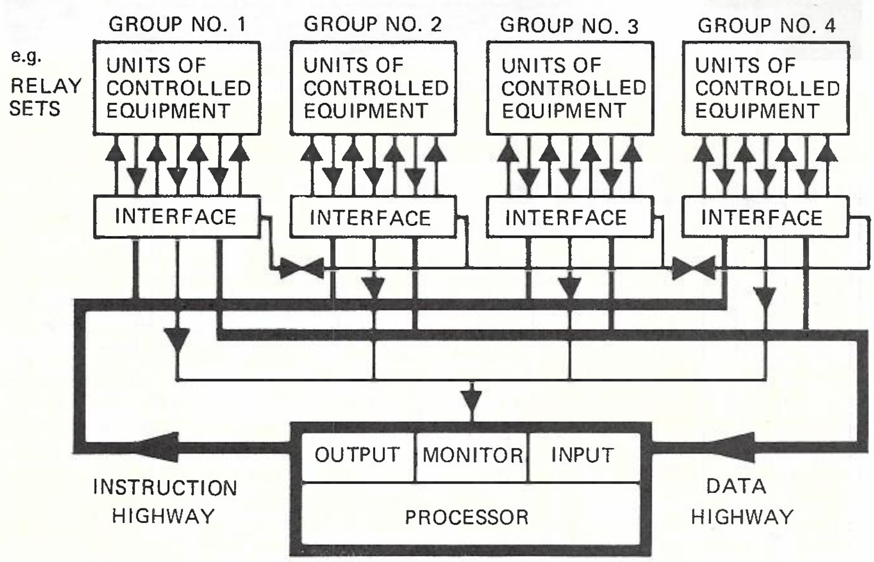

Fig. 4 — Technique of Processor Control.

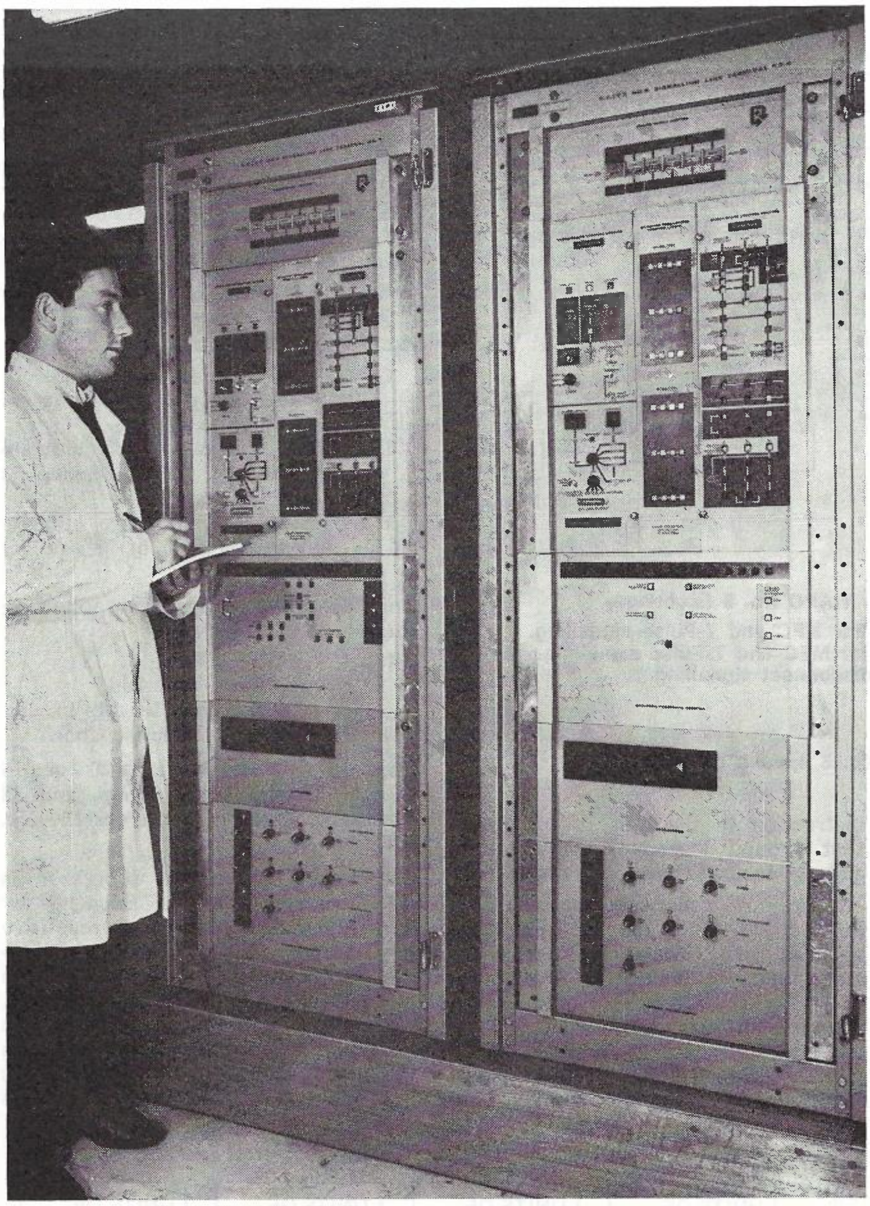

Fig. 5 — Signal Link Terminals for System No. 6.

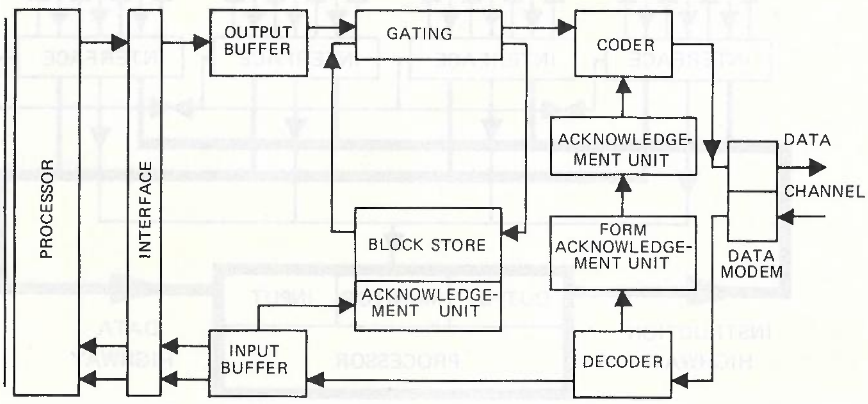

Fig. 6 — Signal Link Terminal — Simplified Block Diagram.

poor use of processor time. However, it does permit some simplification of system design, and the No. 6 Exchange is small enough to not overload the processor's capacity. In a larger system, a more sophisticated scheme would be necessary.

The Processor

The field trial exchange is controlled by a BTMX processor, which is a forerunner of the processor used by B.T.M. in the 10 C system. The BTMX processor was used in Phase A and B testing of signal links and terminals, as well as for exchange control. Further details of its use are given in Part 2 of this article.

Signalling Link Terminals

Fig. 5 shows the signalling terminals which monitor and control the flow of messages on the No. 6 signal link. The terminals occupy the upper half of each cabinet, the space below being used for processor interface and power supply and modem equipment.

The terminals themselves present an interesting example of the choice open to a designer in providing logical functions in either software or hardware. For largely historical reasons, the APO terminals are a hardware design, while in a number of other No. 6 field trial exchanges software terminals were installed; that is, the logical operations needed for signal link control were carried out in the processor itself. These two approaches gave equivalent results and an ultimate choice would depend on economics and reliability.

Fig. 6 shows the signal terminal functions in block diagram form. Briefly, terminal operation is as follows:

The processor loads signal messages into the output buffer. Messages consist of 20 bit signal units and in effect are telephone signals in respect of particular speech channels. The coder adds an 8 bit error detection code to the signal unit and passes it to the data modem and data channel (signal link).

Simultaneously, messages are received from the distant end. The decoder checks to see whether an error has occurred in transmission, and if so, initiates a request for retransmission of the message.

Retransmission is controlled by breaking the stream of transmitted units into 12 unit blocks. The last unit in each block is a special acknowledgement unit. It identifies the block being transmitted and acknowledges the correct reception of the eleven units in the last received block.

The block store temporarily stores units which have been transmitted until an acknowledgement unit is returned from the distant end.

The functions described were realised in a terminal design using some 50 printed circuit cards. An interesting sidelight on the rapid rate of advance of solid state technology is provided by the observation that this design, of 1969 vintage, could be realised in 1971 using an estimated 15 cards only. In 1972, however, with computer-on-a-chip integration, 2 cards would be sufficient.

TESTING THE No. 6 EXCHANGE

In view of the considerable interest in installation of processor-controlled exchanges at the present time it is worthwhile to provide a brief history of the preparation of the exchange equipment.

In broad terms, the preparation of the exchange can be broken up into four distinct test stages:

(i) *Hardware Testing Hardware*, where test equipment is used to run the hardware through a series of tests.

(ii) *Software Testing Hardware*, where special programs are written by which the processor exercises the hardware. These programs are not the operational programs to be used in the completed exchange.

(iii) *Hardware Testing Software*, where portions of the operational programs are run with the exchange equipment. Simple functions are performed in the hardware, for example a relay is 'pushed up', and the response of software is checked.

(iv) *Software Testing Software*. A comprehensive sequence of tests leading up to testing of the complete operational software system. These tests are carried out using the computer to monitor its own performance. Details are given in Part 2 of this article.

It is worthwhile to go into a little more detail about these test stages.

During tests of hardware, a methodical sequence was built up, starting with tests on components and ending with reliability tests of complete switching operations. Experience has shown, for example, that all integrated circuits should be tested prior to use, particularly if larger and more complex circuit cards are used.

The No. 6 exchange and signal terminals used over 800 printed circuit cards equipped mainly with T.T.L. logic components. The problem of logic circuit testing therefore received some emphasis, and special instruments were developed.

Special Test Instruments

Instruments which were developed by the APO Research Laboratories and which proved particularly useful were as follows:

An Electronic Circuit Tester. This is a manually operated test-bed where a circuit card may be exercised by means of input function switches, power supplies, and output level metering. (Ref. 3.)

A Programmable Circuit Tester. This tester used the BTMX processor to carry out a series of tests prerecorded in programs written by the operator. It was used for testing cards with longer production runs only, as the difficulties of writing comprehensive test programs for complex cards proved very time consuming. (Ref. 4.)

Processor Simulator. This instrument generates a 16-bit instruction word under manual control. The instrument may be connected to the exchange instruction highway in place of the processor, so that equipment control functions may be exercised. Its use allowed the processor to remain free for software testing. The processor simulator is provided with a display screen on which the particular instruction being generated is decoded and displayed. It may be seen in the background of Fig. 7. (Ref. 3.)

Miniprogrammer. (Ref. 3). This instrument extended the function of the Processor Simulator by use of a 32 word instruction store. This allowed the operator to store and repeat enough instructions to cycle the switching equipment through a typical operation, for example, setting up a switched connection.

In later testing the Miniprogrammer was also used with the processor as an 'instruction dump' — when connected across the exchange instruction highway it provided a record of drive instructions output by the processor. The Miniprogrammer is shown in the foreground of Fig. 7.

Terminal Test Set. — A signal unit

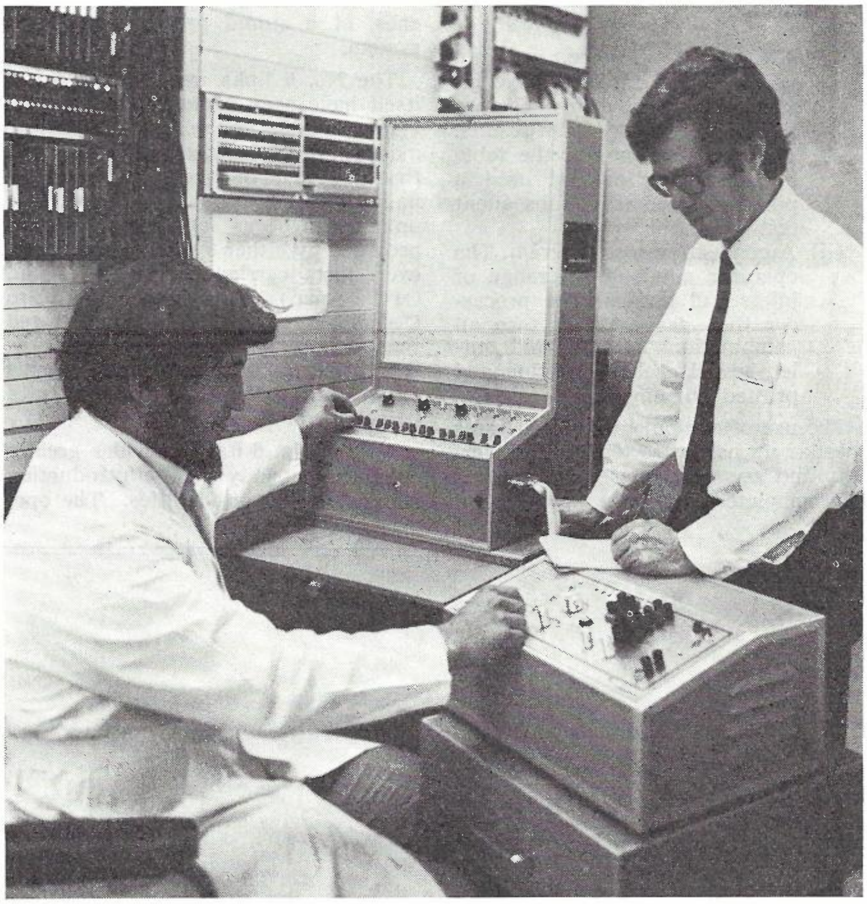

Fig. 7 — Test Instruments for Exchange Hardware.

generator was built to allow testing and fault clearance of the signal terminals.

Equipment Test Programs

The largely manual methods described above were extended by the use of a suite of equipment test programs. These programs took advantage of the speed and flexibility of processor control. In fact, it can be said that the processor itself is the most useful test instrument available to the installer. Its use for thorough pre-cutover testing provides one of the advantages of stored-program control in telephone exchanges.

Thoroughness in hardware testing prior to operational software trials is an inescapable necessity. It would be a brave man indeed, who would attempt to unravel the evidence produced by adding an incompletely proved software system to unpredictable hardware.

The equipment test programs for the No. 6 exchange switching equipment took advantage of the processor's ability to scan equipment states after each drive instruction, and to print details if an unexpected condition was observed. Two main programs were used:

(i) A general purpose program which used a table of drive instructions, time delays (before scan) and expected scan results. The operator entered the table by teletypewriter and used a punched tape for subsequent test repetition.

(ii) A connection test program. The operator nominated a range of inlets and outlets. The processor then generated in turn all combinations of inlet and outlet, tested each connection and printed out any fault details.

The use of equipment test programs speeded up hardware testing considerably and was particularly useful after the completed exchange was shifted from the APO Research Laboratories location in Exhibition Street, Melbourne, to its field trial site at Windsor, Melbourne, during a 2 week period in October 1971. It was noted that the test programs should have identical timing and scanning characteristics to those of the programs to be used later in exchange operation, in order to provide a completely adequate test.

Test programs were not used as extensively on the signal terminals as on the switching equipment. This was because the terminal logic functions are performed independently of the processor which is not normally able to scan internal equipment states. In practice, this proved something of a disadvantage as time consuming manual methods had to be used.

Some further notes on test programs are provided in Part 2 of this article.

NATIONAL TRIAL RESULTS

The national trial has allowed a detailed assessment of the effects of adding No. 6 signalling to the national trunk network. Separately, APO Research Laboratories staff have been involved in the complete design, apart from the processor and crossbar switches, of a stored program exchange system.

The No. 6 links and System No. 6 itself have been demonstrated to provide a reliable and versatile signalling medium. Unfortunately it is a truism that the result of mixing different signalling systems in one network is unlikely to be as satisfactory as that provided by either system alone. However, tests carried by the APO and OTC (Aust.) from October 1970 to December 1972 have demonstrated that any signalling delays, such as those incurred in translation of signals from MFC to System No. 6, and vice versa, are minimal.

System No. 6 itself provides greatly enhanced capacity for the introduction of new signals or facilities. The operational experience gained in the national trial will be used to inform an eventual decision as to its introduction and will allow accurate comparison with other new signalling schemes that become available.

FUTURE USE OF SYSTEM No. 6

In December 1972 the C.C.I.T.T. decided to adopt the revised No. 6 System as the International Standard, and it can be assumed that System No. 6 will shortly come into fairly general use as an international signalling system. Not the least reason for this is the widespread familiarity with its use produced by the FT6 field trial program. However, the optimistic hopes that a universal signal system might be achievable have not been completely realised. Since 1970 a variety of new common channel system proposals have emerged which provide improved performance, particularly for national networks. Whatever the outcome, it is certain that the development of System No. 6 and its international trials now completed, must be regarded truly as a milestone in the history of telephony.

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NATIONAL FIELD TRIAL OF C.C.I.T.T. SIGNALLING SYSTEM No. 6: PART 2 — SOFTWARE

*G. J. CHAMPION, B.E.E. and R. H. HAYLOCK**

INTRODUCTION

This article describes the software (stored programs) designed and implemented by engineers and programmers of the Switching and Signalling Branch of the APO Research Laboratories to control the exchange hardware and the signalling links of the APO Research Laboratories CCITT Signalling System No. 6 Field Trial Exchange. Early work which considerably influenced the structure of the No. 6 software was performed by Messrs. M. K. Ward and F. J. W. Symons. (Ref. 3).

The CCITT Signalling System No. 6 is more fully described in other documents (Refs. 1 and 2) and in Part 1 of this article. Briefly, it is a common channel signalling system employing a 2400 bit/second data stream with format capacity to convey signals for approximately 2000 voice channels. In view of the large amounts of data requiring manipulation at high speed, computer or processor control of the signalling and signalling link is a prerequisite. Such a signalling scheme would normally be an adjunct to a telephone exchange which is already of the stored program type using high speed electronic processors. The APO Research Laboratories have produced a suitable stored program control exchange to examine the operation and properties of the No. 6 System.

THE PROCESSOR

The processor is very similar to a general purpose computer and contains the stored programs which control the actions of the associated exchange and signalling link hardware. It is, in effect, the brains of the exchange providing the logical processes used in telephone call handling as well as controlling the flow of signals on the common channel signalling link.

The processor used is a BTMX model manufactured by the Bell Telephone Manufacturing Co. (BTM) and is a forerunner of the processors to be used in the 10C exchanges. It has the following characteristics:

Word Size: 16 bits + parity bit.
Memory: 16384 words of magnetic core memory.
Speed: 2 microsecond memory cycle.
Instruction Set: 66 instructions.

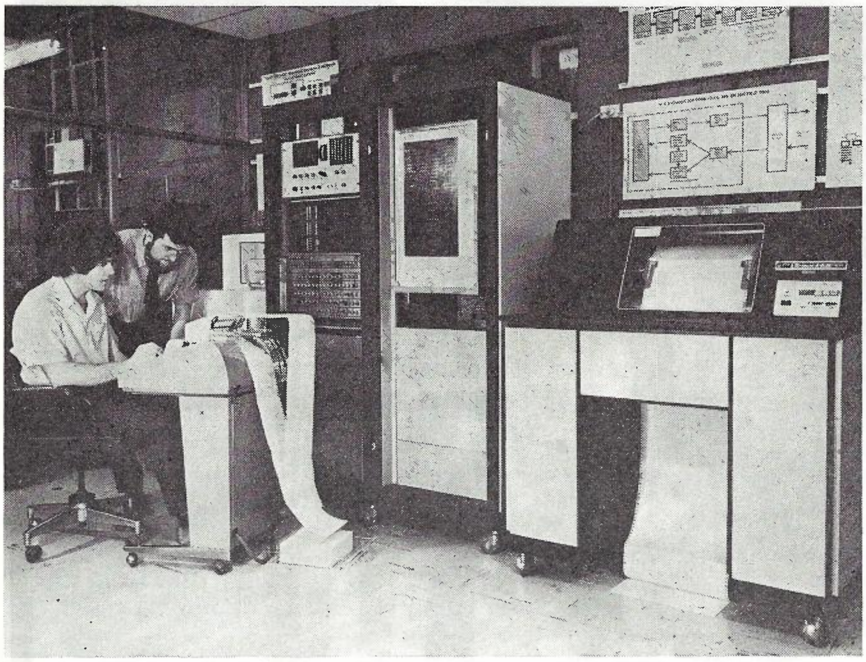

Fig. 1 — Windsor Exchange — Processor Room. The BTMX processor is the left hand cabinet of the pair with the ASR 33 teletype in front and the high speed line printer to the right.

Peripherals: ASR 33 Teleprinter.
High Speed Paper Tape Reader.
High Speed Paper Tape Punch.
200 line/min. Line Printer.
AC Bus for input/output.
8 line priority interrupt system.
Memory Display Unit.

Programming Language: Bell Assembly Program (BAP).

The programming language is an assembler language one step removed from the instructions the processor executes. Each instruction has a one to one correspondence with a machine instruction as compared to a high level language such as Fortran where one instruction may result in 10 or more machine instructions. An assembly language has been used as it results in much more efficient programs both in time and size than any present high level language.

THE SOFTWARE

The description of the software systems required to implement the Field Trial will be broken into the following parts:

(a) The Software System — or basic software framework.
(b) The Operational System used for live call handling.
(c) The GEC Tape Simulation System used in the Phase A trials.
(d) The Dynamic Simulation System used in the Phase B trials.
(e) Program Preparation.
(f) Program Testing.

THE SOFTWARE SYSTEM

The Software System provides the basic framework of facilities to support the programs which actually perform the design functions of each particular system. The same basic framework is used for each of the three systems, developed for the trial with suitable modifications to suit each.

The important functions it performs are:

(a) to provide the system with a 'real-time' reference.
(b) To order the work to be done by the various programs into a suitable priority structure and arrange its execution.
(c) To provide communication facilities between the system and its human operators.
(d) To provide a means of communication between the various programs of the system.

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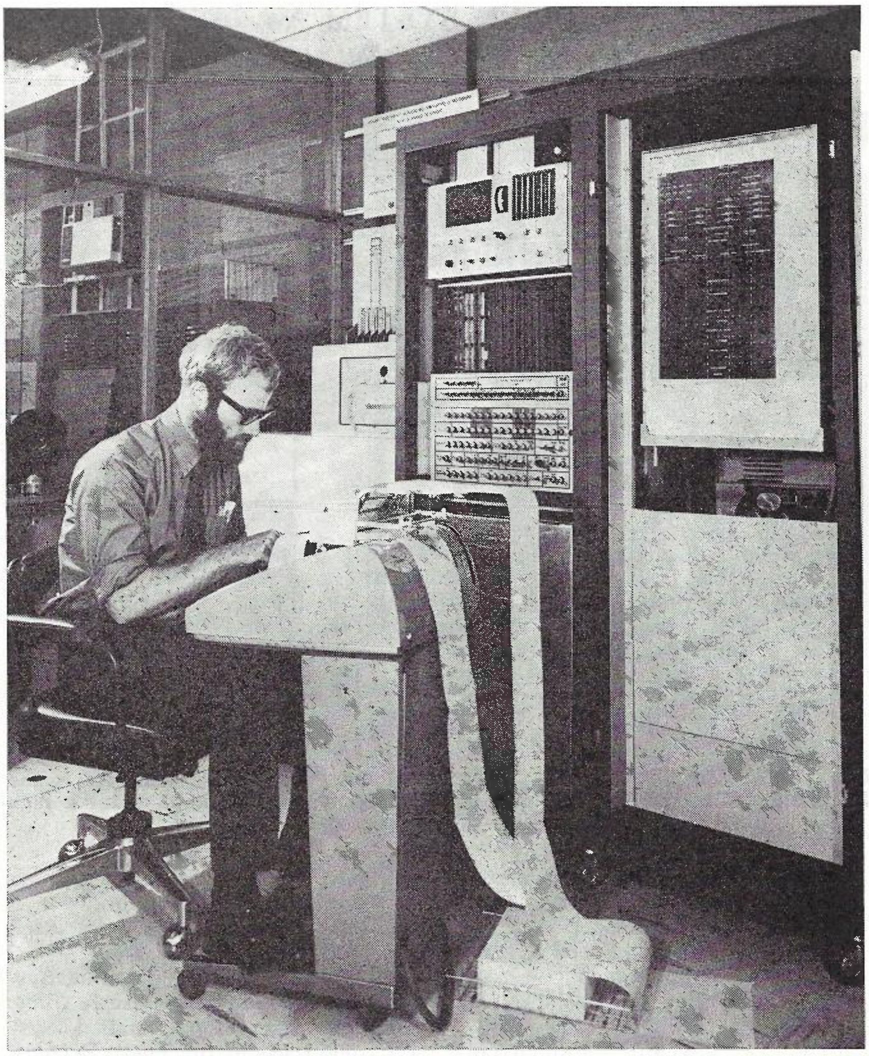

Fig. 2 — BTMX Processor with the 32 Word Memory Display in the Upper Right Hand Cabinet.

Real Time Reference

The basis of the 'real-time' reference is a hardware 'clock' which produces pulses at a regular rate. The rate is determined by the resolution of real time required by the system and is set at 15 ms for all systems used in the Field Trial.

The pulses are placed on an 'interrupt' line to the processor and cause it to interrupt whatever program it is executing and execute a special 'interrupt program'. This program sets a clock interrupt flag and returns immediately to the interrupted program.

Work Priorities

There are two separate priority levels for the execution of most programs known as 'clock level' and 'base level'. Clock level is entered whenever the clock interrupt flag is set (i.e. every 15 ms) but after completion of the program currently being performed. Base level work is done in the time remaining before the next clock interrupt after all clock level work is completed. Clock level work consists of programs which must be performed regularly, whereas base level work can be delayed if there is insufficient time at the moment.

The receipt of information from the hardware must be performed regularly to prevent loss of information and thus is part of the clock level work. The analysis of this input information may be deferred if necessary and is performed in base level.

The Monitor Program

The monitor program provides the executive control of the operational system, by controlling execution of the call handling programs according to predetermined priorities (see Fig. 3). It has two main parts, the Clock Level Monitor and the Base Level Monitor.

The Clock Level Monitor: This programs monitors the 15 ms clock interrupt flag and calls for execution of the scanning, driving and timing programs, according to a predetermined schedule if it is set. Some are performed every clock cycle, while others are only performed every second, fourth or eighth cycle. Program selection is via a directory table arrangement.

The Base Level Monitor: The base level programs perform the major part of call processing in the system and are fed via hoppers which provide a queuing function. The base level monitor examines each type of hopper for entries according to a preset priority. Whenever a hopper is found to have entries, one hopper entry is unloaded and control passed to the appropriate base level program for processing. On completion of processing, control is passed first to the clock level monitor for a check if the clock interrupt flag is set, and if not, then back to the base level monitor.

All entries in a particular hopper are processed before passing to the next lower priority hopper. If no hopper contains an entry and the 15 ms clock has not yet interrupted and caused the clock flag to be set, control passes to the Communications Supervisor program, (COMSUP). While no changes are occurring and hence no work is generated for the processor, it idles by stepping around the loop from clock level monitor to base level monitor to COMSUP and back.

The Communications Supervisor (COMSUP)

Once the processor is set in operation, human interaction is only necessary for maintenance and statistical purposes. The facility of interrogating the processor memory via the console tele-typewriter, line printer etc. is known as man-machine communications and must proceed without affecting the simultaneous operation of the processor in its primary function of call handling.

COMSUP is a man-machine communications system designed for the on line control of the peripheral devices:— teletype, line printer, paper tape reader, and paper tape punch. These functions are performed at the lowest priority level using only slices of time which the processor has available between performing its normal tasks. This may mean that at periods of peak load the devices may

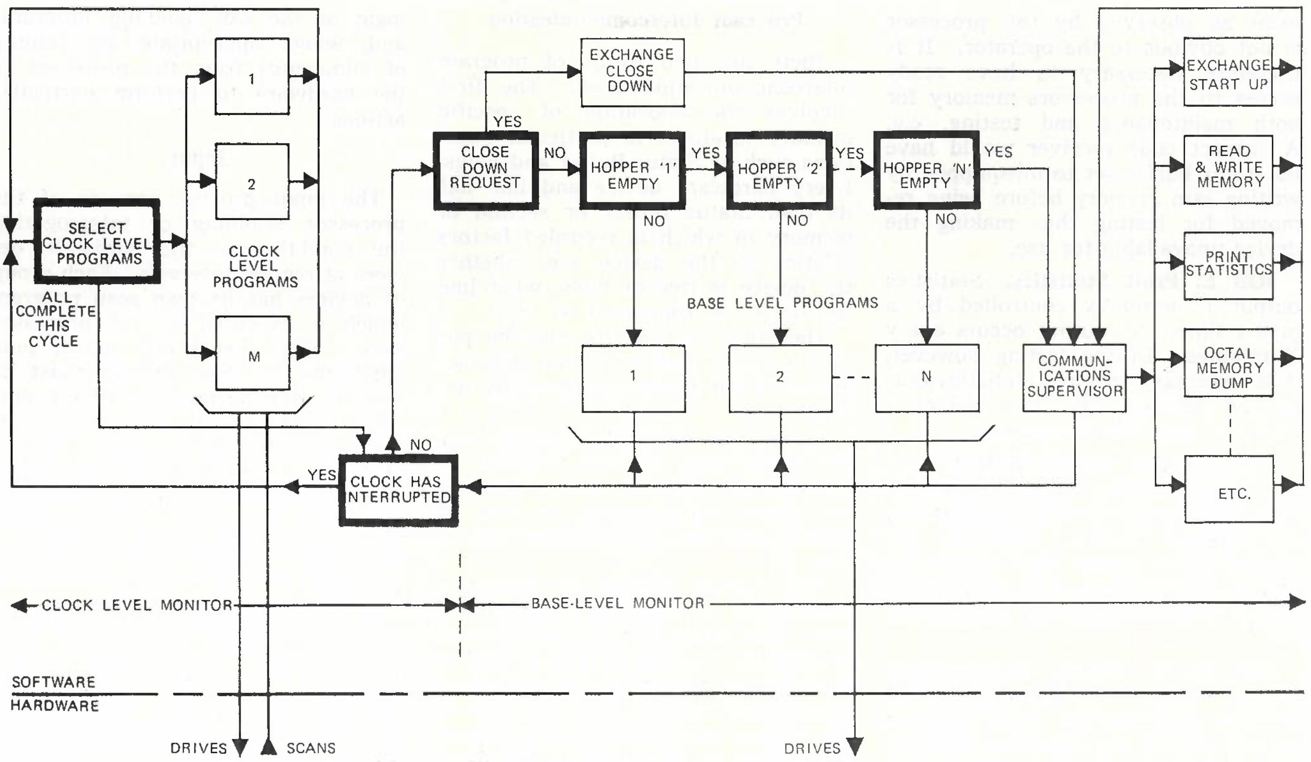

Fig. 3 — The Monitor System for the No. 6 Exchange.

slow down momentarily but this is unavoidable if a high grade of subscriber service is to be maintained. As the devices differ greatly in speed, their operations must be interleaved to give continuous and apparently simultaneous operation.

The functions of COMSUP fall into three main areas:

Normal line interrupt handling.
Device control.
Job programs.

Normal Line Interrupt: All of the man-machine devices may interrupt the processor on the one common line known as the "Normal" interrupt line. This line is similar to the Clock Interrupt Line but has the lowest priority of all interrupts. An interrupt is a signal to the processor that one of the devices has new information ready for input or has completed processing the last piece of output. The occurrence of such an interrupt causes the processor to transfer its control to the normal line program which interrogates each device in turn to see which has caused the interrupt. In the case of output-complete, the program sets a flag for the particular device while if it is new input information it is accepted and stored. This program is executed whenever an interrupt occurs but does a minimum of work leaving the bulk of the work to the low priority remainder of COMSUP.

Device Control: As the teletype is the focal point of the man-machine system and the jobs performed by it are many, its control function is incorporated in the main COMSUP program. Other devices however have only one task to perform and their device control is incorporated in the task program. Because of the slow speed and low priority of the teletype, messages for output must be queued via a special hopper. If the hopper is empty, the teletype is set in input mode waiting for the operator to type an input.

Job Programs: To allow the operator to use the teletype for manual logging purposes, there is normally no response to initial input unless a special sequence is typed in when 'JOB' is typed out from the processor. The operator may then type any of the characters A through S followed by a colon, giving him access to one of the following job routines. The use of a special sequence provides a measure of security against deliberate or inadvertent interference.

JOB A Start Up
„ B Close Down
„ C Call Trace
„ D Read or Write Memory
„ E Print Statistics
„ F Octal Dump of Memory
„ G Load Program
„ H Stop Loader
„ I Print Hopper Buffer
„ J Reset Statistics Counters
„ K Enter Time of Day
„ L Read Time of Day
„ M Manual Change Over of Signalling Terminals
„ N Manual Change Back of Signalling Terminals
„ O Print Call Events Buffer
„ P Punch Traffic Data
„ Q Stop Traffic Data
„ R Vacant
„ S Exit to Debugging Console

Subsequent input characters are directed to the job routines for analysis and action which will vary according to the situation. The system is designed for ease of modification as the job requirements varied during the field trial.

Some of the more important job routines are as follows:

JOB A: Start Up. The software system has two states: 'Idle' when only COMSUP programs are executed and 'Active' when the full system is operating under control of the monitor program. The main function of the start up program is to initialise the state of processor memory and the exchange equipment by resetting all exchange devices and by clearing all software call data areas.

JOB C: Call Trace. The processor maintains the identities of incoming and outgoing lines connected together and traces a connection on demand.

JOB D: Read or Write Memory. With a processor controlled exchange the state of a particular item of equipment as observed by the processor is not obvious to the operator. It is therefore necessary to have ready access to the processors memory for both maintenance and testing. e.g. A suspect code receiver would have its status buffer set to unequipped by writing into memory before being removed for testing thus making the device unavailable for use.

JOB E: Print Statistics: Statistics output is normally controlled by a preset timer, i.e. output occurs every X minutes. During testing however, it is necessary to have statistics output on demand, e.g. after one or a series of calls have occurred.

JOB I: Print Hopper Buffer. During system testing it is necessary to create a history of events taking place in software; hopper loadings, exchange drive words etc. These are loaded into a spare area of memory which is printed out on demand by Job I.

Jobs M, N: Manual Change Over, Change Back, of the Signalling Links. So that maintenance work may be carried out on the signalling link and or terminals, it is necessary to be able to change to the stand-by signalling link and back again on demand. This is carried out by job programs M and N in conjunction with the signalling link security program.

JOB O: Print Call Events. The more important results of the field trial concern mainly the details of calls carried and the times at which these events occur. Arrangements have been made to gather these details from the call handling programs and store them sequentially in one of two buffer areas in memory. When one buffer fills the buffers are swapped over, and the full one printed out and reset.

Job O provides for immediate printout of a partially full buffer.

JOB S: Operators Console Program. The operators console program is a general purpose control and debugging aid which is completely independent of the operational system.

It does not use the processors index register or interrupt system and simply idles within itself while there is no input or output. Job S causes entry to the Operators Console Program and may be used to freeze the operational processor by preventing entry to the operational program. It provides the usual Read and Write memory plus a number of other very useful facilities. This is a testing aid and must be locked out once the processor is carrying live traffic.

Program Intercommunication

There are two forms of program intercommunication used. The first involves the allocation of specific memory locations to particular functions such as Status Buffer and Flags. Every hardware device and line has its own Status Buffer or section of memory in which is recorded factors relating to the device, e.g. whether the device is free or busy, what line the device is connected to, etc.

The state of a device may be put into a Status Buffer by one program and read out nondestructively by another.

A flag (or memory location) may be raised (set) by one program to tell another program that a particular event has occurred or that it should perform a particular operation.

The second means of intercommunication is via the hopper system. The effect of the program controlling the hoppers is akin to a physical hopper where one or more programs load entries into the top of the hopper and another program takes out entries at the bottom. The hopper entry consists of one, two or three words of data and these form the basis of the unloading program's operation. Not only does the hopper transfer information but it effectively queues the work for the unloading program. This is particularly significant in the case of programs whose job is to allocate a free device to a new call. If no device is available, the hopper entries or device requests stay in the hopper until they can be fulfilled. Each hopper will be loaded and unloaded at the request of different specific programs but a common program actually performs the loading and unloading process. Typical hoppers are the Seizure, Clear Down, Received Signal and Code Receiver Queue hoppers.

THE OPERATIONAL SYSTEM

The Operational System used for handling live calls consist of approximately 80 individual programs and subroutines in addition to the Software System described above. Twenty of these programs operate in clock level and consist of the scanning, some driving and the timing programs. The remaining programs are in base level or are subroutines which can be called by either clock or base level programs.

The call handling process consists of the input of data to the processor and its recording in the processor memory, analysis of the data by the logic of the call handling programs and, where appropriate, the issuing of commands from the processor to the hardware to perform particular actions.

Input

The input process consists of the processor scanning or interrogating the condition of the hardware devices at regular intervals. Each group of devices has its own scan program which is executed by the processor every clock period (15 ms) if new conditions in those devices must be seen as soon as possible after occurrence or every 'n' clock periods if the urgency is not so great. Values of n equal to 2, 3, 4 or 8 have proved adequate. Changes in the signalling conditions of the line signalling relay sets are considered urgent whereas the detection of cross-office voice path continuity is not as urgent.

The scan program for a particular group of devices interrogates each device in the group in turn. It compares the current state of the device against a record kept in memory (last look word) of the condition of the device last time it was scanned. Changes in condition, if any, are detected and analysed for type of change and the resulting action determined. This action may simply be to update the device's Status Buffer. An alternate action may be to start a timer (e.g. to determine whether a T pulse is short or long) or to load a hopper with data to cause another program to take further action. The work done by clock level programs is kept to a minimum as it is essential that even under peak conditions the average time spent in clock level must be appreciably less than 15 ms to avoid losing complete clock periods.

Some typical scanning programs are as follows:

Scan Line Signals — scans the conditions of the E leads of the T signalling relay sets and the loop condition of the L1 signalling relay sets. Typical hoppers loaded are the Seizure hopper and the Clear Down hopper.

Scan RS — scans the free/busy conditions of each of the four RS's (switches) used to connect signalling devices to line relay sets. Only one RS matrix is provided for each type of coupling (e.g. Code Receiver to Incoming Relay Set) and it can only be used for one connection at a time. Requests for connections or disconnections are queued in the appropriate hopper (e.g. Couple Code Receiver hopper) and a new request is only extracted from the hopper when the RS is seen to go free.

Scan Signalling Terminal — scans the hardware terminal connected to the signalling link for new signalling messages. This program analyses each signal unit received, rather than using a 'last look' technique, as the information flow rate is much greater than the other cases. No. 6 signals are passed to an analysing program via a hopper for subsequent action.

Various of the above scan programs also look at fault bits related to the devices scanned to keep a check on the health of the hardware. An indication of fault in most devices will cause their removal from service, whereas the failure of the marker (only one provided) will cause a graceful close down of the exchange.

Analysis and Action

Upon detection of a new call arrival an area of memory of 16 words known as a Dialling Buffer is allocated to that call until it has been established. A software timer limits the time the Dialling Buffer is in use on a particular call to 45 seconds in a similar manner to a crossbar register time out. The Dialling Buffer contains the identity of the calling line, the digits dialled, the selected outgoing line and other information relating to the call such as the identity of the Code Receiver used etc.

As digits are received by the system, they are analysed by a hopper fed program — Digit Analysis — and stored in the Dialling Buffer for that call. Part of the analysis includes the determination of the 'call forward' point and, when sufficient digits are received, the 'String Programs' for the call type are initiated.

Each of the actions required during a call is given its own program identity. Different call types require differing actions and differing sequences. A given call type will use a 'String' of the appropriate actions for its completion. All told there are 28 Action Programs making up 6 different strings.

The String identities are given in Table 1.

Another String — Number 3 — is used to clear down calls which fail to mature.

As an example of String composition, String 5 consists of Action Programs I, A, J, K, L, M, N, O, P and H, whereas String 8 consists of Action Programs A, J, K, L, F, M, N and H. Action Programs I, O and P relate to incoming No. 6 signalling and F to incoming m.f.c. signalling. The remainder are common to both call types.

The String Programs control the call setup by calling in other programs such as the 'Allocate Code Sender Program' by loading a hopper when a Code Sender is required or by issuing instructions to the hardware such as sending a seizure pulse (T signalling) on a selected outgoing circuit.

The String Programs are executed one by one in turn as call setup proceeds. The final program in every String tests for satisfactory completion of the exchange connection and arranges for release of the Dialling Buffer and its replacement with a smaller Supervision Buffer (4 memory words) which remains in use for the duration of the call. The Supervision Buffer records the incoming and outgoing lines and the answer/clear back state of the call.

Multiple Calls

Only one copy of each program is resident in the memory of the processor although the exchange must be capable of setting up many calls at a time. In fact the processor is a serial machine and can only execute one program at a time but with a typical program execution time of 150 microseconds it can be made to appear to the outside world to be handling many calls at once.

A given program may be executed many times in a period, each time for a different call. If it is a hopper fed program each hopper data word will give it the identity of the device or call for which it is currently to do work. If it is a String program, the identity of the Dialling Buffer for the given call will be stored in a known memory location and the Dialling Buffer will be accessed for the necessary data.

Timers

There are many timing functions in the system, two of which have already been mentioned. (Dialling Buffer time out and the timing of T signalling pulses). Others include the time out of various hardware functions to take appropriate action if the hardware fails to operate and the timing of sequences in the signalling link security arrangements.

A timer is a specific memory word which is made active by setting it to a negative value. The timer program in clock level will increment each active timer word value by one each time it is executed and check its value for zero. An active timer going to zero indicates completion of the timing interval and the appropriate action is taken. As the timer program is entered regularly every n clock periods (15n ms), the initial negative value of the timer sets the length of the timer interval.

Output Commands

The output of commands to the hardware in a multi processor installation must be arranged so that two processors do not try to drive a device at the same time. One approach is to only output during clock level and ensure that not more than one processor is in clock level at a time. In the CCITT No. 6 case with only one processor, output can generally occur as soon as the need arises and can come from clock or base level programs. An exception is the output to the signalling terminal which involves the queuing of signal units under high load and the regular output of units as required by the transmission rate of the data link. Thus a special Signalling Link Output Program is provided and is executed every clock period.

Security

Signalling Link Security: The CCITT Signalling Specification No. 6 provides a comprehensive security arrangement involving a variety of reserves for the regular link. The APO exchange provides a regular link, a fully equipped synchronised reserve link and an unequipped reserve link which is normally used as a voice channel when not required as a signalling link.

The Scan Signalling Link program provides information to the Link Se-

TABLE 1: CALL STRINGS

Incoming Line	Outgoing Line		
	To Lonsdale ARM	To Test Phone	To Sydney
From Russell PABX	String 8	String 2	String 1
From Lonsdale ARM	String 8	String 2	String 1
From Sydney	String 5	String 6	String 7

curity program on link and terminal health and link error rate. The Security program takes action to transfer signalling link traffic from the regular to the reserve in the event of unacceptable operation on the regular link. Further changeover is possible to the non synchronised reserve and a special routine is provided for the unlikely event of all links failing. Automatic changeback to the regular link is performed when it has proven itself capable of handling traffic and a manual changeover — changeback arrangement is provided for link maintenance.

Traffic Security: The Field Trial exchange has major portions of it unsecured against failure — e.g. only one processor and one marker. Control lines are provided into the originating ARM exchanges to automatically block further incoming traffic in the event of an exchange close down due to equipment failure. The same lines are driven by a program that monitors the number of free, healthy outlets to each ARM to block further traffic if none are available. The lines are also used to let traffic in on start up of the system and stop traffic on closing it down.

TAPE SIMULATION SYSTEM

This system was devised to provide a test of the common channel signalling link using a fixed pre-ordained list of signal units coresponding roughly to a number of typical call sequences. No control of the exchange (excluding the signalling terminals) was required and no call setup logic was performed.

A list of typical signal unit sequences was prepared by GEC, England, for use by all participants in the International trials.

The GEC System was designed to transmit units from the GEC set in strict sequence at signalling link traffic rates variable between 0.1 and 0.8 Erlang. This stream of units was received by the distant exchange (OTC) and checked for such things as units received in error, units received correctly after retransmission, units received more than once due to block retransmission or block slip, number of block slips, units lost etc. Similarly OTC transmitted the same sequence of units to APO who performed similar checking.

The system consists basically of the operational Scan Signalling Link and Signalling Link Output programs suitably modified together with some special analysis programs. Most of the exchange control and call setup programs were omitted.

A statistics program was included in the COMSUP area to provide automatic line printer dumping of the statistical counters at predetermined intervals. To avoid loss of data during dumping, the counters were set up in a table and accessed via a First Word Address (FWA). Two such tables were used with the FWA being swapped to the other table just before dumping began.

DYNAMIC CALL SIMULATION

This system was developed to provide information on the traffic handling capacity of the No. 6 link. In this system, messages typical of a number of different calls were generated dynamically by software at random intervals at both ends of the link and transmitted with various levels of deliberate error injection. Parameters similar to the GEC System were measured. The software system for this test consisted of operational programs wherever possible, however, a number of special programs were written for generation and termination of calls, timing of responses and gathering of a large quantity of statistics on such things as message output queueing delay, calls initiated, calls failed etc. This system was also used to test the security arrangements for the No. 6 signalling link.

PROGRAM PREPARATION

The coded program that the processor executes is the end result of a complex process. The initial step is to define in general terms the operation and requirements of the completed system. Boundaries must be set between what is performed in hardware and what is done in software.

Economics is the basic consideration in this decision for production systems with aspects such as reliability, maintainability etc. also of very considerable importance.

The costs of hardware are fairly obvious but the software costs are a little more obscure as the cost of the roll of punched tape containing the system is trivial. Factors which must be considered in software costs are the cost of processor and the amount of memory required, the cost of program specification and coding, program testing and system testing, and the cost of subsequent system modification for new features or simply system growth.

In an experimental situation it is most important that the implications of the above on the processor capabilities and the flexibility of the system for modifications be well understood as limitations of processor memory size and an inability to modify the system as the experiments proceed are very severe.

PROGRAM TESTING

Program testing was carried out in three distinct stages:
Unit testing.
TESSAR testing.
On-line testing.

Unit Testing

The operational system is composed of over 100 program units which are all tested individually before being combined. The unit test system simulates the environment in which the program is to operate and provides data to exercise all possible paths and combinations within the program with results printed on either the line printer or teletype.

TESSAR Testing

TESSAR (The Test Event Sequencing, Simulating and Recording system, see Fig. 4) is a program which resides in memory, together with the greater part of the operational system programs. TESSAR replaces the exchange equipment and simulates it by intercepting all output commands to the exchange, analysing them and returning the appropriate result. It also controls execution time of the operational programs so that an apparent real-time simulation can be provided. TESSAR itself is controlled by an events list which is written for each type of call to be tested. All results are printed out on the high speed printer for speed and ease of analysis. TESSAR was devised by Mr. A. Thies of the APO ADP Branch.

On-line Testing

On-line testing of the operational programs commenced with the basic man-machine system and monitor and moved from the first simple seizures to simple calls and finally full load traffic. Testing was greatly facilitated by the following hardware and software features:

Conditional Halt: The BTMX processor is equipped with two sets of keys. The first may be used to select any address in memory while the second selects one or more of the six methods of referencing a memory location, e.g. fetch for execution, write into etc. The processor will halt whenever the selected combination occurs, with the transient condition — contents of registers etc. — available for examination. Thus, for instance, the

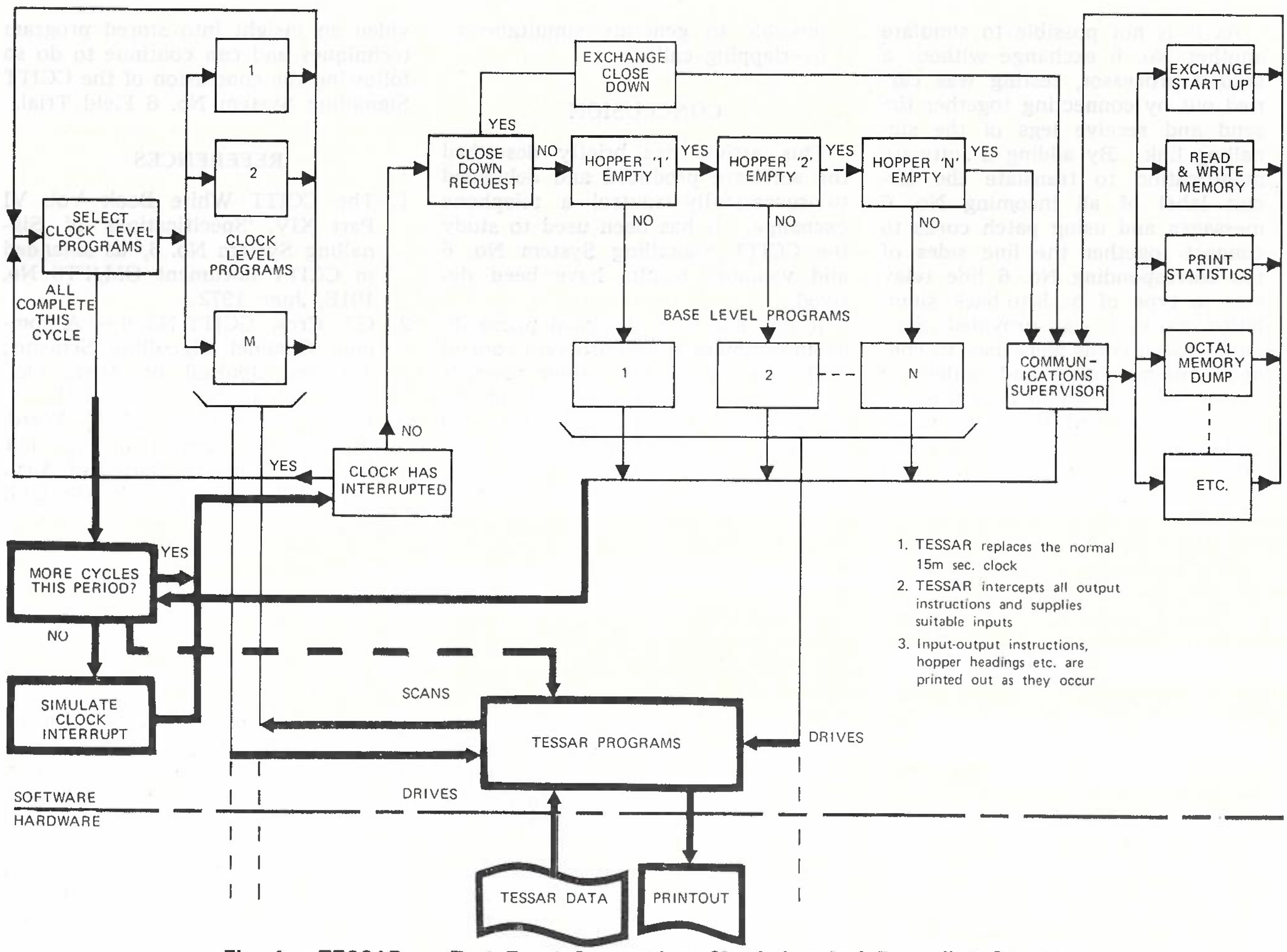

Fig. 4 — TESSAR — Test Event Sequencing, Simulating And Recording System.

execution of a particular program can be checked.

Core Memory Display: This is a device driven by program which uses light emitting diodes to display the contents of 32 selected words in core memory. As it is updated every 15 ms any transient conditions lasting longer than this are readily visible. It is normally used to display Dialling Buffers, Status Buffers etc.

Parity Trap Facility: The conditional halt facility has the disadvantage that it cannot be used for operational testing because it halts the processor nor can it be set on several locations at the same time. For testing purposes the parity trap facility allows incorrect parity to be set on any one or a number of locations in memory.

Whenever one of these locations is referenced by a load or fetch instruction, the detection of incorrect parity by the processor will cause an automatic exit to a routine to print out the appropriate processor registers etc. for later analysis before continuing on with normal operation.

Software Events Buffer: A telephone call, as seen by the operational programs consists of changes of state, each resulting in some period of software activity — loading and processing of hopper entries, instructions to the exchange etc. A history of these events is kept by storing a copy of all hopper loadings, instructions output to the exchange, and calls to important subroutines in spare memory for later examination.

This memory buffer is used in a cyclic manner, so that when the events stream overflows the buffer, overwriting will occur. However, the buffer will always contain the last 400 entries which may be printed for analysis.

Automatic Dialling Buffer Print Out: Most calls which fail for reasons other than the called party being busy will do so during the Dialling Buffer stage. These premature cleardowns are handled by a special string of programs — the 3 string. On entry to the 3 string, the Dialling Buffer contains all information on the call at that time including the identity of the program which decided to clear the call down.

The 3 string entry program transfers this information to a holding buffer for printing when time permits before proceeding with cleardown of the call. Thus a record is obtained of all premature cleardowns, their cause and the identity of equipment used.

Automatic Exchange Tester (AET): As the No. 6 exchange communicates with an ARM exchange, it is necessary to be able to simulate the ARM exchange for test purposes. This is done by using a standard ARM AET which can generate repeated calls to any selected number.

The AET can be left running for long periods to provide statistical results for a large number of calls with Dialling Buffer printouts providing the details of premature cleardown.

As it is not possible to simulate another No. 6 exchange without a second processor, testing was carried out by connecting together the send and receive legs of the signalling link. By adding a software modification to translate the circuit label of all incoming No. 6 messages and using patch cords to connect together the line sides of the corresponding No. 6 line relay sets, a type of back-to-back simulation working was provided. Similarly, patch cords were used to connect crossbar inlets and outlets so that a test call would pass through the exchange up to twelve times undergoing the translation from m.f.c. to No. 6 signalling or vice versa each time. In this way it is possible to generate simultaneous, overlapping calls.

CONCLUSION

This article has briefly described the software produced and debugged to successfully control a telephone exchange. It has been used to study the CCITT Signalling System No. 6 and valuable results have been derived.

It has not been designed primarily as an optimum stored program control exchange system but rather towards the end of providing a suitable means of studying a signalling system. To this end a number of separate systems have been developed. The operational system, in particular, has provided an insight into stored program techniques and can continue to do so following the conclusion of the CCITT Signalling System No. 6 Field Trial.

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TECHNICAL NEWS ITEM

DETECTOR FOR AUTOMATIC IDENTIFICATION OF EXCHANGE SERVICE TONES

A multi tone detector has been designed by the Post Office to detect the standard exchange service tones, e.g. plant congestion tone, busy tone, ring tone and also 820 Hz test tone used on test numbers for maintenance purposes in the Australian exchange network.

This detector will be used in Traffic Route Testers to correctly classify the results of sampling of the switching and signalling performance of the telephone network. A further application will be in association with automation of the Appointment & Reminder Service, which will be introduced with Stored Program Control Trunk Exchanges. This will depend upon correct recognition of service tones to confirm the establishment of its calls to step exchange destinations.

Reliable automatic identification of these tones requires that their characteristics such as frequency, level, pulse periodicity, harmonic content and signal/noise ratio be kept within closer limits than is necessary for subscribers or operators monitoring progress during the establishment of telephone calls. This will require in future for both acceptance testing and maintenance, a greater emphasis on checking the service tone generation, distribution and injection methods to ensure that the tones throughout the A.P.O. network comply with the appropriate specifications.

TECHNICAL NEWS ITEM

HIGH DENSITY IMAGE STORAGE TECHNOLOGY WITH HOLOGRAPHIC MEMORY

The Central Research Laboratory of Hitachi Ltd. has developed a method for direct, high density memory storage of all kinds of digital or analog information such as photographs, diagrams and letters through application of the laser holographic memory, the world's highest density digital information memory that Hitachi earlier developed. This new technological development has brought holographic memory a big step nearer to practical application. The holographic memory consists of laser beam memory elements that are used to record information in a storage medium as interference fringe patterns.

This high density memory can store a page of image information in a small circle less than 1mm in diameter. At this rate, all information, including photographs, diagrams and letters, contained in 500 pages each 210mm x 297mm in size can be stored in a space equivalent to one postage stamp (20mm x 25mm). (In terms of document information, this means that 10,000 letters can be stored in a space 1 mm in diameter.)

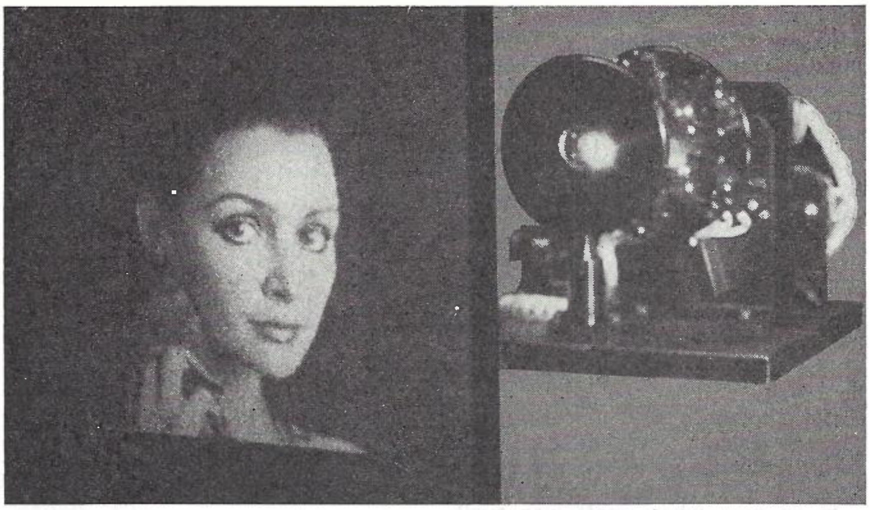
Hitachi research engineers have overcome the defect of past image memory technology in which an improvement of the image resulted in a lessening of the storage density. In the new Hitachi memory, analog information is divided into parts smaller than the human eye can detect and subjected to laser beams, which then pass through random phase shifters and are concentrated by a lens. In short, the random phase shifter method for digital information that Hitachi earlier developed has been applied to image information storage. By this new method, the memory density of image information has been raised to the limits of optical theory.

(A random phase shifter is a special plate developed by Hitachi researchers that makes possible image information storage by evenly distributing the information-bearing laser beams in the storage medium. The optical plate is made of multi-layered thin films of cerium oxide evaporated on the glass substratum through several kinds of random phase shifters.)

Reading is done simply by throwing a laser beam on the holographic memory. The image is reproduced automatically, and there is no need for optical elements such as lenses. This method, therefore, is much simpler than the conventional micro-film method. Reading speed has been vastly improved to one micro-second.

The illustration shows an information retrieval model comprising a mini read-out device containing 20 kinds of information. A keyboard is used to select the required information.

The new memory device has a wide range of possible applications such as for volume data storage, image filing, information retrieval and video discs.



Reproduction of Stored Image with Holographic Memory.

THE DESIGN AND CONSTRUCTION OF A MODERN TELECOMMUNICATIONS FACTORY

*T. E. HODGKINSON**

INTRODUCTION

It was decided in December, 1969 to amalgamate the telecommunications manufacturing facilities of the Philips group in Australia. At that time factories were located in Sydney, Melbourne and Adelaide. Two divisions were formed; a Radio Division in Melbourne and a Telephone Division in Sydney. The Telephone Division's major products are:

Telephone and telegraph transmission systems
Data transmission systems
Private Manual Branch Exchanges

The existing premises in Sydney were located in a congested area with inadequate parking, and they were considered to be quite unsuitable for the combined operation and for expansion. The Board of Directors decided to purchase a block of land and build a new factory. A suitable site was obtained at Moorebank, near Liverpool, N.S.W.

This new factory of 150,000 sq. ft. was officially opened on the 21st June, 1972, by the Postmaster General, Sir Alan Hulme.

CHOICE OF SITE

Several factors were considered to be most important in the choice of a building site. Ideally this should be:

Close to the city
Large enough for the erection of further buildings as the need arose
Easy access to major roads
In an area where staff was available as increases became necessary and,
At the same time within reasonable travelling distance from the homes of existing Sydney staff.

By necessity, the final choice was a matter of compromise between these various factors, the most difficult being location in modern urban conditions.

After inspecting many sites, one was chosen at Greenhills Avenue, Moorebank, about 23 miles from Sydney. The site covers approximately 30 acres, rectangular in shape, and flat enough to make building relatively easy. Within a radius of about 5 miles, particularly to the west, are a number of new suburbs. These show a high level of home building activity and should provide an excellent source for recruiting labour. The suburbs are within easy reach of the site by private or public transport.

SITE DEVELOPMENT

Description of the Site

The site plan is shown in Fig. 1.

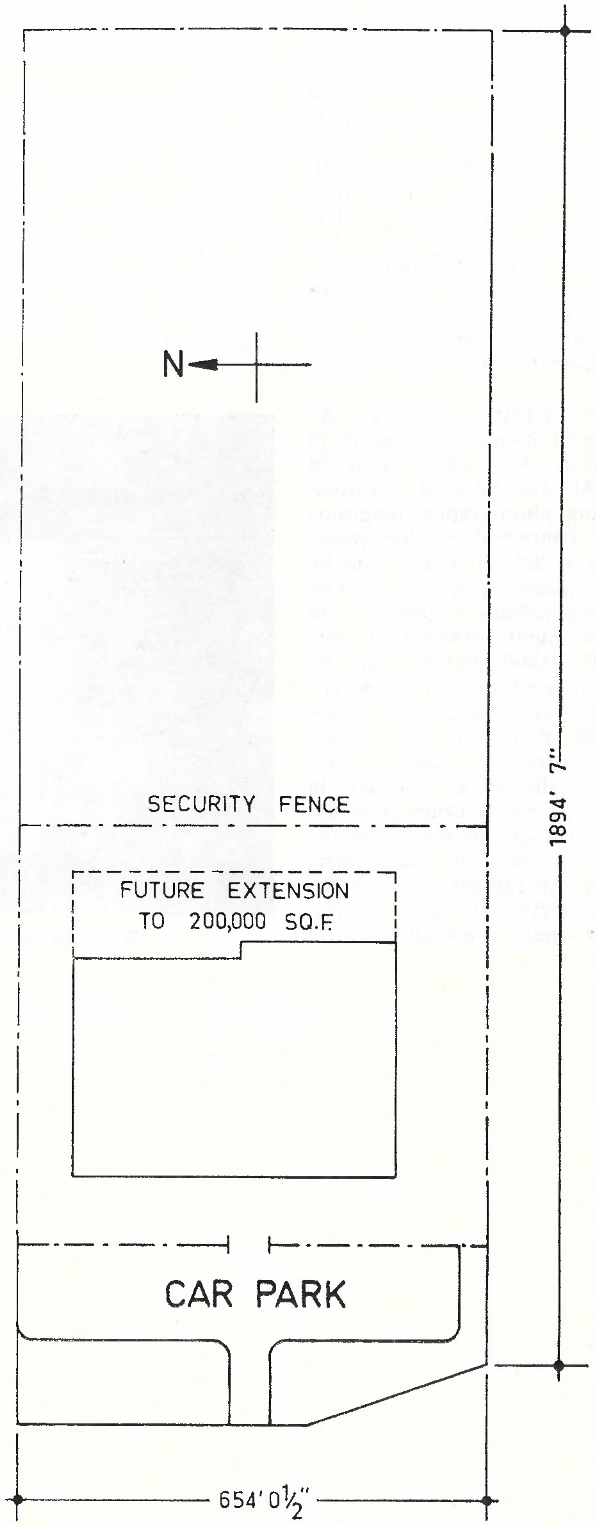


Fig. 1 — Site Plan.

* Mr. Hodgkinson is Managing Director, Telephone Division, Philips-T.M.C.

Along the south side of the purchased site of approximately 1800 ft. x 650 ft., an expressway is planned. This expressway will not have access to the site.

The land on the north side is owned by Leyland Australia which has its spare parts store on this site.

The eastern end of the Philips T.M.C. site is serviced by Centenary Avenue. Here a minor part of the land has swampy conditions which can be improved. After construction of Centenary Avenue, this part may become a self supporting area.

The west end along Greenhills Avenue has sewerage and water available and Greenhills Avenue provides better access for industrial traffic than Centenary Avenue.

These circumstances made it preferable to build upon the western part first.

Site-Layout

The location of the building was determined by several considerations:

Site conditions as explained
Security
Parking facilities
Fire regulations
The future expressway
External traffic flow

Security and Parking

For adequate control it is required to restrict the number of cars having access to the actual factory site as much as possible. As a consequence the employee parking should be outside the secured area which is controlled by the guard and is separated by a security fence. All cars entering the site pass the gatehouse and are registered by the guard.

The secured area is set back from the western boundary a distance of 280 ft., leaving an open space of approximately 4 acres, part of which is landscaped and the remainder paved for the parking of employees' vehicles. Local Council regulations require one car-parking space for every two employees. To allow for increased staff required as the Company expands, a large parking space was provided from the outset.

Fire Regulations

The fire regulations make it possible to build single storey buildings without a sprinkler installation and without fire-proof walls up to an area of 200,000 sq. ft. The restriction which is imposed is that the distance between the building and the site boundary or to the other buildings on this site must be 60 ft. or more. Fire-proof walls are considered to restrict the internal flexibility and were, therefore, avoided.

A sprinkler system is not only expensive, but is also not desirable in factories producing electronic equipment.

As sufficient space is available on the Moorebank site it was decided to erect a single-storey building and maintain an open space around the building of at least 60 ft. wide.

To enable the detection of fires a thermal fire alarm system is installed connected with the gatehouse and the local fire brigade.

Extensions

The actual building is 143,000 sq. ft. (including canopies 149 800 sq. ft.) and can be extended in the eastern direction by another 57,000 sq. ft.

The next building when needed will be 60 ft. distance from the first to meet the fire regulations.

Building Disposition

An expressway is to be constructed along the southern boundary of the site, and for this reason more attention was paid to the aesthetic design of this side of the building. In the internal layout, it was felt desirable to have maximum natural light in the office and laboratory areas and these were therefore located on the South side to avoid heat problems from the sun. The load on the air-conditioning system was considerably reduced by this plan. This arrangement permitted flexibility in aesthetic design. The location of the main entrance to the building on the South face fitted in with this concept, and also provided convenient access by visitors, most of whom would be involved with personnel in the office area.

Traffic Flow

A ringroad is constructed around the factory; however, industrial traffic is directed to the loading docks on the north side, while company cars drive around the south side to the covered carparking area at the rear of the building. This covered parking is constructed by extending the roof of the factory. Any extension of the assembly area would be in this direction, in which case this roof extension would cover the new area.

DESIGN OF THE BUILDING

Prime Considerations for the Design

The most significant factors in the design of the building were:

Optimal efficiency for the flow of work and a minimum waste of space, with no bottlenecks in production flow.

The location of areas related to one another, while considering aspects of noise, clean or dirty trades, and air-conditioning load.

The movement of large numbers of people to work places and eating spaces, and the control of these movements.

The manufacturing office and laboratory area should be air-conditioned to avoid adverse influences of extreme weather conditions, and to provide a clean atmosphere.

Work Flow

The fundamental manufacturing process of Philips T.M.C. is one of piece-part manufacture, assembly and test. The products are relatively small and light in weight, while quantities range from small to medium. Material handling is not then a major problem, and emphasis must be placed on material flow and flexibility of the production layout.

In addition to the main assembly and test area there is a sheet-metal shop and printed-circuit manufacturing area. As noise, dust and air contamination generated in these areas is detrimental to the main assembly operation, these processes must be isolated in separate areas, and can then be regarded as component suppliers to the main-stream operation.

The layout of the assembly and test area is product-orientated, in that separate production lines are set up for each product or group of products. These are set up in parallel so that material issues are made at one end and the finished items delivered from the other. The product build-up is such that holding cannot be undertaken at this point and must be centralised in a central area.

Looking further at the operation of Philips T.M.C. it is desirable to group the whole stores and packing operation in one area as this permits better utilisation of personnel and simplifies supervision. At the same time inwards and outwards goods movements are not continuous and require similar facilities so there is much to be gained by grouping these activities.

A further study of the types of goods received showed that the main heavy items delivered were raw materials for the sheet metal shop and laminate for the printed circuit area, while at the same time heavy material handling equipment was desirable for moving machines in the sheet metal shop.

Fig. 2 shows the actual layout adopted. The laminate and sheet metal stores have been separated and located near the heavy lifting equipment already required by the sheet metal shop. Although these are well

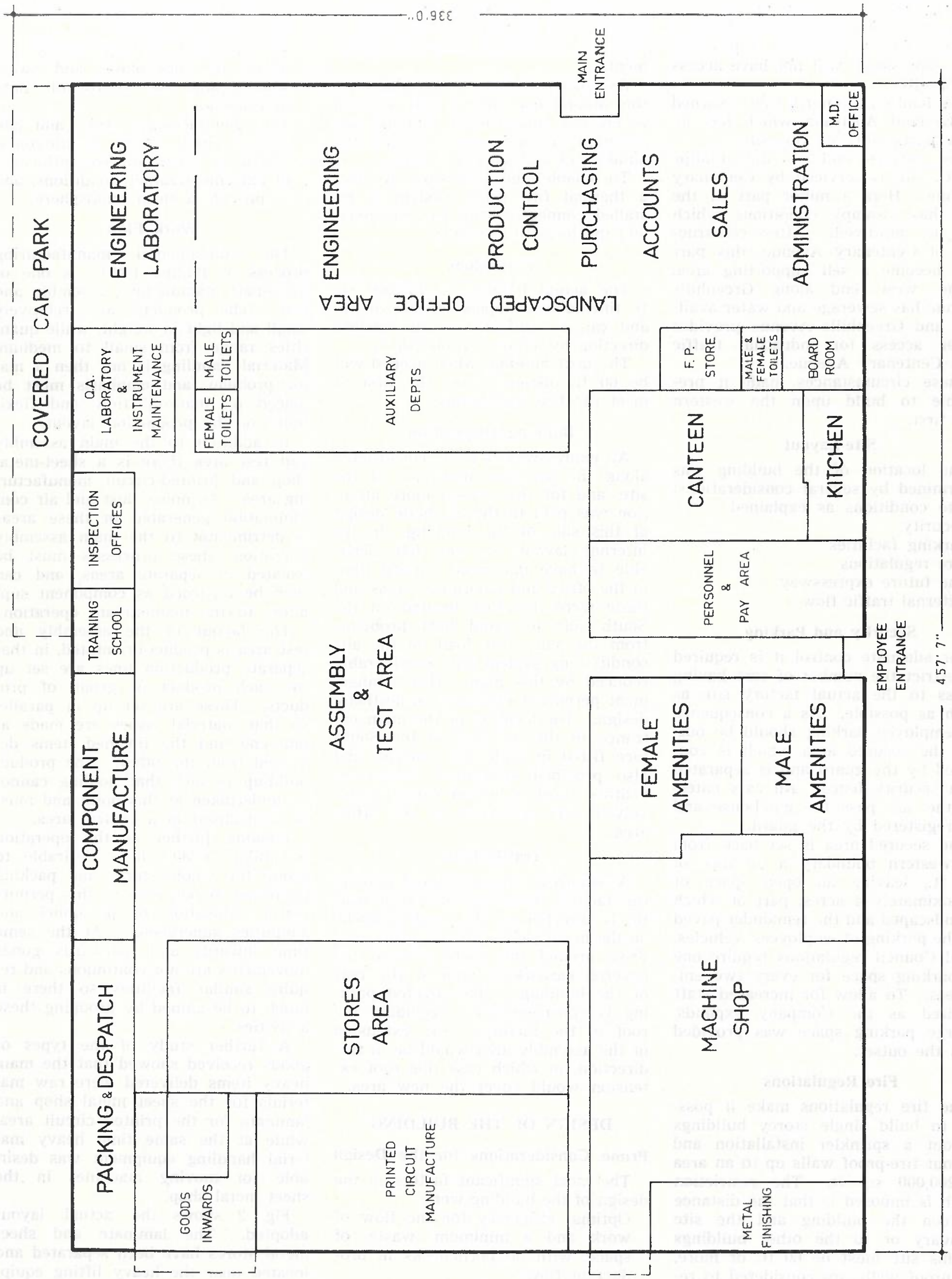


Fig. 2 — Plan of Factory.

separated from the main stores area, goods movements are relatively infrequent and the conveniences of handling plus the reduced distance to the consuming departments more than offsets this disadvantage.

Factory Auxiliaries

A number of smaller working areas, closely related to the main assembly area, but requiring good communications with the main office are suitably located between the two. These are quality control and inspection, methods, production planning, and instrument maintenance groups.

Personnel Department

The personnel department is located adjacent to the employee entrance and includes offices for male and female personnel officers, first-aid section, rest room, interview rooms, and a waiting area for prospective employees. A full-time nurse is employed in the first-aid area and provision is made for a visiting doctor as the need arises.

Staff Amenities

Locker rooms, toilets and showers are provided for an ultimate staff of around 800. A games room adjacent to the assembly area is provided to cater for entertainment during the luncheon break. For recreational activities after working hours, a billiard room with a new full size billiard table complete with billiard and snooker sets has been provided in addition to the above.

Cafeteria

A well-equipped kitchen and cafeteria serves a choice of hot meals as well as light food. The provisioning, cooking, and serving of the meals is done on a contract basis and meals are subsidised by the company.

The total staff, including management, uses the cafeteria on a self-serve basis. When important visitors are on the premises the board room, adjacent to the cafeteria, doubles as a dining room and meals are served to the guests and their hosts.

Main Office

The main office has an area of 25,000 sq. ft. and is landscaped throughout, except for the Managing Director's office which is situated in the south-west corner. The philosophy of office landscaping was considered carefully before the decision was made. The main advantages are:

- For staff used to working in an open office the surroundings are more pleasant than those provided in a conventional compartmental office.
- Communications between individuals in a section and between individuals in separate but associated sections are improved.
- The layout is more flexible than where individual offices are provided, and changes to working positions can readily be made as circumstances alter.
- The air-conditioning ducting system is simpler.
- More natural light is available throughout the area when there are not individual offices placed around the perimeter.

The main disadvantages are:

- Staff accustomed to working in individual offices tend to feel a loss of privacy and status when located in a landscaped office.
- A fear exists that their work will be interrupted by extraneous noise from other areas. This fear is more imaginary than real because the average type of demountable partition (particularly those having glass panels) provides rather poor acoustic shielding.

After considering the advantages and disadvantages it was decided to adopt landscaping. Typical areas are shown in Fig. 3. Acoustic and visual

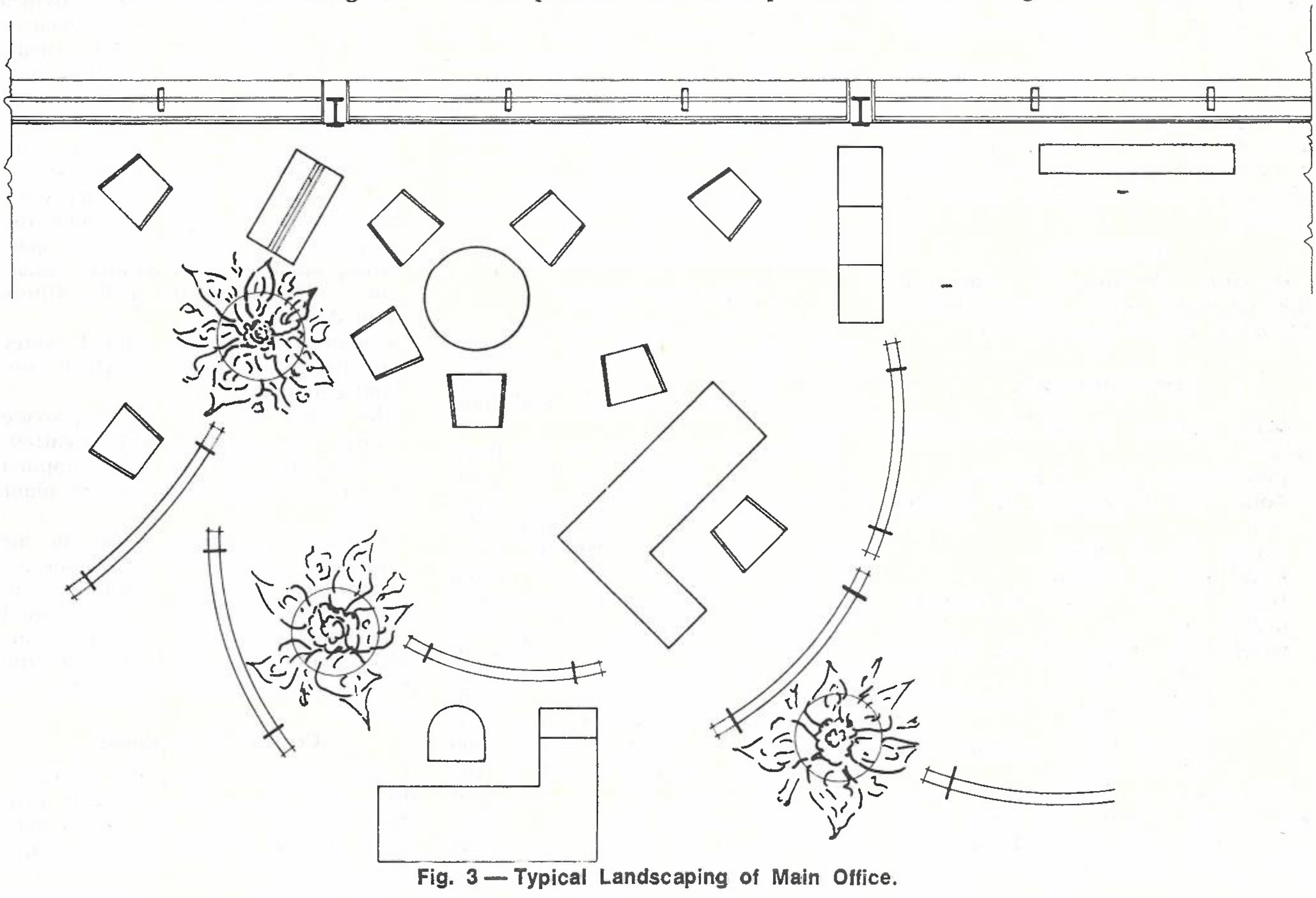


Fig. 3 — Typical Landscaping of Main Office.

screening is provided by indoor plants in fibre-glass tubs and by acoustic screens. The whole area is carpeted. By necessity the furnishings used must be of a high standard. Interior decorators and acoustic consultants were employed in the design and layout of the area.

The office contains the following sections:—

Senior Executives
Accounts and Costing
Commercial
Reception Area
Purchasing and Production Control
Drawing Office
Electrical Engineering

These sections are positioned in accordance with optimum work flow. In addition are included a library, two conference areas and two rest areas where staff can partake of tea or coffee whenever they wish: there are no fixed morning and afternoon tea breaks.

Frequently 'white noise' is distributed throughout a landscaped office to reduce the effect of extraneous noise. It was decided to take advantage of the normal air-conditioning noise to achieve the same result, and this appears to be satisfactory. When the area becomes occupied to its full capacity it may be necessary to install a 'white noise' sound system. The saving in air-conditioning equipment cost is significant.

In our particular case, the overall cost of acoustic screens, soft furnishings and indoor plants was less than the cost of the office partitioning that we would have had to provide for a small group of senior employees.

Laboratory

A large laboratory is located at the end of the office, adjacent to the Electrical Engineering Section.

CONSTRUCTION

Main features of the construction were:

Construction time 10 months.
Total area 149,800 sq. ft. (13,490 m^2).
Length 312 ft. (95m).
Width 456 ft. (139m).
Height overall 17 ft. - 21 ft. 6 in. (5.20m - 6.60m)
Height, net Offices 9 ft. (2.70m) under ceiling.
Laboratories 12 ft. (3.60m) under ceiling.
Factory 14 ft. (4.20m) under light ceilings.

The factory is designed on a module of 4 ft. x 4 ft., and, apart from a few minor exceptions, this module could be maintained throughout the design. The roof superstructure, which is completely independent from inside walls, is a steel portal frame with columns at 60 ft. centres and frames 24 ft. apart. The total weight of the steel construction is 240 tons. This construction is supported by concrete fittings and beams on piers approximately 6 ft. long.

Concrete floors with expansion joints are constructed throughout the building. The roof of galvanised iron sheeting is insulated underneath with mineral wool.

The outside cavity walls of the building are built of modular bricks of cream blonde colour. More than 400,000 bricks were used. Internal walls are single modular brick walls in locations where required by the process conditions. Such areas are, machine shop, canteen, printed circuit, chemicals, wet areas, amenities, or where walls were considered to be fairly permanent. All the other internal walls are constructed of studs with painted hardboard sheathing.

SERVICES

Fire Protection

To provide maximum flexibility within the building no fireproof walls or doors have been installed. No water sprinklers have been used, but, instead, fire hoses, hydrants and extinguishers have been strategically located throughout the building, and a thermal alarm system connected to the gatekeeper and the local fire brigade has been provided. This arrangement is acceptable under the local fire ordinances. Fireproof areas are provided for flammable liquids, archives and packing materials.

Electrical System

The electrical installation uses inhouse products wherever possible. These include an extensive busbar system for power supply, and light fittings.

Electricity is supplied by the Prospect County Council via two padmounted enclosed transformers operating in parallel. These supply the main switchboard at 240/415 volts, 50 Hz, 3 phase and neutral. From the main switchboard PVC insulated aluminium cables run on ladders mounted above the false ceiling to feed the various distribution switchboards. A unique feature of the installation is the use of overhead plugin busbars. A centrally located 800 amp busbar runs the length of the factory and from this 400 amp and 125 amp busbars are fed. These smaller bars are fitted with tap-off boxes where a final sub-circuit is required. This system allows full flexibility of location of equipment, and assembly lines can be arranged as desired. Outlet boxes have been fitted to the 800 amp busbars to feed the factory lighting directly.

Power and telephone cables within the main office are distributed through an under-floor dual-channel ducting system with a 12 ft. grid. These ducts were installed before the concrete floor was poured and are flush with the floor surface. A power outlet and telephone outlet can be installed anywhere along the length of the ducting convenient to the desk layout.

Lighting

The office areas are illuminated with fully-recessed fluorescent fittings giving an even light level of 60 lumens per square foot.

In the assembly areas a level of 70 lumens per square foot is achieved by rows of twin-tube fluorescent fittings mounted 14 feet above the floor level.

The car parking area and internal roadways are illuminated by mercury vapour street light fittings mounted on 20 foot high poles.

Air-conditioning and Ventilation

The air-conditioning system divides the building into seven zones, each of which is supplied with cooled or heated air by its own unit. Within each zone, distribution is by concealed ducting.

Each of these air-conditioners contains the following components:

A belt driven centrifugal supply air fan, which is sized to handle the required air quantity whilst operating against the frictional resistance offered by the coils, filters and ducting.

Cooling coils using chilled water as the cooling medium, which cool and dehumidify the air.

Hot water heating coil, to provide warm air during cold weather. Chilled and hot water is supplied from equipment in a central plant room.

A bank of filters to clean the air passing through the conditioner.

In order to achieve maximum economy in operating costs, the system is designed to function on an all-outside air cycle, at such times as the outdoor temperature conditions are suitable.

Central Plant Room

The central plant room contains the refrigeration plant, (which provides chilled water for the conditioner cooling coils), and the hot water boiler.

The refrigeration plant comprises one centrifugal refrigerant compressor driven by a 400 h.p. motor with shell and tube condenser and water cooler, in a single unit. This equipment has a capacity of 400 tons of refrigeration, and produces 533 gallons per minute of chilled water at 6°C. The condenser water is cooled by two cross flow cooling towers, with induced draught fans.

Centrifugal pumps circulate the chilled and condenser water through their respective cooling systems.

Hot water at 82°C is provided by an oil fired water tube boiler, with a capacity of 2,000,000 BTU's per hour. This uses light fuel oil supplied from a 2,000 gallon underground storage tank.

The main plant is operated by automatic pneumatic controls, and is started and stopped by a time clock. Pneumatic pressure is provided by an air compressor and air receiver.

Design conditions in the individual zones are controlled by room thermostats, which initiate the operation of chilled water valves, heating water valves, and dampers to achieve the required temperature conditions. The all-outside air cycle comes into operation automatically when conditions permit.

The dark room packaged conditioner and humidifier have electric controls to regulate the temperature and humidity.

All main controls are centrally located in 4 switchboards. The main switchboard houses the time clock, together with the controls for the centrifugal chiller with its associated equipment, and controls for conditioners 1, 2, 3, 4 and 5, and also the fire cancellation relay, which stops the entire plant in the event of fire.

The other switchboards control the boiler plant, ventilation fans, tank room fans and conditioners 6 and 7.

The entire plant switches on and off at the times set on the clock and functions automatically when the controls on the switchboard are set to the 'automatic' positions.

Mechanical Ventilation

All mechanical ventilation and exhaust systems are designed to meet the local authorities' requirements for adequate ventilation.

Ducted exhaust systems are installed to ventilate the locker rooms, toilets and air-conditioning plant room.

Roof, ceiling or wall-mounted ventilation fans are employed for the air compressor room, first aid room, oven room, tank room and impregnation department. All of these fans discharge to atmosphere, and are treated where necessary to minimize atmospheric pollution.

The kitchen exhaust system includes a stainless steel hood over the cooking equipment, with a grease filter and an exhaust fan which discharges through the roof.

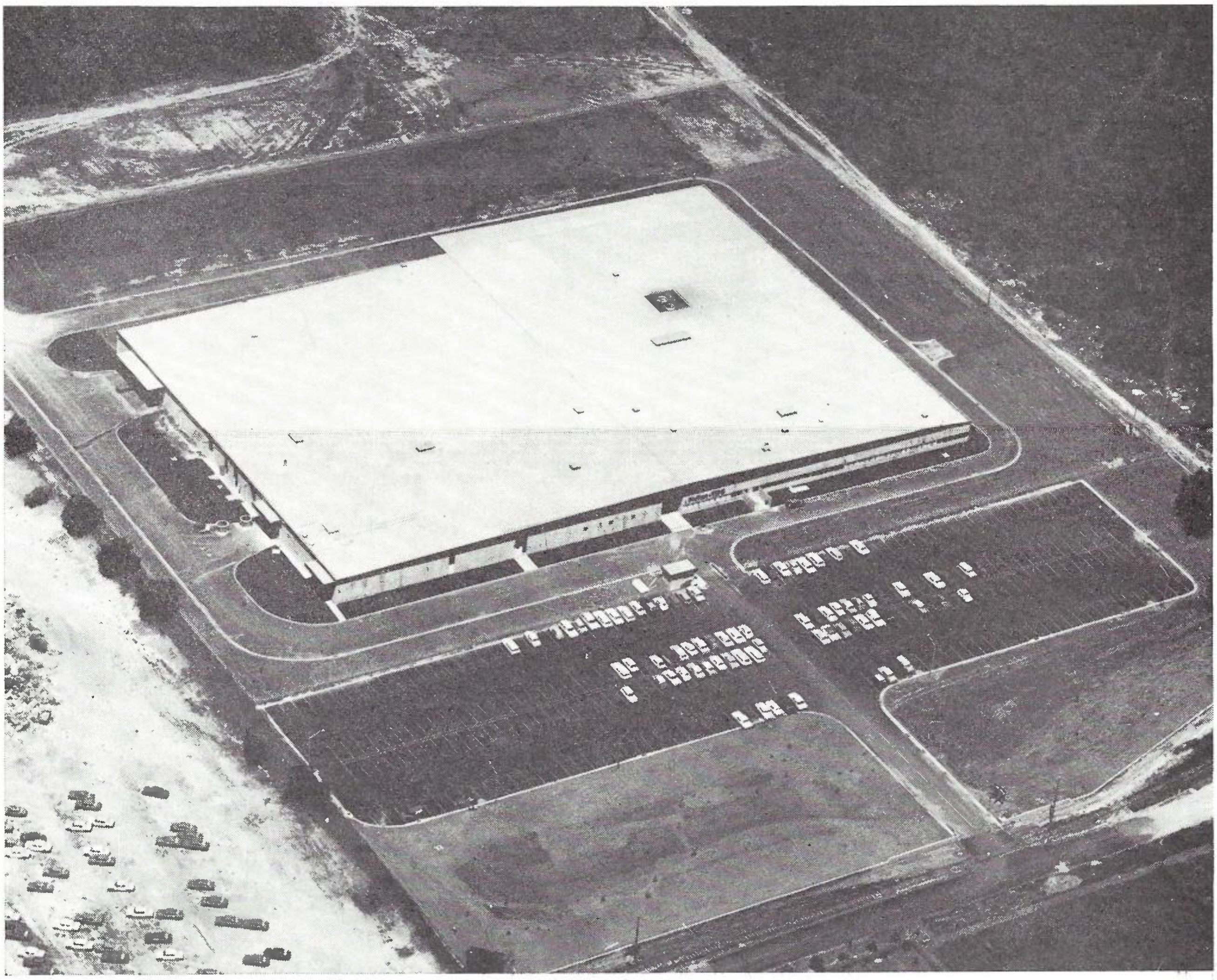


Fig. 4 — Aerial View of Completed Factory.

Pollution Control

The printed circuit manufacturing section of the factory when operating at its intended capacity requires an effluent treatment system that can handle discharges of alkaline or acidic wastes that vary from 1500 to 2000 gallons per hour. Before actual disposal, these wastes have to be neutralized and made safe in accordance with the local Metropolitan Water Sewerage and Drainage Board regulations. The Industrial Division of Philips has supplied a neutralization system that is designed to control automatically and continuously monitor these effluents.

The system consists of two reaction tanks in series with one another. The tanks are accurately proportioned in relation to the discharge rates, with inlet and outlet ports positioned so that a characteristic flow pattern is achieved.

Both tanks are equipped with agitators which ensure complete distribution of the reagent in the effluent.

Neutralization is achieved in the first tank and if necessary conditioned to finer limits in the second tank depending on the condition of the effluent. Treatment is made either with an acid or alkali reagent. Special anti-corrosive solenoid valves are used to dose these reagents.

The system uses miniature solid state controllers with anticipatory time proportioning action.

Ultrasonic cleaning techniques are employed to prevent contamination of the electrodes, ensuring accurate pH readings.

The pH transmitters and ultrasonic generator are mounted in a box adjacent to the tanks, and the rest of the indication, control, and recording instruments are mounted in an airtight, acid-fume resistant, glass fronted box in the office section of the plating plant.

The instrument box has a mimic panel which shows every stage of the neutralizing process. The mode of operation can be either automatic or manual. In the manual mode dosing of the reagent is performed with the aid of push buttons on the instrument panel.

The system has been designed to accommodate future expansion of the plating works if required.

Telephone System

The telephone system was specially designed and produced in our Telephone Laboratory for our requirements. It provides limited automatic facilities centred around a 100 line cord switchboard.

COMPLETION

The effective completion date was January 1972, and progressive occupancy was obtained from November 1971 onwards. An aerial view of the complete factory is given in fig. 4.

CONCLUSION

The task of shifting a manufacturing operation from one location to another is never an easy one. This project involved not only the shifting of two manufacturing operations, but also their co-ordination whilst the construction of the new building was proceeding. The successful conclusion was due to first class co-operation and effort from the builders and their sub-contractors, and from the many members of the staff who were involved.

ACKNOWLEDGMENT

The author wishes to thank the Management of Philips Industries Holdings Ltd. for permission to publish this article.

A ROUTINER FOR TRUNK CIRCUIT TESTING IN ARM EXCHANGES

G. FOOTE*

INTRODUCTION

A previous article (Ref. 1) discussed the methods being developed by the Australian Post Office for the supervision of the STD network performance. These arrangements were to include three basic equipments, the trunk test console, the traffic route tester (TRT) and an automatic trunk relay set routiner. Of these, the TRT is in service, generating calls over the STD network and the trunk test consoles are in use in ARM exchanges; only the routiner, which is still under development, remains to be put into service. The function of the ARM routiner is the imposition of various tests upon each trunk circuit as it is selected by the access control. Because the tests to be applied embrace all equipment associated with each trunk circuit, the proposed routiner differs greatly from types in common use and has some novel features. This article explains the functions of the routiner and points out some departures from previous practice.

FUNCTIONS OF A STEP EXCHANGE ROUTINER ACCESS CONTROL

Fig. 1 shows the basic layout of the usual type of routiner access control which connects selectors, or relay sets, to the routiner test unit one at a time and in cyclic order. The equipment items to be tested are wired to the bank outlets of access switches, the inlets of which are connected to the test unit by one common set of conductors known as the 'test common'. The access switches are stepped from outlet to outlet to obtain access to the individual items of equipment to be tested. When all items reached via one access switch have been tested the next switch is brought into use for access to a further set of items of the same equipment. The process continues until all equipment has been tested. The use of one test common for connection of all access switches is possible because there is no chance of intrusion from any other source, there being only one routiner associated with a test common.

THE ARM TRUNK CIRCUIT ROUTINER ACCESS CONTROL

In the case of the trunk circuit routiner the conditions outlined above do not apply and arrangements to prevent intrusion are required.

In an ARM exchange connection between the test consoles and the trunk relay sets, outgoing and bothway, is established by access controls, one of which is provided for each console testing outlet. The presence of more than one test console in an exchange requires the provision of more than one test common in order to avoid delays in testing. It is convenient to partition the relay sets into groups of 30 since FUR and FDR are accommodated 30 and 15 respectively to a rack, and provide a separate test common and access switch for each group. A test for a free access switch is therefore also a test for a free test common. The trunk test arrangements, therefore, consist of a number of consoles, each with an individual access control and primary distributor group, all sharing the same access switches. To test a trunk, the officer at the console dials a code which causes the test common and access selector appropriate to the required relay set group to be seized by his console's primary distributor and stepped to the outlet associated with the required trunk.

The routiner gains connection to the relay sets by means of the same test commons and access selectors, but using its own group of primary distributors. This means that the routiner access control must be capable of testing for a free condition before seizure of a test common and access selector, and must be able to switch the associated test common to the test unit. Fig. 2 shows the arrangement for test console and routiner access. It will be noticed that a further departure from the method used in Step exchanges (shown in Fig. 1) is that the test commons are not directly connected via the access switch but via the contacts of TA relays, which are provided one per relay set. Each access switch controls the operation of 30 TA relays so that each test common serves a group of 30 relay sets. Only one lead is required to each relay set to operate the TA relay; the test commons consist of ten leads each.

* Mr. Foote is a retired officer, see Vol. 20, No. 2, page 138.

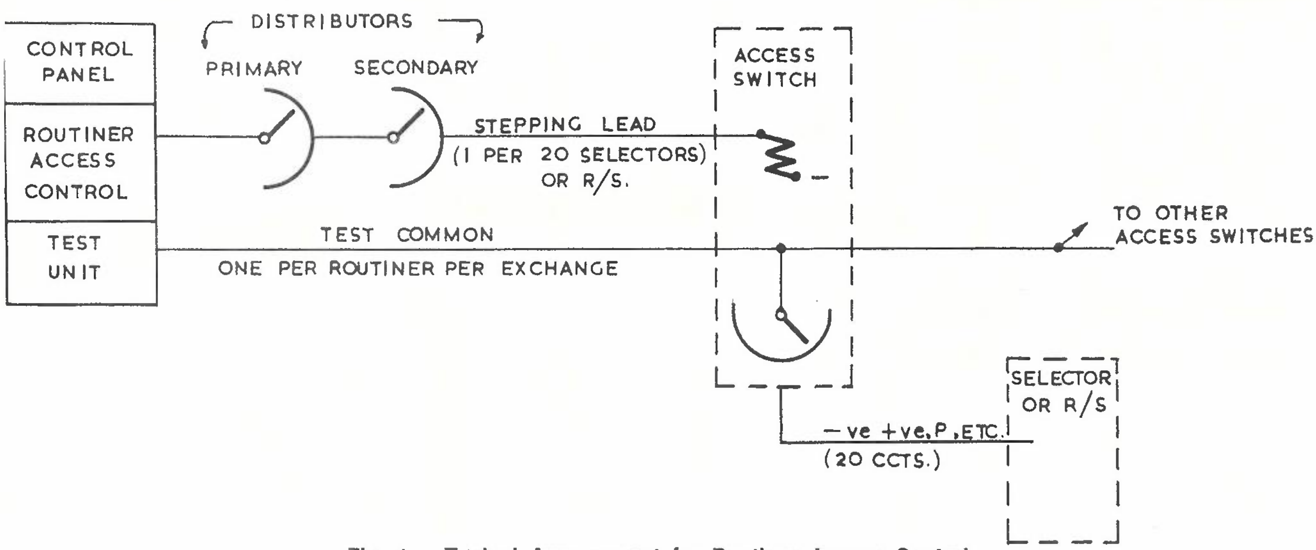


Fig. 1 — Typical Arrangement for Routiner Access Control.

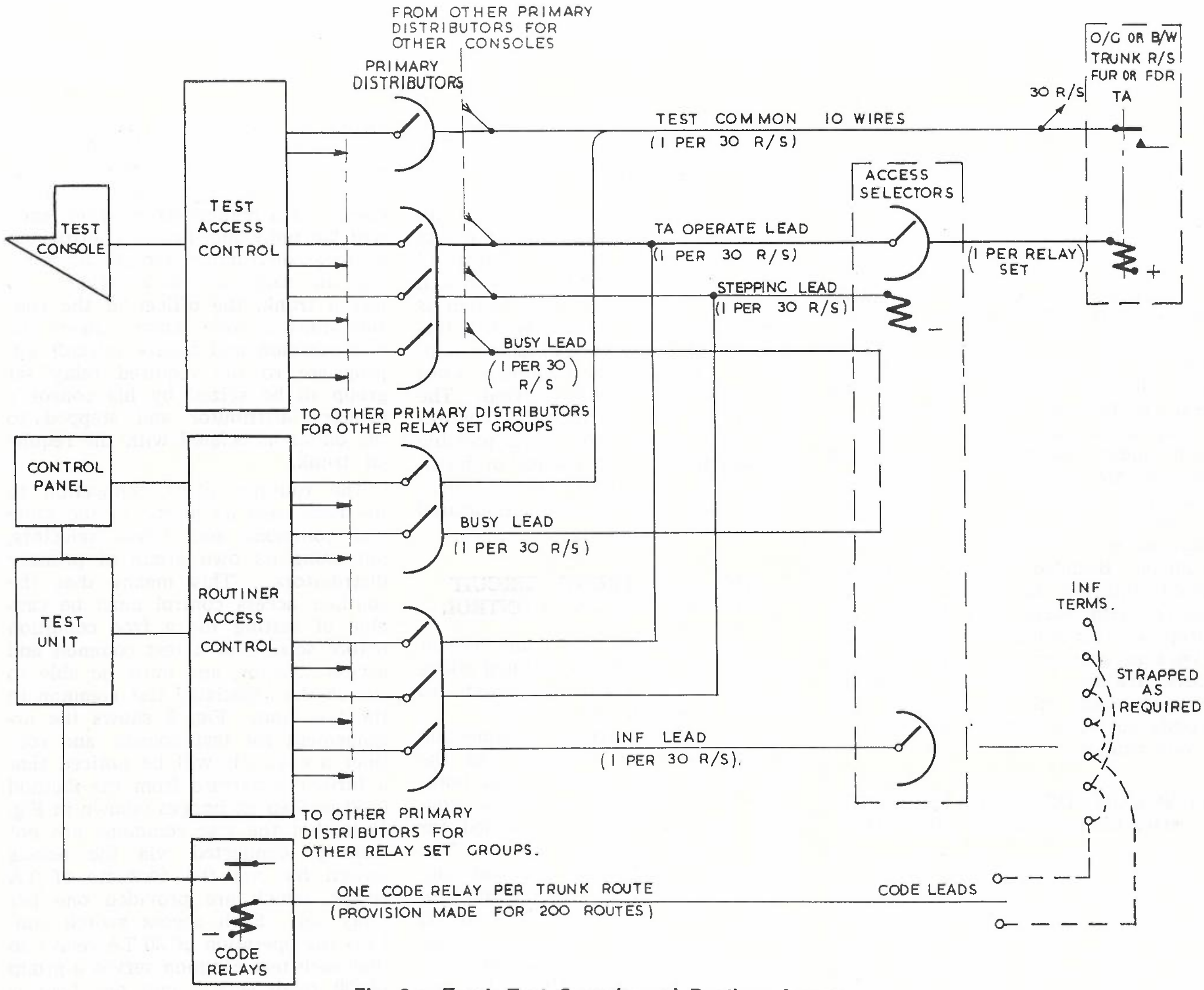


Fig. 2 — Trunk Test Console and Routiner Access.

TESTS APPLIED BY THE ROUTINER

The test unit applies tests to check the line signalling and transmission characteristics of each trunk. This is carried out by setting up calls to a Test Call Answer Relay Set (T.C.A. R.S.) and a Pulse Length Monitor (P.L.M.) in the distant exchange. These devices co-operate with the test unit in the routiner to enable it to conduct the required tests. Details of these tests have been discussed in an earlier article (Ref. 2).

ESTABLISHING THE TEST CALL

In order to set up a call, the routiner must be aware of the routing and whether decadic or M.F.C. signalling is required as dictated by the type of terminating equipment in the distant exchange. Information on the digits to be sent and the signalling mode is obtained by code relays. One code relay serves all the relay sets associated with a trunk route and is operated via an access switch in the same manner as a TA relay. Code relays are operated by the routiner access control only and are not used by the trunk test consoles. A strapping field accessed by these code relays provides a memory to which the test unit refers when a call is to be set up.

The distant exchange may be crossbar, step or hybrid, so that both M.F.C. and decadic signalling facilities will be needed. The test unit is advised of the nature of the distant exchange by means of the code relay and, at the point at which sending is required, either calls in the test register for M.F.C. signalling, or switches the trunk to the decadic signalling circuit which is contained in the test unit itself. Should a request be made for decadic signalling, during the transmission of M.F.C. signals, then the decadic signal circuit is routed to the first digit to be sent decadic and the test register is released. Fig. 3 shows the basic arrangements for sending. The KSR is of a standard type but is permanently wired into the routiner. Likewise the test register which is, however, a special piece of equipment is actually a much smaller version of the register used in the exchange.

CONTROL OF THE TESTS

The strapping field provides information on the T.C.A.R.S. access number and the nominal transmission losses of the circuits under test to set the pass/fail criteria for the transmission tests. Each outlet of the access switches connected to a TA relay has a counterpart on a partner code relay arc. By strapping together all code relay outlets pertaining to relay sets on the same trunk route and connecting these to the one code relay, the details required by the test unit are switched into the routiner at the same time as the relay set testing points are connected to the test common (Fig. 2). If a request has been made for decadic signalling during the set up of the transmission test call, the routiner remembers this and will carry on with the pulse test, to check the pulse repetition performance of the circuit. This is done by setting up a call to the distant Pulse Length Monitor (P.L.M.). The test unit again refers to the code relays and is given the code to be sent for connection to a P.L.M. which, on seizure, returns a 'ready' signal to the test unit. A series of digits are now pulsed into the P.L.M. which signals back the results of its examination to the test unit by means of service tones. Either of the transmission or pulse tests, but not both, may be cancelled by operation of a key.

Recording the Results

In common with many routiners a printer is provided for this purpose. When a busy trunk, or a busy access switch, is encountered details of the busy equipment are recorded before the test unit is routed to the next trunk or next access switch.

Route Testing

The access control will test relay sets in cyclic order; that is the order in which they appear on the racks and as they are wired to the access switch outlets. Relay sets serving the same route will not necessarily be found adjacent to one another on the shelves and are likely to be found dotted "here and there" over the available racks. In any case any group of more than 30 trunks will occupy more than one access switch and a means of testing only those relay sets serving a particular route is needed. This route testing facility, which is illustrated in Fig. 4, is provided in the following manner. Each code relay represents a particular trunk route and is wired through a partner route key in such a manner so as to operate in series with the CX relay when the route is to a crossbar exchange, or CS relay when the distant terminal is step : hybrid exchanges are treated as crossbar, as M.F.C. signalling will be required if only initially. When requiring to test the relay sets of a chosen group the associated route key is operated together with the common route control key. With the two keys operated all relay sets associated with the chosen route will be tested normally

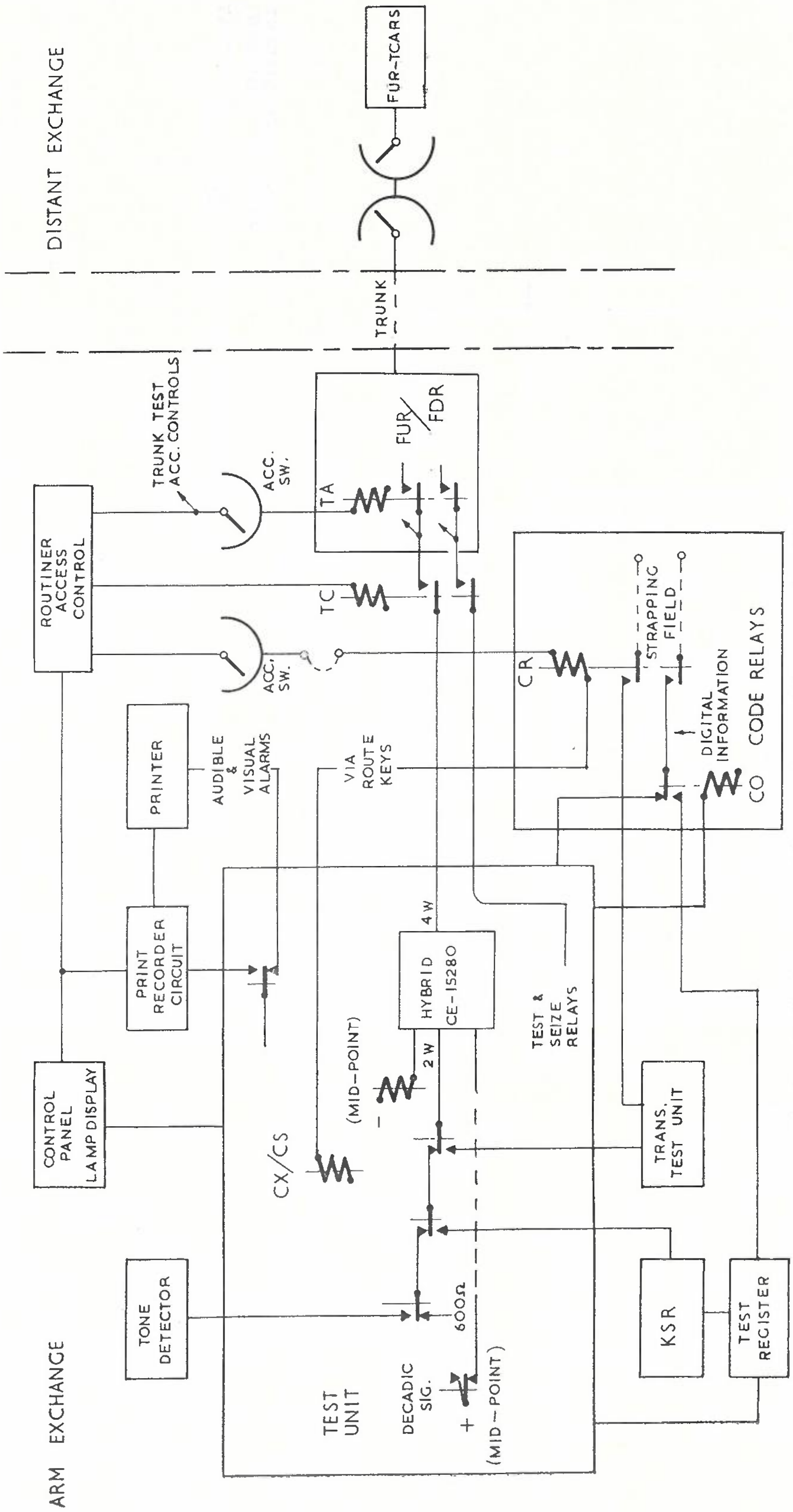


Fig. 3 — Basic Arrangement for Sending and Transmission Testing.

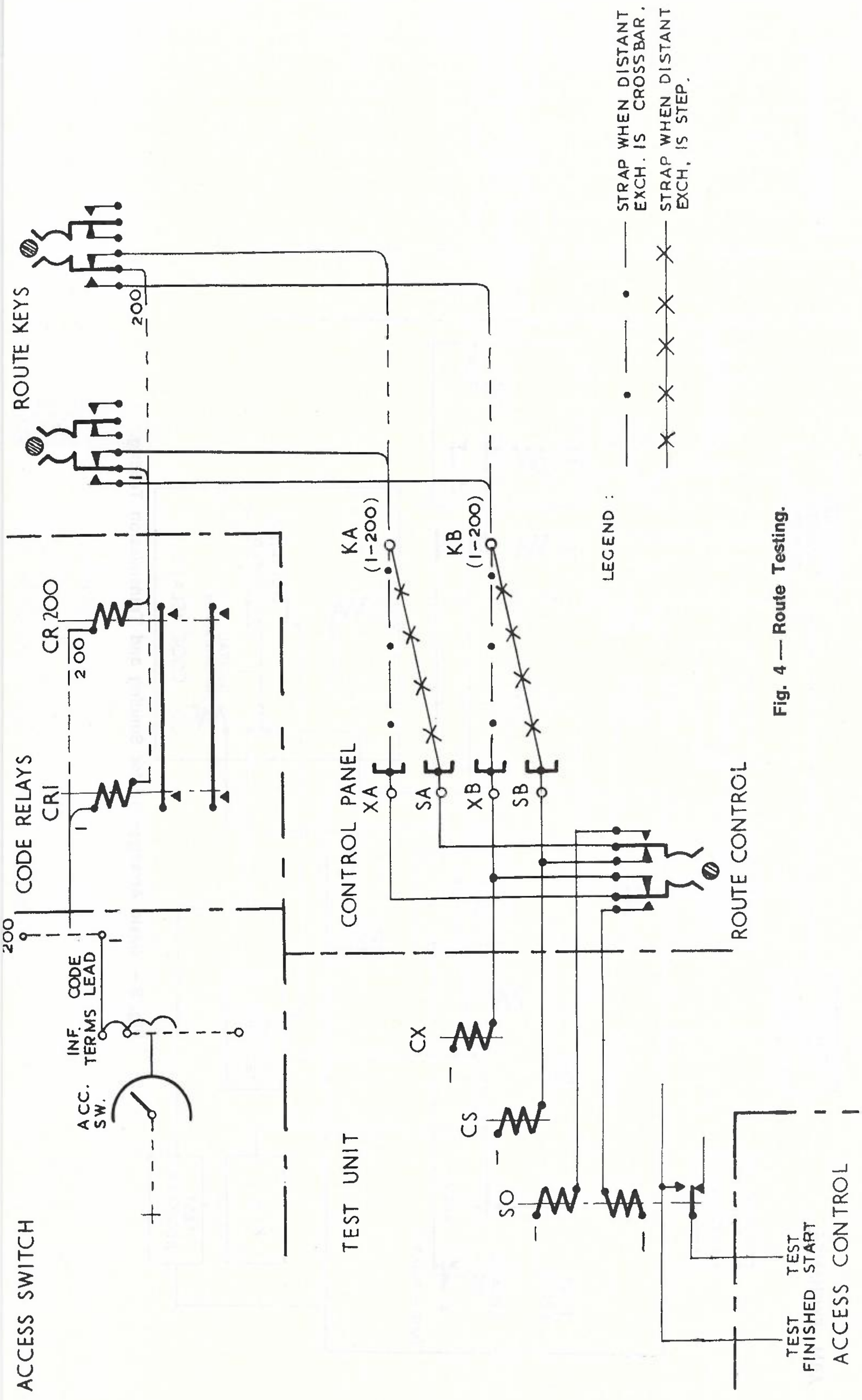


Fig. 4 — Route Testing.

as the code relay will operate in series with either CX or CS; relay sets of any other route will be passed over as the code relay operates in series with SO instead of either CX or CS. With SO relay operated the test start signal is passed back over the test finished lead and the access switch is stepped to the next outlet without a test being made.

Routiner Throw-off

As the common point of connection to a trunk from both the consoles and routiner is the access switch, a testing officer on a console will be confronted with a busy signal on dialling the code of a relay set when the associated access switch is engaged. If the switch is in use by another console then access is barred and the testing officer receiving the 'access switch busy' signal must wait until it is disengaged. This is not the case when the access switch is in use by the routiner as the consoles have first priority and are able to throw-off the routiner, seize the switch and then dial the remainder of the code to gain connection to the desired trunk. On receiving the busy signal, the testing officer does not know which equipment is using the access switch but he may then depress the 'throw-off' key; if the routiner is the cause of the busy signal then the access switch will be released and homed. The busy signal is removed from the console and remainder of code may be dialled. Should another console be using the switch then the depression of the throw-off key will have no effect and the busy signal will persist thus providing a warning that access is not available. For the routiner, two modes of behaviour are possible when the throw-off signal is received, the choice being by means of a key on the routiner control panel which may be left in the normal or 'Wait' position or operated into the 'Next Group' position. In either case receipt of the throw-off signal, which will persist until the console clears the connection, causes the routiner to disengage itself from the access switch which then returns to the home position in readiness for setting by the console. With the key in the 'Wait' position the routiner access will stay with all control switches in position until the throw-off signal is removed. It will then wait until the access switch is homed before seizing and stepping it around to that position occupied before throw-off. Testing then resumes at the point at which it was halted. This is arranged by providing a partner switch in the control which is kept in synchronism with the access switch in use. The throw-off signal allows the access switch to home but the partner in the control stays in position to mark the outlet to which the access switch must later be reset. A wait of an indeterminate time ensues if this method is adopted. If this is undesirable the 'Next Group' mode may be employed. With the key in this position the receipt of the throw-off signal is noted and access switch released but now the printer is called in to record details of the relay set which was under test together with the information that the routiner was thrown off. After making a record the printer signals back and is then released. The next access switch is now seized if free, and the sequence proceeds from the first circuit in this new group. Upon examining the printer read-out the maintenance officer is made aware of the point at which release occurred and at any convenient time may return to this particular relay set.

THE CONTROL PANEL

The panel, which houses the keys relative to the various functions together with a lamp display indicating the relay set under test and reason for the routiner stopping (such as an encountered fault, access switch or relay set busy etc.), is designed to be remote from the routiner and may be installed in any convenient position. If desired the printer may be switched off, in which case audible and visual alarms are given instead of a read-out.

CONCLUSION

To enable experience to be gained through which the value of this routiner may be assessed the initial trial installations are in progress in the ARM exchanges at Sydney, N.S.W., and Hamilton, Victoria. Its ability to check automatically the most important functions of outgoing and bothway trunk circuits is expected to make the ARM Trunk Circuit Routiner a most useful maintenance tool.

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TECHNICAL NEWS ITEM

PROGRESS IN IMPLEMENTATION OF SUBSCRIBER TRUNK DIALLING

Good progress is being made in achieving the national target of 66% of trunk calls to be subscriber dialled by 1975.

It appears that all States will achieve their targets, and some may exceed them. National S.T.D. penetration has been increasing at an average annual rate of about 6% for the past seven years from 1965 to 1972, and has now reached 57%. However, it is expected that the annual rate will decrease over the next few years to about 4% as fewer new origins and destinations are added and the increase in S.T.D. penetration will mainly depend on increased S.T.D. usage. This would mean that the 1975 National S.T.D. target of 66% could be exceeded by about 2% or 3%.

MAINTENANCE AND PERFORMANCE OF L. M. ERICSSON CROSSBAR SWITCHING EQUIPMENT IN AUSTRALIA (PART 1)

*B. J. CARROLL, A.R.M.I.T.**

INTRODUCTION

In order to ensure that all the requirements of routing flexibility, charging and transmission necessary for the successful implementation of the Community Telephone Plan would be realised, the A.P.O., after a study of the various switching systems available, decided in 1959 to adopt the L.M. Ericsson common control crossbar system. Subsequently ARF102 exchanges were installed in Metropolitan areas and in the larger Provincial centres, ARK511 and 521 in rural areas and ARM exchanges in the trunk switching network.

Apart from the fact that the L.M.E. crossbar equipment would provide the required facilities, one of the fundamental reasons for its adoption was its potential for low maintenance costs. Crossbar systems had been in use for a number of years in many parts of the world and their service reliability and low maintenance effort were well established before the A.P.O. installed its first crossbar exchange.

The purpose of this article is to outline the experience of the A.P.O. with the operation of crossbar equipment in this country. The article is presented in two parts; this first part deals with ARF switching plant. The second part, covering ARK rural exchanges and ARM switching equipment, will be published in the next issue of the Journal.

DEVELOPMENT OF THE TELEPHONE NETWORK

In 1962 when the crossbar installation program was launched the decision was taken to cease forthwith further purchase of step equipment and to use crossbar switching plant for all new exchanges and as extensions to existing step installations. At that point in time 81% of the 1.8 million telephone services were connected to approximately 2000 step type exchanges, with subscriber trunk dialling facilities being available to about 3% of the subscribers. Today 50% of all trunk traffic is subscriber dialled, with S.T.D. access being available to 2.26 million subscribers.

The following statistics indicate the growth and development of the automatic telephone network in this country

	1965	1971	1980 (proposed)
Lines of Step Equipment	1,700,000	1,400,000	1,300,000
Lines of ARF Equipment Metropolitan Areas	154,000	1,300,000	2,800,000
Lines of ARF Equipment Country Areas	48,000	284,000	640,000
Lines of ARK Equipment	26,000	221,000	575,000
Equipped Ends Trunk Switching (includes ARM and Computer Controlled Equipment)	—	45,000	248,000

GENERAL EXPERIENCE ON PLANT PERFORMANCE

Experience with ARF crossbar equipment indicates that the plant will provide high long term reliability with little maintenance attention, provided it is correctly installed and operated by skilled staff. Some of the initial installations show no significant increase in fault incidence over the past nine years. The service performance of these exchanges as measured from a customer's viewpoint is also stable and well within the targets specified by the A.P.O.

The only significant point to date is that there is some evidence of contact erosion, particularly on hard worked relays operating in relatively low inductance circuits. This problem is currently under investigation. The MFC signalling and the crossbar switch have proved very reliable in service.

On the question of operational economy, the current average recorded manhour rate of 1.05 manhours per telephone station per year is high compared with figures in the order of 0.3 to 0.5 manhours per line recorded by various overseas administrations. (Based on the ratio of lines to stations this represents 0.2 to 0.34 manhours per station.) However, there is ample evidence to indicate that our operational costs could be reduced and figures in the order of 0.34 manhours per telephone station obtained, particularly for equipment located in metropolitan areas. At present approximately 66% of the A.P.O. crossbar plant is located in the six capital cities.

In evaluating the performance of crossbar plant in this country, and particularly when making comparisons with results achieved overseas, consideration should be given to the following significant background features with respect to the Australian operational environment:

(i) The crossbar plant was integrated into established step networks and in many cases was installed as extensions to existing step exchanges. A separate crossbar network was not established. This has accentuated interworking problems, and not allowed the best utilisation of skilled staff.

(ii) The level of installation activity throughout the network has been high.

(iii) The system has been subjected to a significant number of modifications, mainly to provide new facilities and also to overcome some design problems, mostly associated with inter-working with the step by step exchange system.

INITIAL INTEGRATION PROBLEMS

It is inevitable that the integration of any new switching system will highlight some unforeseen interworking problems, no matter how carefully the system has been designed or the interface conditions specified by the customer. Most of the initial problems with crossbar, however, were not due to design defects in the system but were attributable to conditions in the step network or to peculiarities of the subscribers plant which had no effect on the simpler step system.

Typical issues in this category were:

(i) *Wrong Number Problems:* These complaints were caused by the sensitivity of the reed relay in the register counting circuit, to short impulses from faulty slipping cam dials or the inductive surge from PABX operator circuits. To rectify this condition it was more economical and expedient to modify the new crossbar registers rather than the equipment already in service.

(ii) *Cut Off Problems:* These became apparent due to the introduction of "time supervision" to the network on crossbar originated calls. Apart from faults in junctions, line relay

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TABLE 1 — ANALYSIS OF LOCAL SERVICE ASSESSMENT. (1971/72)

	Sydney	Melbourne	Brisbane	Adelaide	Perth	Hobart
(i) Step Originating to the Network						
(a) % Effective	65.2	68.5	68.7	77.0	61.5	78.5
(b) % Customer Loss	17.6	17.2	15.7	13.5	23.1	10.9
(c) % Congestion Loss	14.5	13.4	14.6	8.7	14.3	10.0
(d) % Switching Loss	2.7	0.9	1.0	0.8	1.0	0.6
(e) % Plant Congestion Loss	1.2	0.8	1.1	0.3	0.5	0.5
(ii) Crossbar Originating to the Network						
(a) % Effective	62.7	66.5	67.7	72.2	61.5	79.2
(b) % Customer Loss	16.9	17.9	15.2	14.8	21.7	9.9
(c) % Congestion Loss	18.0	14.4	16.1	12.4	15.6	10.5
(d) % Switching Loss	2.4	1.1	1.0	0.7	1.2	0.4
(e) % Plant Congestion Loss	1.4	1.5	1.0	0.5	0.5	0.4
(iii) Crossbar to Crossbar						
(a) % Effective		68.1	68.4	72.8	66.0	78.9
(b) % Customer Loss		17.3	14.7	14.4	17.7	10.2
(c) % Congestion Loss		13.5	16.0	12.2	15.3	10.7
(d) % Switching Loss		0.7	0.8	0.5	1.0	0.2
(e) % Plant Congestion Loss		1.2	0.6	0.3	0.2	0.2

sets and wiring reversals in exchanges, these troubles were caused by the failure of switchboard operators to ensure that "hold" keys were used when transferring calls.

In addition to the abovementioned conditions it became evident that correct setting of the thermal relay in SR's, FIR's and Reg-L's played an important part in ensuring that cut-offs were reduced. The adjustment of the time supervision in registers has become even more critical with the introduction of Subscriber Trunk Dialling, especially where registers are subject to heavy traffic.

(iii) *Post Dialling Delays:* In local networks this is no longer a problem as post dialling delays are under 4 seconds for at least 95% of all calls. However, to reduce the possibility of subscribers releasing connections during the setting up of trunk calls to distant step networks, a proposal to apply a muted tone to the line whilst the register is connected is being considered, as post dialling delays can exceed 10 seconds on S.T.D. calls under certain circumstances.

The introduction of field reporting systems, such as Defective Material Reports and Defective Performance Reports for all types of switching plant, has ensured that A.P.O. engineers and telephone plant manufacturers receive prompt feedback of information on any faults due to design changes, faulty components or changes in manufacturing techniques.

SERVICE PERFORMANCE

Service Assessment of Live Traffic

The service performance targets set for the total originating traffic for local networks is as follows:

Switching loss	1.5%
Congestion loss	1.0%
Successful calls	75.0%

The figure for successful calls excludes call loss due to congestion, wanted subscriber busy, wanted subscriber does not answer, recorded announcements and faults.

The results of service assessment for capital city networks for the year 1971/72 are set out in table 1 under the following classifications:

(i) Calls originating from step equipment.
(ii) Calls originating from crossbar equipment, and
(iii) Calls switched entirely by crossbar plant.

It will be noted that the switching loss for calls switched by crossbar equipment (category iii) is less than that recorded against calls originating from step exchanges. Whilst the percentage of calls successful is at present in the same order for all three categories of call, there has been a tendency for call loss due to congestion (total wanted subscriber busy and plant congestion) to be higher for crossbar originated calls. However, the results recorded over a number of years clearly indicate that as the percentage of crossbar plant increases there will be a marked overall improvement in the service performance of the various networks.

Traffic Route Testing

The performance of the switching plant and network is also checked by test calls generated by Traffic Route Testers. These particular test calls are programmed and controlled by the Network Performance Analysis Centres in each State. The target set down for traffic in local networks is for a total call loss of 2%. (This includes 1% switching loss and 1% plant congestion).

The average network call loss (switching plus congestion loss) for capital city networks (Table 2) clearly indicates that the performance on crossbar to crossbar calls is considerably better than that experienced in step to step calls. Within the local exchange the call loss for crossbar exchanges is usually in the order of 0.1 to 0.3%.

TABLE 2: AVERAGE CALL LOSS ARTIFICIAL TEST TRAFFIC (1971)

Capital City	Crossbar-Crossbar	Step-Step
Sydney	1.5%	2.6%
Melbourne	1.6%	1.6%
Brisbane	0.9%	1.3%
Adelaide	0.4%	0.8%
Perth	—	—
Hobart	0.5%	1.8%

PLANT PERFORMANCE ARF EQUIPMENT

Fault Incidence

From a detailed analysis of the fault statistics recorded over a period of three years for approximately 100,000 lines of ARF equipment, mainly from the Melbourne metropolitan network where service targets are being met, the average fault incidence for switching equipment faults is 16.6 faults per 1,000 lines per year. When M.D.F., I.D.F. and miscellaneous equipment faults are included, the figure is increased to 20 faults per year. This is less than 20% of the number of faults experienced with step equipment. A similar Commonwealth wide study on the fault incidence for ARF equipment conducted in 1965 also indicated an overall fault rate of 20 faults per 1,000 lines per year. It is also evident from the information available that the fault incidence for the initial ARF installations is not higher than the more recently established installations. These latter figures were obtained from networks with a relatively high level of installation activity, a large number of relatively small crossbar exchanges (even at this point in time less than 20% of the exchanges are over 10,000 lines) and with crossbar equipment installed as extensions to established step exchanges.

Faults by Location

Table 3 indicates the incidence of faults on particular plant items and expresses them as a percentage of the total equipment faults. It also provides an indication of the mean time between fault conditions for individual plant items.

Faults by Type

In this particular table (Table 4) the faults included in the sample have been further analysed into fault type. It was noted than 30.3% of the recorded faults have been caused by wiring defects directly attributable to installation activity, equipment modifications and strapping changes. For ARF exchanges the A.P.O. has required numerous equipment modifications designed mainly to add new facilities. Some of the modifications have been necessary to provide for new interface conditions or to overcome design defects.

TABLE 4: FAULTS BY TYPE

Equipment	Type of Fault	Percentage of Total Faults
Crossbar switches	Electrical 4% Mechanical 8%	12%
Relays	Electrical 18.6% Mechanical 21.2%	39.8%
Wiring	Factory Wiring 10.8% Caused by A.P.O. Staff 30.3%	41.4%
Components		5.8%
Printed Circuit Boards		1.3%

TABLE 5: METHODS O F FAULT DETECTION

Maintenance Aid	Percentage of Faults Detected
Alarms	4.9%
Service Alarms (DL) .... (Time out supervision on common control equipment)	13.2%
Traffic Route Tester (TRT)	16.9%
Statistical Meters	3.5%
Fault Recording Register (RKR)	6.5%
Use of Standard L.M.E. Test Sets .... (Manual testing of registers, SR's and junction relay sets)	11.2%
Staff Observation	22.2%
Reports from Distant Exchanges	6.4%
Reports from Subscribers and Network Performance Analysis Centres	15.2%

TABLE 3: FAULT LOCATION

No.	Equipment	Percentage of Total Faults	Mean Time Between Faults
1	Subscriber line circuit (LR/BR)	5.8	400 years
2	Subscribers line markers (SLM)	8.3	1 year
3	S.R. relay sets (SR)	9.6	70 years
4	Register finders (RS)	4.5	4 years
5	Registers local (REG-L)	13.6 }	5 years
6	Registers incoming (REG-I)	3.4 }	
7	Code sender finder (SS/AB)	1.6	2 years
8	Code senders (KSR)	4.4	3 years
9	Group stage markers (GV)	10.5	3 years
10	Crossbar switch racks (SL & GV)	19.0	—
11	Incoming relay sets (FIR)	7.5	50 years
12	Outgoing relay sets (FUR)	6.6	80 years
13	Miscellaneous	5.2	—
14	Crossbar switches (included in 10 above)	12.0	50 years

Methods of Fault Detection

The exchanges sampled for this analysis are equipped with standard L.M.E. maintenance aids, with the exception of the Fault Recording Register (RKR) which has been modified to detect MFC signalling failures, in addition to its normal function of supervising the electrical condition of the calling subscriber's meter and line circuit. An additional aid known as Automatic Disturbance Recording equipment (ADR) is currently being introduced, and this will be discussed in more detail later in this article. It is not installed at the exchanges selected for this review. Table 5 sets out the percentage of total faults detected by each aid.

From the information in Table 5 it will be noted that approximately

50% of the faults are detected by manual testing, use of the TRT, or by staff observation. In Perth (W.A.), where a number of relatively large crossbar exchanges (5000-7000 lines) are operated on an unattended basis, the average number of faults detected by staff observation is lower. However, in some instances up to 20% of the faults are detected by this means. There is little doubt that these faults would eventually be detected by other means if the effect of the fault had any marked impact on the performance of the exchange.

The Traffic Route Tester (TRT) still retains its place as the most important aid with respect to fault indication and possibly accounts for a large proportion of the reports received from distant exchanges.

MAINTENANCE AIDS DEVELOPED BY THE A.P.O.

The aim in developing these aids is to:

(i) reduce the amount of manual testing currently being performat many crossbar exchanges,

(ii) to provide more detailed information as an aid to fault location, and

(iii) to facilitate the remote supervision and control of crossbar exchanges with the view of reducing operating costs whilst at the same time ensuring that service to the customer is maintained within the specified performance limits.

With well trained staff, crossbar exchanges can be maintained efficiently with the basic maintenance aids supplied by L. M. Ericsson; however, under the operating conditions existing in this country, it is considered that the development of the following aids will facilitate the introduction of the management techniques necessary to reduce current operating costs.

The Register Identifier

To assist in the analysis of faults detected by the TRT, circuits have been developed to record the identity of the register (REG-L) associated with the faulty call. This facility can be provided for hybrid exchanges (i.e. exchanges not equipped with crossbar subscribers line equipment) as well as full crossbar exchanges. This has been found necessary to reduce call tracing, particularly on calls to the step network. A further reason for the development of the circuit is that the normal service alarm supervision provided for registers is influenced by the calling habits of the subscribers.

Fault Recording Register (RKR).

The most logical and economical method of supervising the performance of switching plant in the network is to automatically sample live traffic. It was with this view in mind that additional features to supervise both M.F.C. and decadic calls have been specified for the new A.P.O. RKR currently being designed by L.M.E., Australia. The unit is designed to interwork with the Automatic Disturbance Recording Equipment, and in the event of a call failure details of the fault type, called number, and related information signalling data will be recorded.

Constant automatic supervision of this nature will reduce the amount of T.R.T. testing required and enable the performance of unattended exchanges to be realistically monitored. Details of this unit, which was modelled on the No Progress Call Detector originated in N.S.W., will be published in the next issue of the Journal.

TRT Remote Call Repeater

Whilst the new RKR will supervise the performance of the exchange from the GV stage onwards, the T.R.T. together with the register identification will be required to supervise the SL stage and all other registers. To provide these facilities at unattended step and crossbar exchanges a Remote Call Repeater is currently under development. This unit, which is controlled by a centrally located parent T.R.T., enables test calls to be generated from remote unattended exchanges. A proposal that the identity of registers used in setting up faulty calls be transmitted to the control station by the ADR equipment is being considered. To enable any type of T.R.T. to be operated as the control unit without modifications a suitable interface unit will be provided.

The unit will also include a facility to enable semi automatic single frequency transmission loss tests to be conducted on junctions outgoing from these unattended exchanges.

Automatic Disturbance Recording Equipment (ADR)

As full details of the ADR have previously been published in the Journal (see Reference 1) it is proposed only to review the main functions in this article. Briefly, the ADR provides a means of telemetering to a remote control section, alarm conditions, details of faulty calls detected by the RKR and the status of key relays in markers at the time of a disturbance. In the reverse direction it enables control signals to be transmitted from the distant control station to reset alarms, connect fault counters, or initiate test programmes. Additional facilities for the computer sorting of marker time-out conditions to aid fault analysis will be introduced early in 1973. The main advantage of the ADR is that it considerably reduces the time required to locate faults in SL and GV marker equipment and provides a means whereby fault conditions at attended or unattended exchanges can be analysed by expert staff located at provincial centres or capital cities. These represent approximately 30% of the total faults.

Automatic Tandem Tester

To complete the record on major developments in the field of maintenance aids mention must be made of the Automatic Tandem Tester which was developed by the Metropolitan Branch of the N.S.W. Administration. The unit generates test calls from GV inlets. These calls terminate on test call answer relay sets located at exchanges served by the tandem. The aid which is currently under evaluation by the N.S.W. Administration was developed mainly for two reasons:

(i) To enable the officer-in-charge to supervise the switching performance of the tandem and all exchanges parented on it (similar facilities are provided at ARM Trunk Exchanges).

(ii) To reduce the time spent on tracing faulty calls through the Sydney network, by concentrating network supervision at key switching centres. Sydney will ultimately have 26 tandem exchanges.

Whilst the prototype unit has located many faults both in the tandem and at other exchanges its overall contribution and value for Commonwealth wide application must be carefully considered against the installation cost, the need to modify existing switching plant and alternative means of obtaining similar results. It is possible that the introduction of inlet identity to the ADR print-outs associated with GV-KMR time outs (currently under consideration) and the additional facilities incorporated in the RKR for network supervision could provide adequate facilities without the need to introduce another maintenance aid or effect further modifications to switching plant.

OPERATIONAL COSTS FOR CROSSBAR EQUIPMENT

The bulk of the operating cost for crossbar exchanges (i.e. 93%) is expenditure on the provision of labour and operating overhead. Table 6 is an extract from the plant cost returns for the year 1971/72 setting out the field labour usage for maintaining crossbar and step switching equipment in both metropolitan and country areas.

TABLE 6—MANHOURS PER STATION 1971/1972

	Crossbar Equipment Mhrs.	Step Equipment Mhrs.
Metropolitan Average	0.9 manhours	1.3 manhours
Country Average	1.3 manhours	1.7 manhours
Commonwealth Average	1.1 manhours	1.4 manhours

Note: 1 In country areas, 44% of the crossbar switching plant is of the ARK type, the majority of the installations being under 200 lines.

Note 2: The figures in this table include the manhour costs for a number of equipment modifications performed by maintenance staff.

Note 3: As the overall ratio of lines to telephone stations is in the order of 1 : 1.5, it will be necessary to increase the above figures by 50% to obtain the equivalent cost on a per telephone line basis.

At present the average manhour rate for step by step plant is 1.37 manhours per station compared with 1.05 for crossbar equipment, despite the much lower fault incidence and all the maintenance features of this latter equipment.

The maintenance manhour rates for capital cities varies from 0.66 to 2.26 manhours per telephone station with at present Perth (W.A.) and Melbourne (Vic.) recording the lowest figures. In Perth, groups of exchanges are controlled from one staffed exchange, which is responsible for a number of unattended exchanges, some of which (for example Morley and Tuart Hill) are equipped for 7000 lines. The unattended operation of crossbar exchanges of 4000 lines capacity is not uncommon in other States.

FACTORS INFLUENCING THE OPERATIONAL ECONOMY OF ARF EXCHANGES

The following aspects have a very real bearing on the fact that to date the maximum possible economic benefit claimed for this equipment has not been achieved:

(i) Many of the initial crossbar installations were made as extensions to established step exchanges which were staffed during normal hours.

(ii) To date approximately 80% of the exchanges are less than 10,000 lines in size. The operational economy is greatly increased where equipment is concentrated, e.g. some large metropolitan exchanges (suburban) are recording figures in the order of 0.3 to 0.4 manhours per telephone station.

(iii) The majority of initial crossbar exchanges in the range 2000 to 4000 lines were established as separate staffed enchanges in accordance with normal step exchange staffing patterns. An analysis of the total workload at crossbar exchanges indicates that less than 50% of the time is spent on actual switching plant maintenance. The staffing requirement is mainly associated with other activities such as M.D.F. and subscriber line testing etc.

(iv) The frequency of installation activity at individual exchanges and tandem switching centres and the numerous modifications which have been introduced. In Table 4 it was shown that 30% of the faults are due to staff activity of this nature.

(v) The variations in maintenance practices adopted at individual exchanges, particularly in relation to the amount of routine testing performed. Full advantage is not always taken of the capacity of the system to tolerate individual faults without a marked degradation in service performance.

STAFFING ARF CROSSBAR EXCHANGES

Based on statistics which indicate that the average fault incidence at ARF crossbar exchanges is in the order of 20 faults per 1000 lines per year (including M.D.F. I.D.F. power etc.), it is the author's view that terminal exchanges (not including high calling rate city exchanges) equipped with 10,000 lines could be adequately maintained by one skilled man with the aid of the standard maintenance aids recommended by L. M. Ericsson, provided that the installation had settled down and was not subject to frequent extension or modification. Bearing in mind that exchanges of this size in the A.P.O. are staffed and allowing also for 50% of the in-charge officers time to be debited to switching equipment maintenance, this would represent a manhour figure of 0.3 manhours per line, or an average 0.2 manhours per telephone station.

However, with approximately 75% of the 400 ARF exchanges installed throughout the Commonwealth being under 6000 lines, and many already established as staffed stations, it is considered that under the current operating environment a figure of 0.35 manhours per telephone station (0.5 manhours per telephone line) would be a realistic overall target.

Considering that as more than 50% of the switching equipment is now crossbar and that, in metropolitan areas in particular, an increasing proportion of the equipment installations will be extensions to existing exchanges (i.e. more in the 6,000-10,000 line range) the above target could easily be achieved in our metropolitan network in the near future. At present a number of individual crossbar exchanges (10,000 lines) in suburban areas are already achieving figures of this order for switching plant maintenance.

It is the author's opinion that with the background of experience gained over the past decade and the number of highly skilled staff available, overall improvements in our operating economy could be achieved by district amalgamations where practical and by meeting future development with existing resources. In the case of metropolitan areas it is considered that existing staff levels could adequately cope with the 2.8 million lines proposed for installation by 1980.

The basic reason for the introduction by the A.P.O. of additional maintenance aids (such as ADR and the new RKR) which will provide a remote printout of switching plant and network fault conditions, is to facilitate the remote supervision of unattended exchanges and to reduce the overall fault location time in staffed and unstaffed exchanges.

CONCLUSION

The successful introduction of crossbar switching plant has made a significant contribution to the economical development of the A.P.O. telephone networks, and to the introduction of Subscriber Trunk Dialling and automatisation of rural networks.

Experience over the past ten years has confirmed that crossbar equipment correctly installed and maintained by skilled staff will provide telephone subscribers with good quality service over a long period. Although we have not, at this stage, fully exploited the operating economy possible with this equipment there is every indication that as the percentage of crossbar equipment installed and the size of inidividual installations increases, we will achieve maintenance figures comparable with those recorded by overseas administrations with similar plant.

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BOOK REVIEW

'ACOUSTICS FOR RADIO AND TELEVISION STUDIOS' I.E.E. MONOGRAPH SERIES 11

Christopher Gilford 1972

Peter Peregrinus Ltd. pp 264, UK price £6.

Chapter Headings

Sound and hearing — Measurement of noise — Background noise in broadcasting studios — airborne-sound insulation — structure-borne sound — Measurement and analysis of sound transmission in studio centres — Reverberation — Sound absorbers — diffusion; distribution of absorbers — Design of studios; general considerations — Design of studios for radio broadcasting — Design of television studios — Appendixes — References — Index.

General

Dr Gilford presents in this book an up to date work on the design of the broadcasting studio structure and its acoustic treatment, and it incorporates advances made in this discipline since World War II. The author has spent most of this period working on research in acoustics in the British Broadcasting Corporation and so the book is authoritative and complete. The table of contents is laid out with precision and the index is comprehensive, so that topics of interest to the reader can be readily located. The bibliography and references (over 150) constitute a wealth of material on this subject in one source.

Book production is of a high standard. It is well printed and laid out, with excellent diagrams and half tone plates. Standard terminology and symbols, together with SI units, are used.

The book would not only be useful to its direct audience, i.e. those concerned with the architecture and acoustic treatment of radio and television studio buildings, but also to others who would wish to design rooms or buildings wtih specified insulation against external sounds, either air or structure borne, or to provide suitable rooms for listening to, or making, music or other sounds under good but not necessarily expensive conditions.

The matter of matching textbook, measurements and calculations to practice is always one of some difficulty when one uses books produced overseas (and frequently for locally produced ones). However, the materials to be used e.g. in absorbers, are given their proper engineering descriptions, such as glass fibre, polyester foam, or sprayed asbestos, etc., and so it should not be difficult for the reader to find commercially available materials in Australia to fit the descriptions, and so to successfully complete assignments.

F. M. Shepherd.

TECHNICAL POSITIONS ESTIMATING PROCEDURE (PART 2)

*D. P. HAMILTON AND K. L. HAFFENDEN, B.Sc., M.I.E.Aust.**

INTRODUCTION

The article which appeared in the October issue of the Journal under title of 'Technical Positions Estimating Procedure (Part 1)' described the background to the development of the new system, and the methods and procedures used to make estimates of workload and staff required in an Engineering Section. Part 2 describes the procedures used by upper management to review operations and to allocate resources to Engineering Sections in the light of their estimates.

PEP is an aid to management in the Engineering Section and State Headquarters. However, it is not a complete management control system in its own right, rather it is a subsystem of the total management system. Other subsystems used to facilitate the assessment of performance in relation to targets and achievements and the subsequent allocation of resources, both manpower and plant include:

- Network Performance and Analysis Centres
- Plant Performance Information Systems, e.g. ALFA and CANTOT
- Costing Systems (Plant Unit Statistics, Statistics of Volume)

The PEP system aims to ensure that each Engineering Section is staffed with suitably qualified and trained people on the basis that:

- the number of staff of each designation is correct for the work to be done;
- all staff work to their relevant functions for the maximum possible time;
- the standard of customer service is acceptable.

In the longer term the PEP system aims to:

- improve control of the many variables which influence technical staff requirements; and hence the basic cost of service operations;
- provide better information for management decisions, such as determination of trainee input levels.

The fact that each level of field management is required to review, each year, its engineering operations and determine a programme of work and staff resources needed for the coming 12 months is not sufficient in itself to achieve all the above objectives. The programme of work and staff resources must be related to the overall proposed targets of service performance, likely availability of funds, staff ceilings, staff availability, and the desirability of allocating available resources to achieve the maximum benefit. To assist in rationalising the various facets that can influence the allocation of resources it was decided to introduce a formal annual review of engineering service operations, to be conducted within each Metropolitan and Country Area, and to be convened by the Superintending Engineer Regional Operations in association with the Assistant Area Managers (Engineering). The review includes a survey of service performance achievements and costs of each Engineering Section, and provides a forum for determining broad policy and guidelines for the subsequent PEP review within each Engineering Section.

Such reviews of service operations in the APO are not new; they have been undertaken in some form or another by most States over the years. The PEP system prescribes a standard format for this review, and this will make information on practices and achievements in one State more readily available for the information of other States. Each year Headquarters will issue a corresponding review of State and Area performance.

'OPERATIONS REVIEW'

As part of the annual review each State issues a publication called 'Operations Review'. The publication is issued in September each year and contains measures of performance of the Engineering Sections for the last financial year and earlier. The measures adopted centre around business activities, staffing, costs and service performance.

The form and content of the publication have been designed to help upper management to assess the overall performance of Engineering Sections and Areas. Because the activities of Sections and Areas are many and varied it is difficult to select a reasonable number of parameters which, in their own right, provide a comprehensive picture. The aim of the publication is to:

- define parameters which, as 'broad pen' devices, indicate or suggest areas of strength or weakness;
- define parameters in sufficient numbers to achieve aims but keep the number to a minimum to allow meaningful discussion without confusion;
- bring together the various major activities which together affect the management of operations in a Section;
- stimulate ideas as to the types of parameters which should be developed in the future to provide more meaningful measures and objectives.

As the publication aims at being a catalyst and includes only a minimum number of 'broad pen' parameters, it does not replace existing more detailed publications such as those provided by Network Performance and Analysis Centres or the Costing System. Where areas of investigation are suggested by the results in the 'Operations Review' publication, it will be quite often necessary to return to more detailed specific studies to seek evidence on which to make decisions.

As the 'Review' is for use at management levels where a multitude of APO activities are assessed, the format has been designed to ease interpretation and facilitate appreciation of the factors appropriate to the type of decisions made at that management level. It shows:

a. overall trends in performance over a number of years;
b. performance of a Section relative to itself over recent years;
c. performance of a Section relative to other Sections, and to the Area and to the Commonwealth.

The format chosen achieves this in a reasonably simple manner without requiring a large series of tables. Fig. 1 is typical of a section of the publication on plant unit costs for, say, a Metropolitan Area consisting of several Engineering Sections. In Fig. 1 the five year trend graph on the left is the performance of the Area as a whole, the individual pillars in the right hand graph represent specific Sections for the last financial year ranked in ascending order; the Sectional performance for the previous financial year is shown as a small circle to the left of the individual pillars and where appropriate, last year's target figures for Sections are shown as small arrowheads.

The last financial year's result for the Area is extended across the pillar graph as a dotted line to ease comparison between Section and Area while the Commonwealth average is shown as a shaded pillar and ranked in the pillar graph for comparison purposes.

The format for most parameters is generally along these lines, i.e., a five year overall trend graph, a two year pillar graph for Sections and the whole

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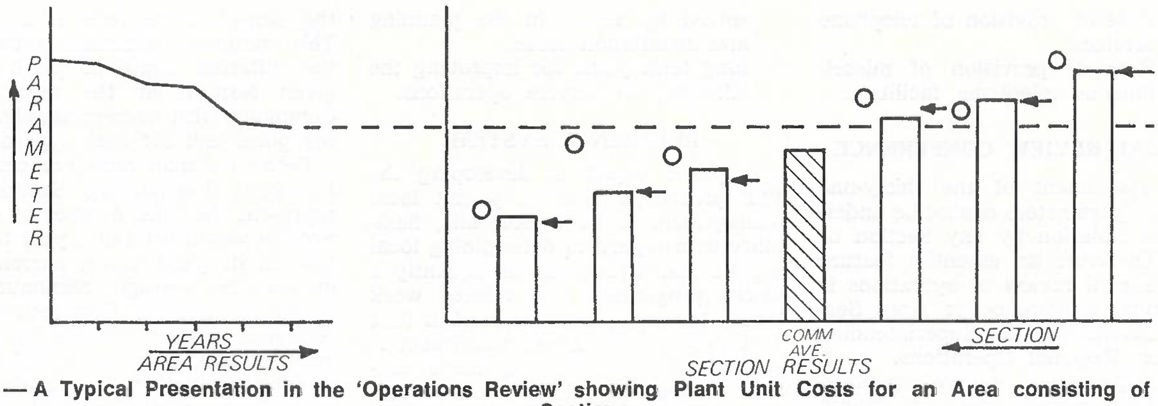


Fig. 1. — A Typical Presentation in the 'Operations Review' showing Plant Unit Costs for an Area consisting of Several Sections.

laid out in a manner designed to ease comparisons and assist the questioning mind.

Initially some 31 parameters have been included, covering the areas of:

- Business Activity
- Staffing
- Cost
- Service

These broad areas are very similar to those published by the British Post Office, the Bell System and other overseas administrations.

BUSINESS ACTIVITY

The parameters in this section offer some measure of the scale of existing operations and level of growth in various Sections and Branches. At present, only three parameters are included:

a. Telephone stations (number of telephone instruments) in situ at a given time.
b. Growth in telephone stations in a given 12 month period.
c. Telephone revenue index.

The telephone revenue index does not attempt to assess profitability. It:

i. assumes the revenue originating in a given region is linearly related to the revenue earned for the Australian Post Office by that region due to originating, terminating and through traffic. This revenue is related to the level of effort expended by a specific portion of the workforce for the region to obtain an index;
ii. recognises that, all other factors being equal, the revenue per manhour may affect the level of further maintenance effort proposed for the region;
iii. assumes staff manhours spent on work other than telephony, e.g., radio or telegraphs is not a controlling item and will not distort the index excessively between Sections or between Areas.

STAFFING

Staffing is recognised as a major variable in the maintenance operations of the telecommunication network. The parameters have been selected to assist in assessing both the short and long term needs of an Engineering Section, and are closely allied to the Positions Estimating Procedure; the last three of the following parameters meet the latter's requirements; the first three are estimated for a given 12 month period:

a. Technical Manhours
b Overtime Index
c. Training Index
d. * Overall Reference Ratio
e. * Reference Ratio for Telecommunications Technical Officer
f. * Reference Ratio for Telecommunications Assistants

* Explanation of the part played by the reference system is given in a later section of this article.

COSTS

Parameters (a), (b), (c), (d) and (g) in this paragraph assist Operations Sections, which undertake internal equipment provision and maintenance type works, to programme their total activities for the coming year in terms of 'Dollars' and 'Manhours'. The rest of the parameters are **plant unit costs in both manhours** and dollars for selected plant accounts. The accounts chosen, in general represent the most significant areas of activities in Area Operations Sections at this stage. Experience may show that more plant accounts should be included:

a. **Internal equipment maintenance (dollars)** — The funds spent in the 12 month period on Internal Equipment Maintenance, as recorded by the Costing System five year trend graphs, are included;
b. **Internal equipment maintenance (manhours)** — Similar to (a) above;
c. **Internal equipment providing (dollars)** — The funds spent in the 12 month period on internal equipment providing plant accounts as recorded by the Costing System five year trend graphs are included.
d. **Internal equipment providing (manhours)** — Similar to (c) above.
e. **Selected plant unit manhours and costs analyses** — These are the plant unit manhours and costs (excluding Administrative) as analysed by the Costing System and published in the "Plant Unit Costs".
f. **Installation costs and manhours for subscribers equipment** — As in most providing accounts, the plant unit costs for subscribers equipment fluctuate somewhat from year to year. For this reason trend graphs for labour and cost are more useful than annual figures.
g. **Internal equipment maintenance index** — This parameter is a measure of overall plant unit costs and is based on the total labour and total cost charged to plant accounts.

SERVICE

Service to the customer takes many and varied forms. The APO has for some time measured a number of areas of service in detail. However, these areas are mainly restricted to automatic telephone switching and the telephone subscriber repair service. Other areas of activity will need to be encompassed in due course. The following parameters are included in the review:

a. **Service assessment**
   i. Local service assessment.
   ii. STD service assessment.
   iii. STD manual test calls.
   iv. Local traffic route tester (TRT) results.
   v. STD TRT results.
b. **Subscribers service**
   i. Subscribers technical assistance reports.
   ii. Subscribers repair reports.
   iii. Fault clearance time.

iv. Rate of provision of telephone services.
v. Rate of provision of miscellaneous telephone facilities.

ANNUAL REVIEW CONFERENCE

The assessment of the thirty-one published parameters cannot be undertaken in isolation by any Section or Area. Therefore an essential feature of the annual review of operations is the annual conference of Area Sections convened by the Superintending Engineer, Regional Operations.

The 'Operations Review' publication, issued approximately one month earlier, is designed as the base document for the conference. As mentioned earlier, it is meant to be the catalyst for profitable discussions and decisions. This publication could be supplemented by additional information at the conference on such topics as:

a. predicted demand for telephone and telegraph services in the State, Area and Section in the coming year, the likely total funds and their allocation amongst the Plant Accounts and the likely level of Directly Classified Funds. It will be appreciated that the year concerned is a calendar year and spans two financial years;
b. likely staff ceilings, trainee intakes, allocation of graduates from the training system, capacity of the schools for secondary course training;
c service aids on order and coming forward, new developments in this area, experience of Sections in the use of these aids, comments from the State Specialist Sections on the existing network in regard to switching and transmission performance, new maintenance engineering instructions coming forward or planned;
d. current APO objectives in regard to revenue, cost of operations, service standards.

These topics plus others such as the results shown up by the annual PEP investigations assist in making decisions on:

1. Sectional operational targets in regard to cost and service for the coming year;
2. tentative allocations of trainees and graduates of the schools amongst Sections — the specific allocations to depend on completion of PEP for each Section prior to the end of the current calendar year;
3. patterns of trainee recruitment in various areas to suit the requirements at the work face in the coming years;
4 service problems which can best be solved by action in the planning and installation areas.
5. long term plans for improving the efficiency of service operations.

REFERENCE SYSTEM

A prime object in developing the PEP procedures was to permit local management to have inter alia, flexibility with regard to determining local service standards and subsequently a works programme and related work force. However, as mentioned in Part 1 of this article staff establishment is subject to Public Service Board control. Therefore, it has been necessary to develop a basis acceptable both to management and the Public Service Board.

The reference levels which flow from the reference scheme are in effect upper limits placed on the authority delegated to the Supervising Engineer to submit a staffing proposal for variations to the staff establishment from the Departmental State 'pool' of technical positions. The levels include an overall Reference Level, calculated for each Section annually by the Engineering Costing System, based on the previous financial year, plus two subsidiary Reference Levels. These *Reference Levels* are designed to provide administrative limits to Delegations of Authority *and do not attempt to state how many technical staff* a Section can have, should have, or will have. The reference scheme has been so designed that each year a proportion of Sections will be above reference.

REFERENCE MANHOURS/ POSITIONS

The reference system is based on selected outputs of the Engineering Costing System and has been developed with the following characteristics:

i. it is a reasonable broad guide of the upper level of technician staffing in a Section beyond which specific staffing proposals to the Public Service Board are necessary;
ii. it uses parameters which are not closely dependent on current technology and can allow for gains in labour productivity due to improvements in practices and techniques;
iii. the parameters are based on existing sources of statistical information and are automatically updated annually by existing information systems;
iv. the parameters are subject to audit if and when required.

In calculating a reference system for each Engineering Section in Australia, a 'notional Commonwealth average' Section was created to do the work of the Section concerned. This 'notional' Section maintains all the different items of plant in the given Section at the most recent Commonwealth average manhour rate per plant unit for each type of plant.

Reference manhours are calculated for each Engineering Section, and represent the total number of hours a Section would need in a year to maintain all its plant at the current Commonwealth average manhour rates shown in the Plant Cost returns. The reference system includes an allowance for providing works such as subscriber installation. Adjustments are made for overtime, leave etc. and also for geographical area of a Section. By using the Costing data, the reference calculations automatically takes account of broad Commonwealth trends in labour productivity.

From the reference manhours so calculated, the equivalent *reference staff positions* per Engineering Section is calculated depending on how many hours per year are allowed to each staff member. This factor has a lower limit of 2080 hours (52 weeks by 40 hours).

Basically the number of staff positions calculated in this manner is the overall reference level for the Section, and provided the Supervising Engineer does not exceed this figure and keeps within the limits of the two sub-reference levels (Telecommunications Technical Officers and Telecommunications Assistants) he can request staff establishment variations direct with the Departmental Officer responsible for the control of the 'pool' of technical positions.

DELEGATIONS OF AUTHORITY UNDER PEP

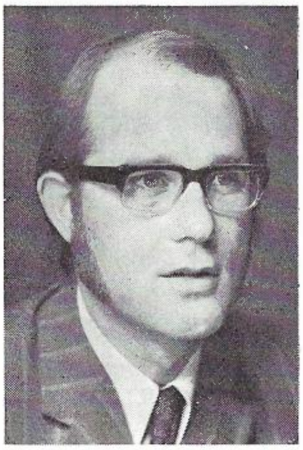
The introduction of PEP in engineering operations areas with its disciplined approach, including its dependence on business planning, organisation planning, matching of designations to the functions to be performed, and overall control by a referencing system is accompanied by a new table of approved authorisations for establishment control of technical districts. They include functions concerning the organising of districts, shift working and the allocation of positions.

The authorisations are an indication that PEP together with Area Management permits active management of engineering operational activities at the local level.

CONCLUSION

To summarise briefly it is management's role to measure effectively to be able to manage efficiently.

OUR CONTRIBUTORS



N. W. McLEOD

N. W. McLEOD, co-author of the article 'National Field Trial of C.C.I.T.T. Signalling System No. 6, Part 1 — A Processor Controlled Exchange', is Engineer Class 3, Network Studies Section in the A.P.O. Research Laboratories. He attended the University of Melbourne where he received a B.Sc. degree in Physics and Electronics in 1963, and continued post graduate studies in 1964 in Electronics and Statistics. The following year Mr. McLeod joined the A.P.O. Research Laboratories Switching and Signalling Branch and has since worked on a number of projects concerned with digital control systems. He was responsible for much of the design of the A.P.O. No. 6 Exchange switching equipment.

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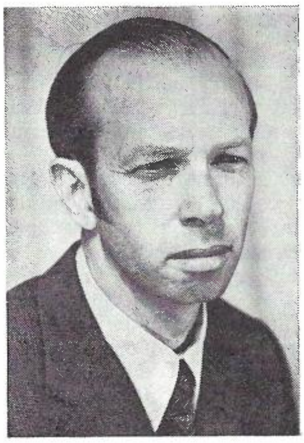
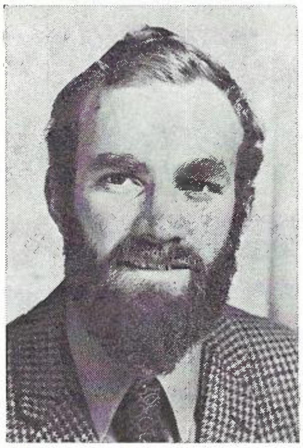


R. H. HAYLOCK



G. J. CHAMPION

G. J. CHAMPION, co-author of the article 'National Field Trial of the C.C.I.T.T. No. 6 Signalling System, Part 2 — Software', joined the A.P.O. in 1960 as a cadet engineer. He graduated from the University of Melbourne as Bachelor of Electrical Engineering in 1963 and spent four years in the Internal Plant Planning area of the Victorian Administration.

In 1968 Mr. Champion joined the Research Laboratories as a Class 2 Engineer and was later promoted Engineer Class 3, Processors Division. He has been involved in a large part of the design and specification of the No. 6 Signalling Link Terminals and the design and specification of the software for the No. 6 call handling programs. He has also been responsible for the Switching and Signalling Branch's processor installation.

★

R. H. HAYLOCK, co-author of the article 'National Field Trial of C.C.I.T.T. Signalling System No. 6, Part 2 — Software', joined the A.P.O. as a Technician-in-Training in 1950. After service in the areas of telephone exchange installation and maintenance he became in 1965 a Technical Officer in the Circuit Standards Laboratory of Telephone Exchange Equipment Section. During this period he continued part-time study and in 1967 entered a Departmental Programmer-in-Training course.

Since 1968 Mr. Haylock has worked with project teams within the Switching and Signalling Branch, Research Laboratories and has been concerned with development and testing of software systems for computer controlled telephone exchanges. More recently as a Programmer Class 8 he has headed the programming team working on software for the Field Trial of System No. 6 at Windsor, Victoria.

★

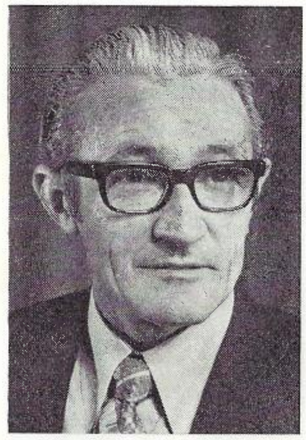
T. E. HODGKINSON

T. E. HODGKINSON, author of the article 'The Design and Construction of a Modern Telecommunications Factory', started his career in the New Zealand Broadcasting Service. He came to Australia in 1949 and joined STC as an Engineer in the Line Transmission Division. From 1959 to 1963 he was engaged in various management roles in International Resistance Holdings Limited. In 1963 he joined Telephone Manufacturing Company as General Manager and became Managing Director of the Company in 1966. Upon the formation of Philips-TMC he was appointed Joint Managing Director responsible for the management of the Telephone Division.

He has been a Councillor of the Australian Telecommunications Development Association for a number of years and is a Fellow of the Institution of Engineers Australia and the Institution of Electrical Engineers.

R. J. VIZARD

D. P. HAMILTON



J. P. KILLEEN

R. J. VIZARD, co-author of the article 'National Field Trial of C.C.I.T.T. System No. 6, Part 1 — A Processor Controlled Exchange' is Engineer Class 3, Systems Development Section in the A.P.O. Research Laboratories. Mr. Vizard joined the Australian Post Office in 1956 as a cadet engineer whilst at Melbourne University. Following graduation in 1958 he commenced duty with Country Branch, Victoria, first at Hamilton and then later at Benalla District Works Division. In 1969 he transferred to Telephone Exchange Equipment Branch, Central Office under the terms of the engineer rotation scheme. Following a further transfer to Research Laboratories in 1970 he took up his present position of Engineer Class 3, Switching and Signalling Branch.

During 1971 and 1972 Mr. Vizard has acted as team leader for an A.P.O. team of engineers, technical staff and programmers engaged in a national trial of C.C.I.T.T. Signalling System No. 6. During 1971 and again in 1972 he visited Geneva to represent the A.P.O. at meetings of FT6, the C.C.I.T.T. group responsible for development of this new system.

★

W. J. TREBILCO, author of the article 'The 2/6 and 4/11 Intercom Systems', joined the A.P.O. as a Technician in Training in 1955 and completed training in the A.P.O. Research Laboratories. He commenced as Trainee Engineer in 1961. After 4 years as an Engineer Class 1 in Metro Exchange Installation South Eastern Division, Melbourne, was promoted to Engineer, Class 2, Subscribers Equipment Branch, Terminal Equipment Design Section, Headquarters.

D. P. HAMILTON, co-author of the article 'Technical Positions Estimating Procedure (Part 2),' is a Senior Inspector in the Establishments Section, Management Services Division, Headquarters. He joined the A.P.O. as a clerk in 1947 and has concentrated his experience in the fields of staffing, industrial and organisational aspects of the department. In particular his efforts have been directed to the Engineering Division Establishment with emphasis on staff loading and grading bases. He was closely associated with the development and introduction of the current staff grading bases for technical staff engaged in the installation, operation and maintenance of telecommunication equipment, as well as the Technical Positions Estimating Procedure (T.P.E.P.)

★

W. J. TREBILCO

J. P. KILLEEN, author of the article 'Dangerous Gases in the A.P.O. Underground Network', joined the A.P.O. as a Junior Postal Officer in 1939.

After war service he occupied positions of Lineman, Cable Jointer and Lines Supervisor on installation and maintenance practices in metropolitan and country areas of Victoria until he joined the Lines School, Melbourne, as a Technical Instructor in 1953. He was promoted to Senior Technical Instructor Grade 2 in 1955 as a technical writer for Lines Schools publications, with the Headquarters Engineering Recruitment and Training Section and subsequently in 1957 was promoted to Inspector, Lines Schools, where he was responsible for co-ordinating the lines training activities in the A.P.O.

In June, 1963, Mr. Killeen was released by the A.P.O. to take up an appointment as Line Plant Expert with the International Telecommunication Union. He was attached to the Malaysian Telecommunications Department to assist with the planning and establishment of telecommunications training centres.

Since rejoining the A.P.O. at the end of 1970, Mr. Killeen has been attached to the Installation Practices Section (Electrical and Telecommunications) with the Headquarters Lines Branch, to undertake major projects. These projects have included the review of working precautions, the methods of controlling gas leakage into the underground network, and the evaluation of gas detection equipment for the protection of staff and property from the hazards of dangerous gases.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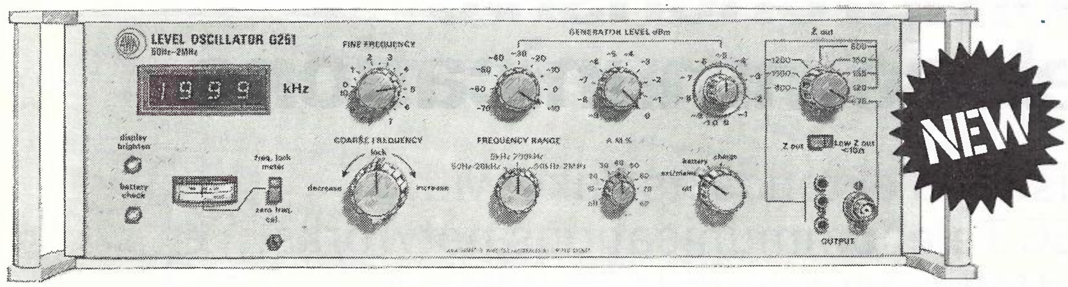
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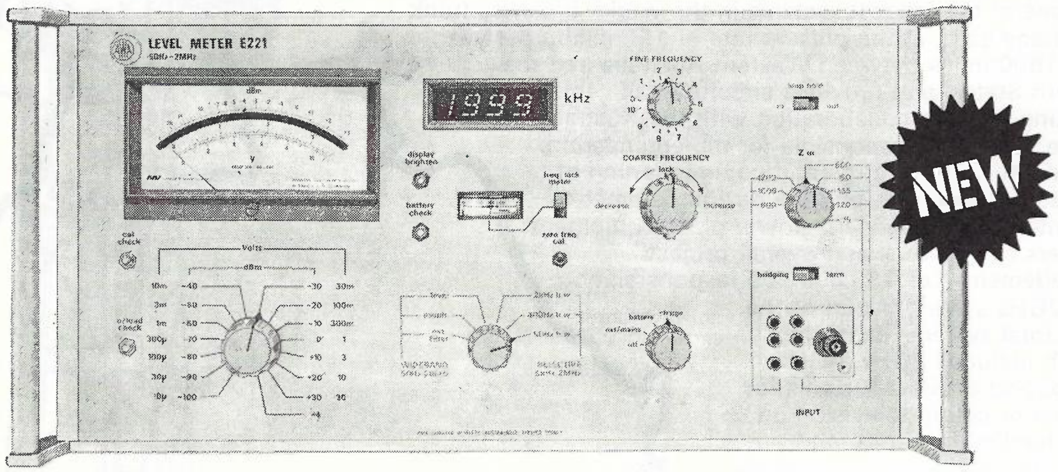
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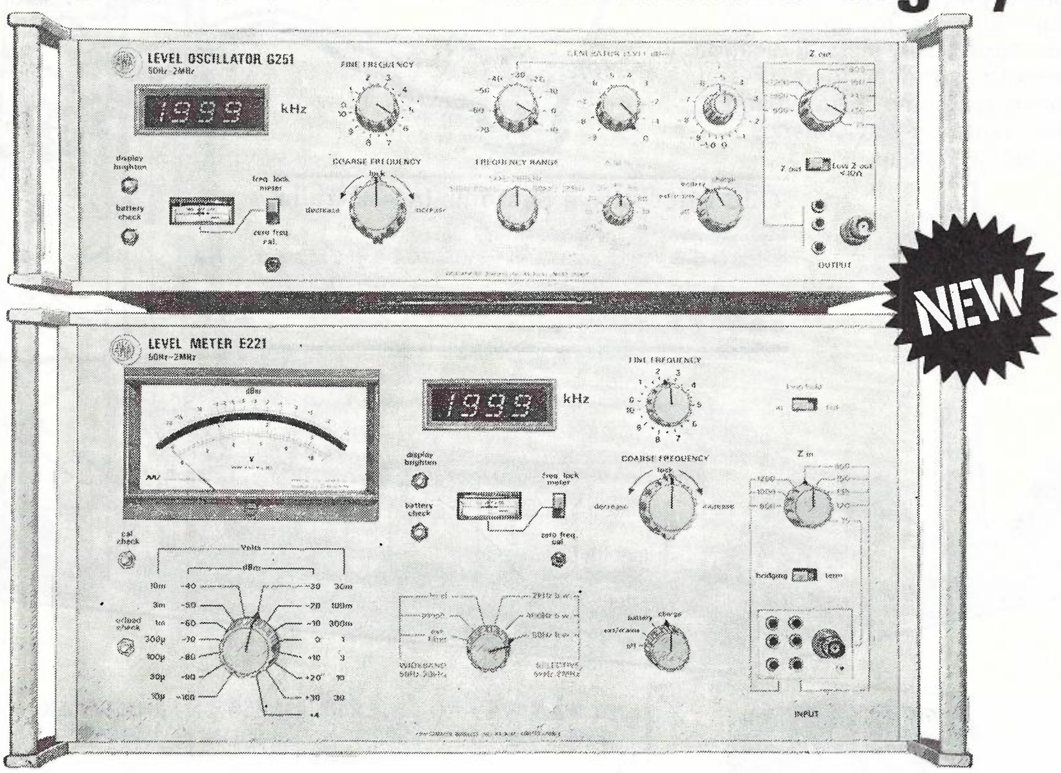
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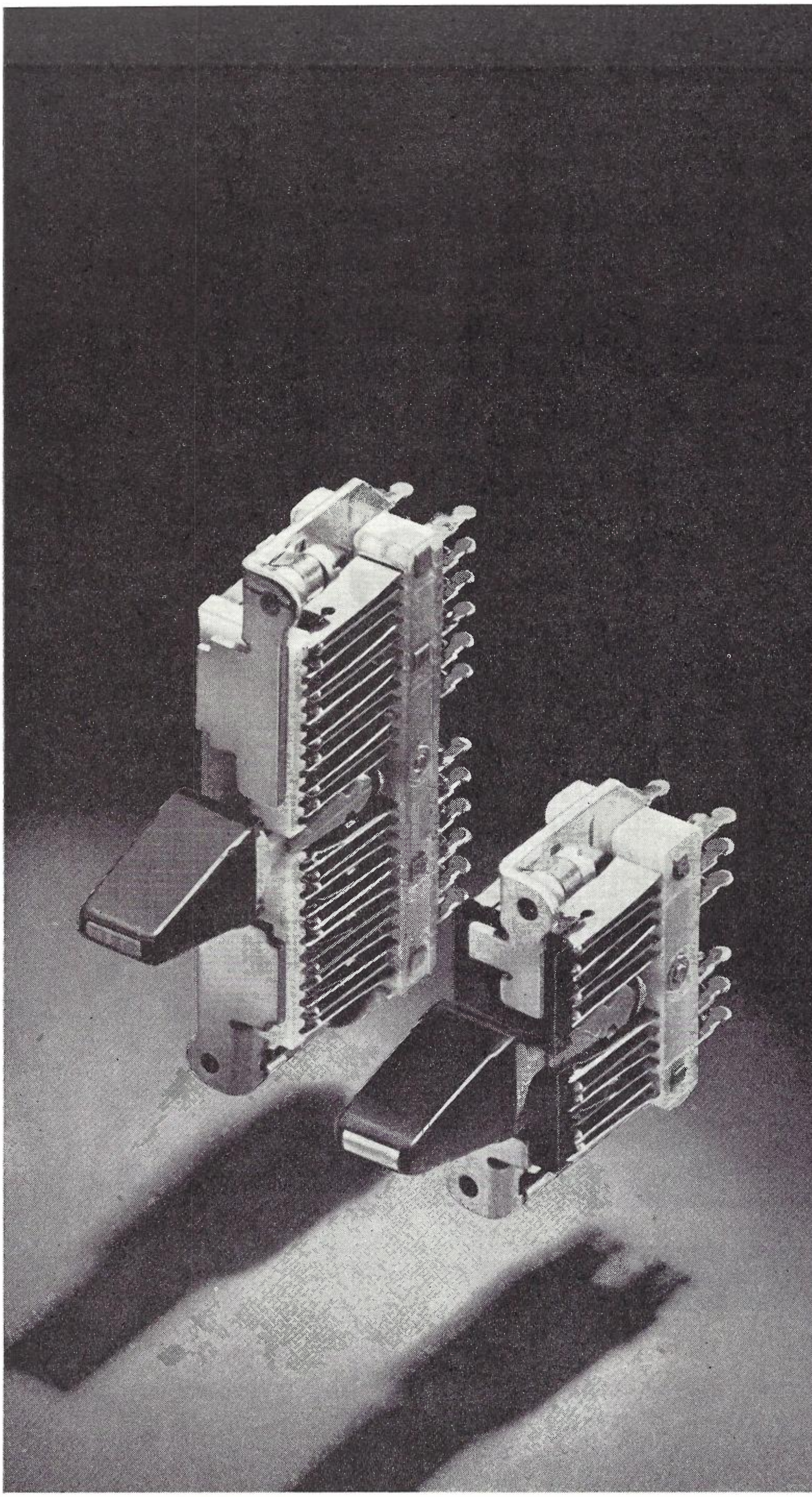

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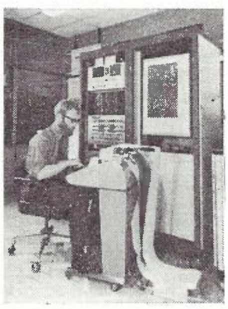
THE TELECOMMUNICATION JOURNAL OF AUSTRALIA

VOL. 23, No. 1
FEBRUARY 1973

CONTENTS



COVER
BTMX Processor,
Signalling System No. 6.

The TELECOMMUNICATION JOURNAL of Australia

ABSTRACTS: Vol. 23, No. 1

CARROLL, B. J.: 'The Maintenance and Performance of L. M. Ericsson Crossbar Equipment in Australia, Part 1.'; Telecom. Journal of Aust., February 1973, page 72.

This paper, which is presented in two parts, outlines the experience of the A.P.O. with the operation and maintenance of L.M.E. crossbar switching equipment in metropolitan, rural and trunk switching networks. Apart from evaluating the service performance provided by the plant, plant performance is examined in detail with respect to fault incidence, fault types and methods of detection. Following a review of current operating costs and factors which influence them the author presents his recommendation on staffing requirements for this equipment under the operating conditions prevailing in this country.

CHAMPION, G. J. and HAYLOCK, R. H.: 'National Field Trial of CCITT Signalling System No. 6, Part 2 — Software'; Telecom. Journal of Aust., February 1973, page 51.

A stored program controlled exchange has been implemented by the A.P.O. Research Laboratories to allow participation in an international field trial of the CCITT Signalling System No. 6. This part of the article describes the stored programs (software) designed and implemented to control the exchange.

FOOTE, G.: 'A Routiner for Trunk Circuit Testing in ARM Exchanges'; Telecom. Journal of Aust., February 1973, page 67.

This article outlines the principles and main features of a trunk circuit routiner for ARM exchanges. The access arrangements and the method of establishing a test call, and the main operational and control features are described.

FREEMAN, A. H.: 'Principles of Trunking and Switching in Automatic Telephone Exchanges'; Telecom. Journal of Aust., February 1973, page 18.

This article is a chapter from a monograph on the principles of telephony to be published by the Telecommunications Society of Australia. The article outlines the underlying principles of the switching and trunking arrangements of automatic telephone exchanges. The switching and trunking arrangements of uniselector, bi-motional selector, crossbar switches and crosspoint arrays used in electronic exchanges are reviewed, together with the fundamentals of trunking systems for preselection, group selection and final selection.

HAMILTON, D. P., and HAFFENDEN, K. L.: 'Technical Positions Estimating Procedure (Part 2)'; Telecom. Journal of Aust., February 1973, page 78.

Part 1 of this article, which appeared in the previous issue, described the background to the development of a new system for determining the numbers and designations of staff required for Internal Plant service operations work in the Australian Post Office. Part 2, in this issue, describes the procedures used by upper management to allocate resources to Engineering Sections in the light of their estimates.

HODGKINSON, T. E.: 'The Design and Construction of a Modern Telecommunications Factory'; Telecom. Journal of Aust., February 1973, page 60.

The article describes a new 150,000 sq. ft. air-conditioned factory built at Moorebank, 23 miles from Sydney, for the telephone division of Philips T.M.C. The factory has been designed for optimum efficiency in the flow of materials and finished products through the manufacturing areas. Staff in the general office, engineering, and drafting areas enjoy the benefits of modern planning with carpeted floors and acoustic ceilings. The factory commenced operations in early 1972.

KILLEEN, J. P.: 'Dangerous Gases in the A.P.O. Underground Network'; Telecom. Journal of Aust., February 1973, page 9.

Significant changes have occurred in gas reticulation and fluid fuel storage and distribution in Australia in recent years, and leakage from a variety of sources into the A.P.O. underground network can result in the build-up of dangerous concentrations of gas. The types of gases, their dangerous characteristics, and the methods being implemented to control the hazards from gas leakage into the network are discussed. The main hazard from the build-up of dangerous mixtures is the risk of fires or explosions, and the provision of portable and fixed combustible gas detection equipment is a major contribution towards the protection of staff and property. The principle of operation and the application of such equipment to the telecommunications environment is also discussed.

KIMBER, M. J. and LANGE, V. W.: 'The Darwin to Nhulunbuy Tropospheric Scatter System, Part 2'; Telecom. Journal of Aust., February 1973, page 35.

Part 1 of this article in the previous issue of the Journal set out the basic design considerations of the system. Part 2 in this issue describes the equipment, the associated power plant, installation aspects and the approach to maintenance.

TREBILCO, W. J.: 'The 2/6 and 4/11 Intercom Systems'; Telecom. Journal of Aust., February 1973, page 3.

This article describes the 2/6 and 4/11 intercom systems, the reasons for their introduction, their facilities and design features. These systems provide the Australian telephone customer with modern table telephones which provide pushbutton intercommunication between a maximum of eleven speaking points and access up to four exchange lines.

VIZARD, R. J. and McLEOD, N. W.: 'National Field Trial of C.C.I.T.T. Signalling System No. 6, Part 1 — A Processor Controlled Exchange'; Telecom. Journal of Aust., February 1973, page 44.

In this paper the authors describe the origin of the common channel signalling system known as C.C.I.T.T. System No. 6. The series of events which culminated in international field trials among eleven participating organisations is described, together with the arrangements adopted by the Australian Post Office and Overseas Telecommunications Commission (Australia) to carry out a national assessment of the new system. Staff of the A.P.O. Research Laboratories designed and developed a processor controlled crossbar exchange for use during the trial. The approach adopted for testing and commissioning the exchange equipment is designed, and a brief summary of the results of the field trial is given.

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