The Telecommunication Journal of Australia

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The

Telecommunication Journal of Australia

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LAYING OF SUBMARINE CABLES ACROSS HAYS INLET, BRISBANE, BY USE OF WATER JETS

J. M. WHELLER

Introduction. Situated on Moreton Bay ten miles north of the Brisbane River entrance is the popular holiday resort, Redcliffe. Access to this holiday resort was by means of an inland road approximately 25 miles long but in recent years a viaduct has been constructed across Hays Inlet giving direct access to the town from Sandgate. This viaduct is known as Hornibrook Highway and is approximately 1¾ miles long. As the route to Redcliffe is now shortened by some ten miles the population of the town has increased from 3,500 to 11,500, whilst the holiday population has been estimated to have been increased 1000 per cent. These population increases render it necessary to provide a considerable number of trunk lines from Brisbane to Redcliffe to meet both the normal and holiday needs. The existing aerial trunk route followed the inland road passing through several minor towns, but between these and Redcliffe there is little community interest whilst on the other hand community interest between Redcliffe and Sandgate has increased considerably. In order to meet resulting increased telephone demands it was found to be more economical to provide the required number of circuits by the use of underground cable than by reconstructing and enlarging the aerial route. Provision of the underground cable, however, necessitated the laying of two 54 pr. 40 lb. armoured submarine cables across Hays Inlet parallel with the viaduct known as Hornibrook Highway. See Fig. 1. It was not practicable to lay the cables on the viaduct itself.

Preliminary Investigation. Hays Inlet consists mainly of sandbanks which are exposed at low tide, but covered with from five feet to six feet of water at high tide. Through this area run two channels, that of the Pine River and the other to Hays Inlet proper. The Pine River channel is 25 feet deep at high tide whilst the other channel is approximately 16 feet deep.

At the northern end of the area is a ragged rock formation which extends approximately 100 yds. into water, and much of the rock is covered by about three feet of sand, whilst near the beach there is a large section of white clay. It had been originally decided to lay the cable across the sandbanks and rely on the tidal action to bury it. Examination of the area indicated that the following factors would prevent this method of laying the cable:—

(i) The electric light standards on the Highway would prevent the cable being laid from the Highway on to the sand below.

(ii) There was not sufficient depth of water to permit the use of a normal cable laying ship whilst dredging could only be undertaken for short periods of the day during the crest of the tides.

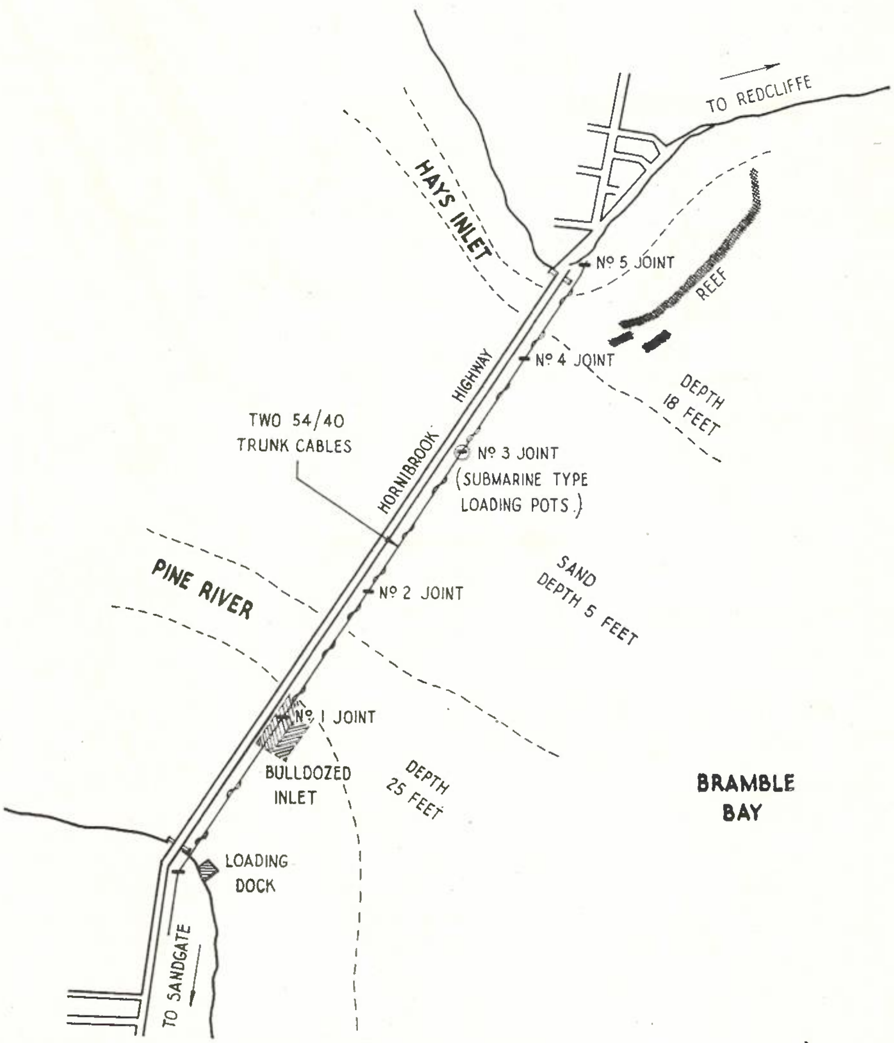


Fig. 1.—Location plan.

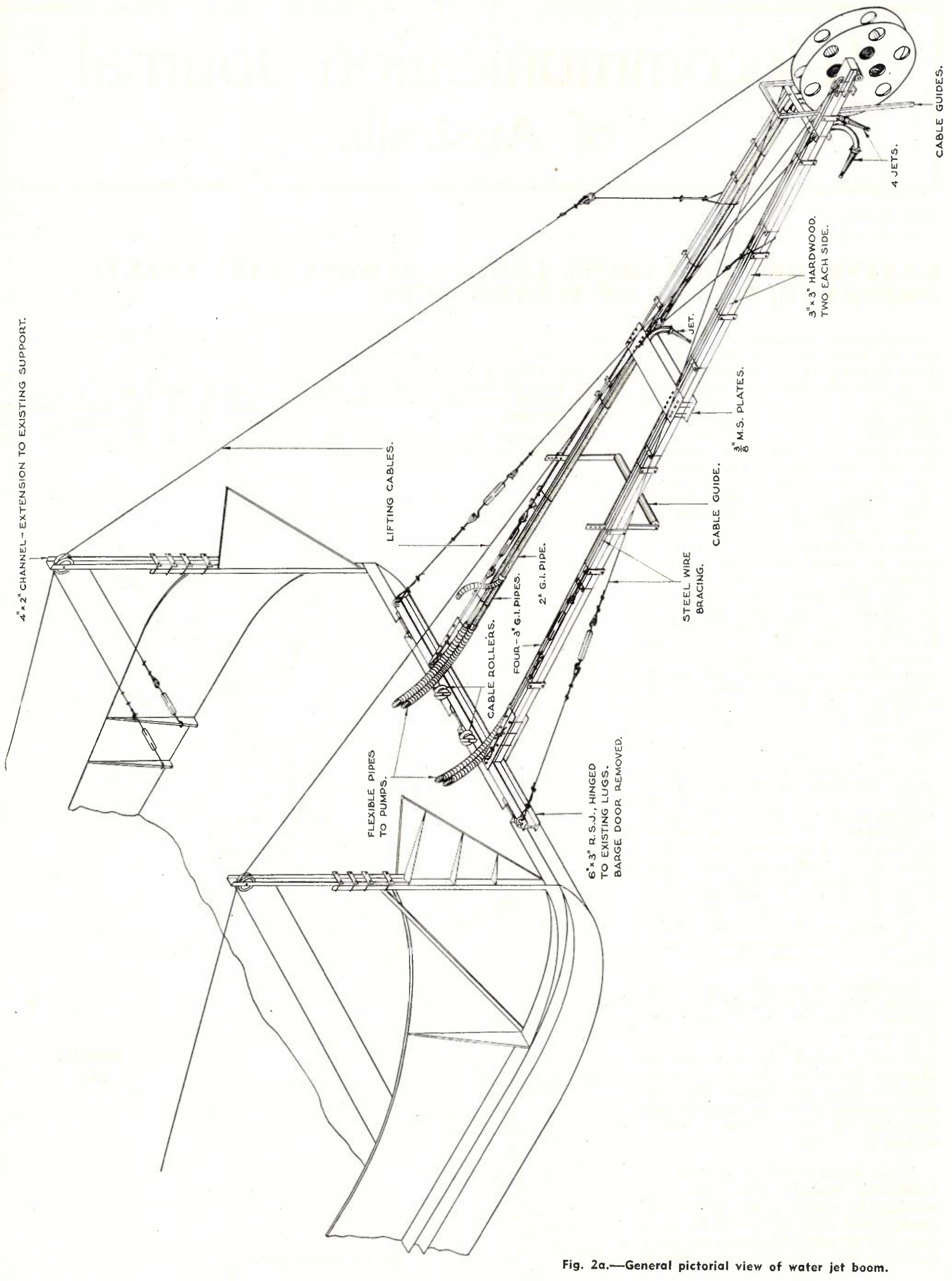


Fig. 2a.—General pictorial view of water jet boom.

(iii) Part of the area is quicksand which would not support a cable jinker even when fitted with tractor type tyres, nor could a tractor successfully operate over the quicksand.

(iv) The Pine River channel occasionally shifts its course, thus requiring the cable to be laid at great depth on either side to the channel to compensate any variations of the channel position.

(v) The need for the cable to be laid at least three feet deep was in order to prevent its being laid bare by occasional gales or being fouled by the anchors of fishing craft.

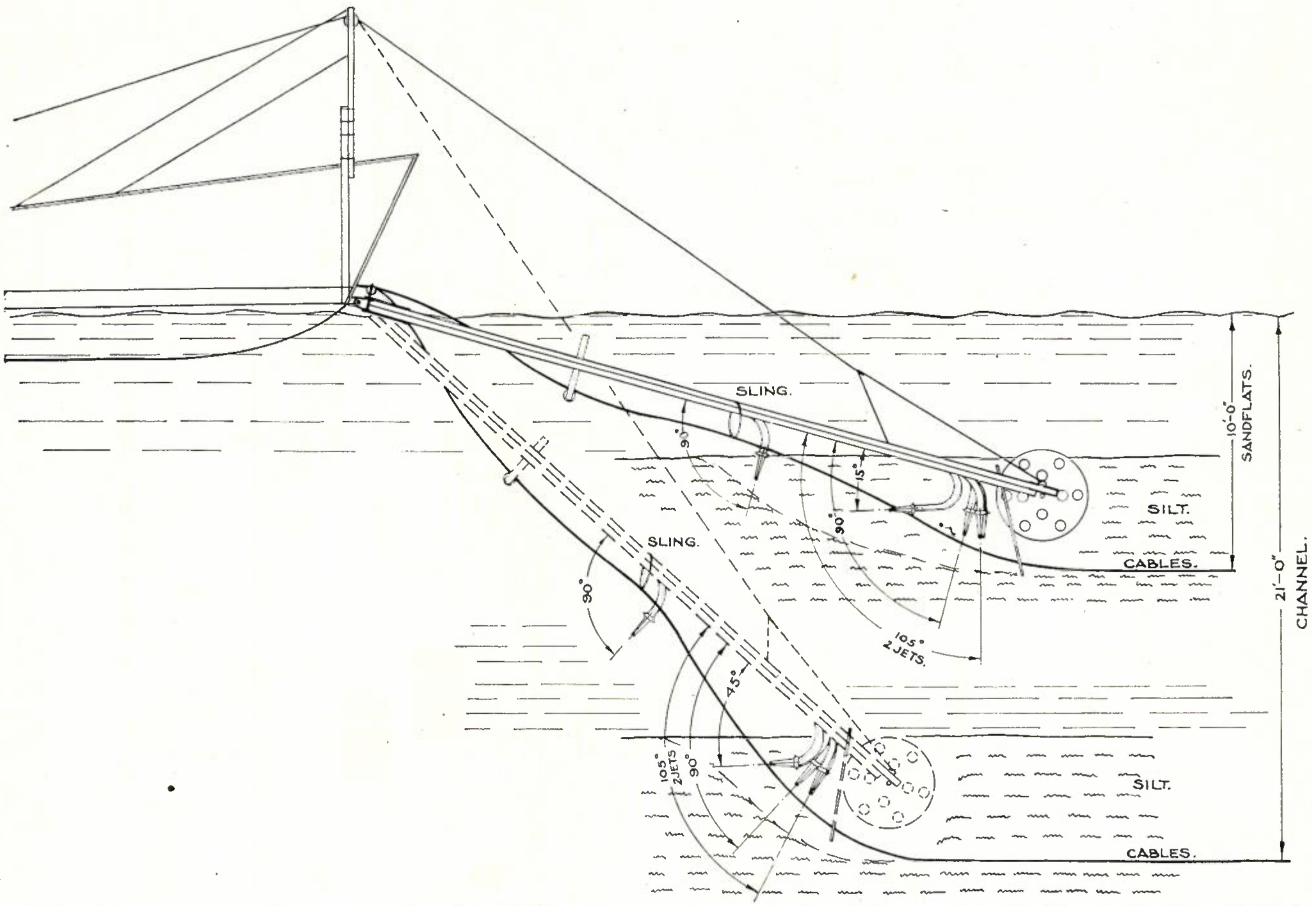


Fig. 2b.—View showing operating angles of jets. The 15° jet angle, which is used in the shallows, is replaced by the 45° jet angle in the channel. Approximate scale: $\frac{1}{8}$ in. = 1 foot.

Due to these factors and the difficult nature of the soft sand it was decided that such a method would take too long and it was doubtful if sufficient cover for the cable would be obtained. The adoption of different methods of laying for the various areas across the inlet was examined but due to the fact that an excessive number of joints would be required, another means was sought by which the whole cable laying operation could be carried out by some single method.

Selection of Method and Preliminary Organisation. In order to lay the cables by a single method it was decided to use high pressure water jets to cut the trench in which the cable would be laid. As a test, two mobile air compressors were set up operating two sump pumps in tandem. A short length of hose fitted with a branch was attached to one pump and a powerful jet of water was directed on the sand and succeeded in cutting a reasonable trench. The success of this test gave rise to the construction of a raft made from four large fuel drums and fitted with a wooden decking and frame and to this was fitted a short boom with the water jet attached thereto. The pumps were located on the raft decking and the air was supplied from the compressors located on the highway. A short length of cable was laid on the sand and the jet was passed over the cable, which sank about two feet into the sand. It was found that due to the rigidity of the cable full advantage of the depth of cut was lost, so a second jet was added and placed about four feet ahead of the original jet. Using the two jets and at the same time increasing the bending radius of the cable a greater depth of laying was obtained. It became apparent that it would be desirable when laying the cable by this means to do so from a height, thus gaining advantage of the increased weight of the cable and that it would also be desirable for the cable to be carried on a barge and fed into the trench at the same time as the water jets were operating.

In view of the success obtained, and the knowledge gained by the tests it was decided to lay the cable by the water jet method and to this end a suitable barge was sought and selection was finally made of the 60 feet Army landing craft with a beam of 20 feet and a fully loaded draught of three feet. This barge was fitted with a drawbridge landing ramp and the hull was of steel construction. The barge selected was not fitted with engines, as their absence meant a decrease in the draught of the vessel when fully loaded. The release of the barge for the purpose as required was granted by Army Headquarters and its equipping for the project is described in a later section in this article. Whilst it was intended to load the barge with the first section of cable and tow it from Brisbane, it was necessary to examine means of loading the barge once it was on the site. There are no wharves in this area of the bay and the only nearby jetty was not capable of carrying the heavy loads required. The highway itself was not sufficiently wide to allow loading to take place from its sides. It became necessary then to examine other means of loading the barge, and it was

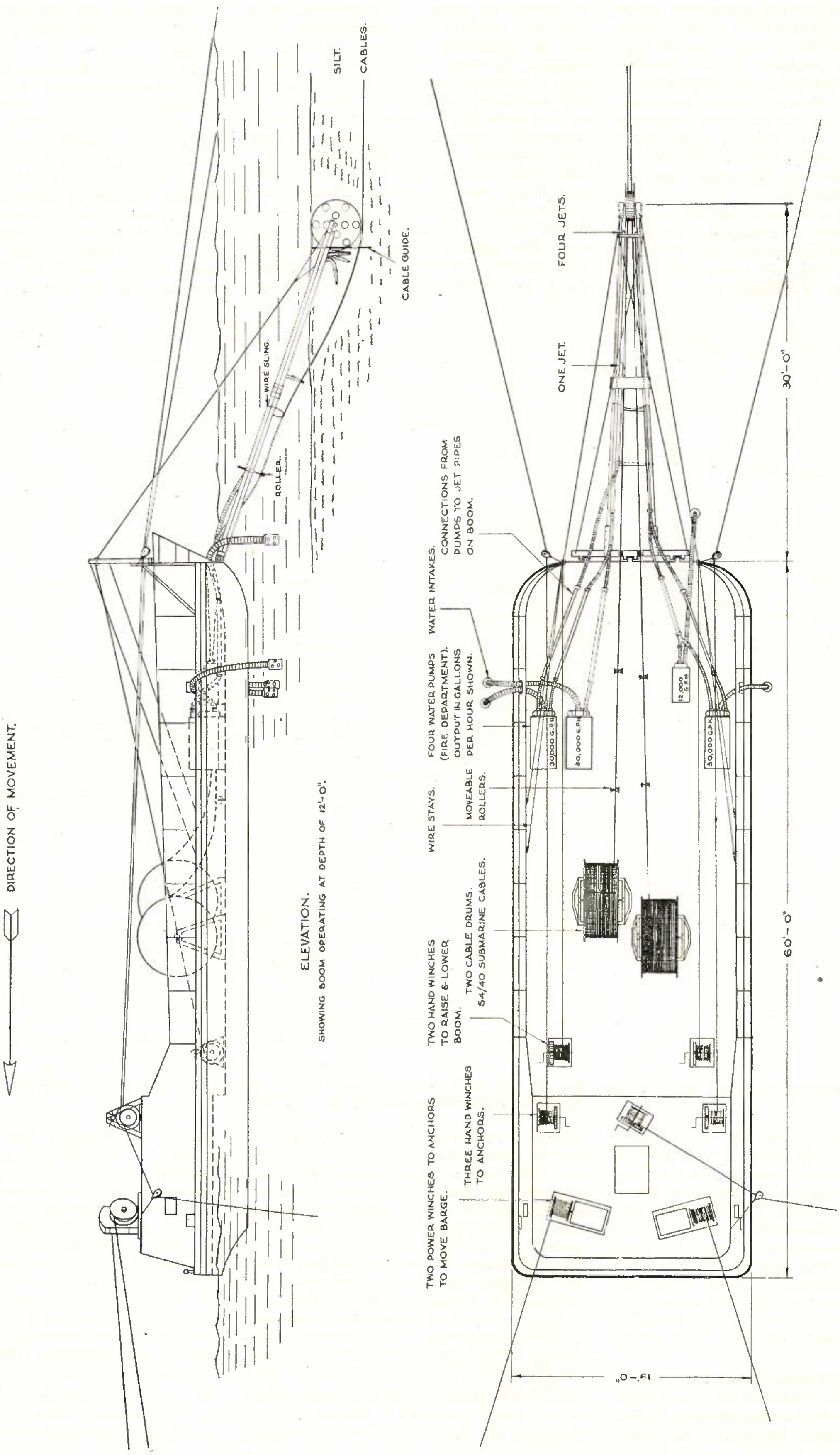


Fig. 3.—Barge adapted for laying submarine cable by water jets.

finally decided to create a small harbour at the sea wall on the southern end of the bridge. This sea wall is divided into sections by means of groynes, and at low tide the sand is exposed along the base of the sea wall. It was decided to bulldoze the sand out during low tide and create an artificial harbour at the sea wall and of sufficient depth to float the barge during high tide and thus provide a very suitable loading dock. By the use of bull-dozers this work was carried out and at low tide seven feet of water is available at the sea wall dock, see Fig. 7. The procedure for handling the barge in and out of the dock was as set out in the following paragraph.

On a rising tide the barge is towed to the dock; close by the two main anchors are dropped and the tide is allowed to sweep it past the dock. When the barge is almost opposite, two winch ropes are picked up from the two bull-dozers on the shore, and these then winch the barge gently into the dock. With this arrangement the two groynes extending from the wall are easily cleared, and after the first attempt it became a very fast operation. At the dock is a Lorain mobile crane and which quickly loads the two drums of cable, see Fig. 8. With this done the bull-dozer winches are slackened off and the barge drifts out from the wall, and winches up on its anchors to a point where it is taken in tow by the towing craft and towed to the next section.

Equipping the Barge. After the barge was taken over from the Army it was towed to a nearby wharf, where cranes placed on board the following equipment:—

Two power winches.
Five hand winches.
Two cable drum stands.
Two drums of cable, approximately seven tons each.
Four water pumps.
One water gin and fire extinguishers
Ropes, anchors, fuel, and other minor items.

The barge was then towed to Hays Inlet and moored at the northern end of the route. On arrival the landing ramp was dropped off into shallow water, in a place where it could easily be recovered, see Fig. 2. The boom which had been constructed at a Line Depot arrived by road transport and was taken out to the barge on rafts. The boom was attached to the barge by means of the landing ramp hinges and was raised and lowered by means of two hand winches placed amidships. Due to the length and weight of the boom it was necessary to lengthen the normal masts which carry the pulleys and rope of the ramp raising equipment. These masts were raised four feet by means of strapped-on sections.

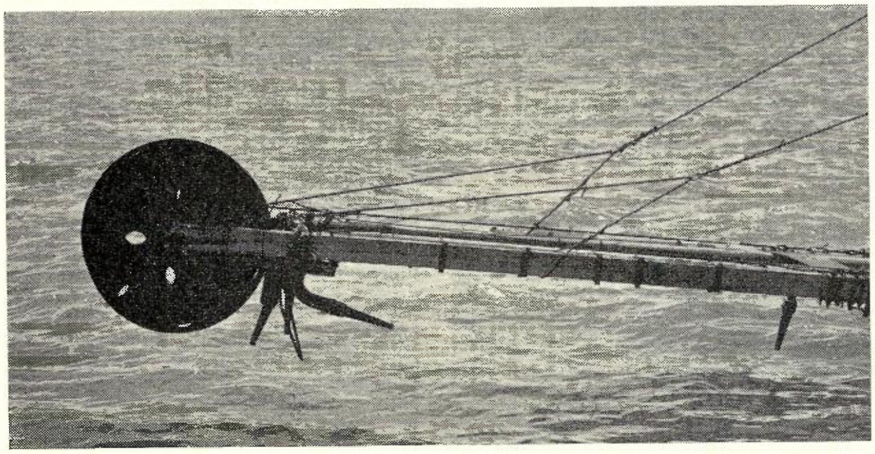


Fig. 4.—Drum and jets.

The boom was 30 feet long and consisted of an "A" 'frame made of double sections of 3 x 3 hardwood. At the hinge end was an "I" beam which fitted to the hinges. At the trailing end was the large roller drum and a few inches further along the boom were the jets. These jets were fed from four galvanised iron pipes each three inches in diameter. At the top end of the boom flexible rubber hose was used to allow for movement of the boom and then more galvanised iron piping was used up to the pumps, where rubber hose was used for the actual coupling to the pumps, see Fig. 3. On the top deck were fitted the two power operated winches and also the three hand winches used for controlling the course, and on each winch was wound 1,000 feet of wire rope.

Water Supply for Jets. Three Chrysler fire pumps were used and each of these developed a pressure of 150 lbs. per sq. in. and delivered 30,000 gallons of water per hour. Endeavours had been made to obtain a fourth, but without immediate

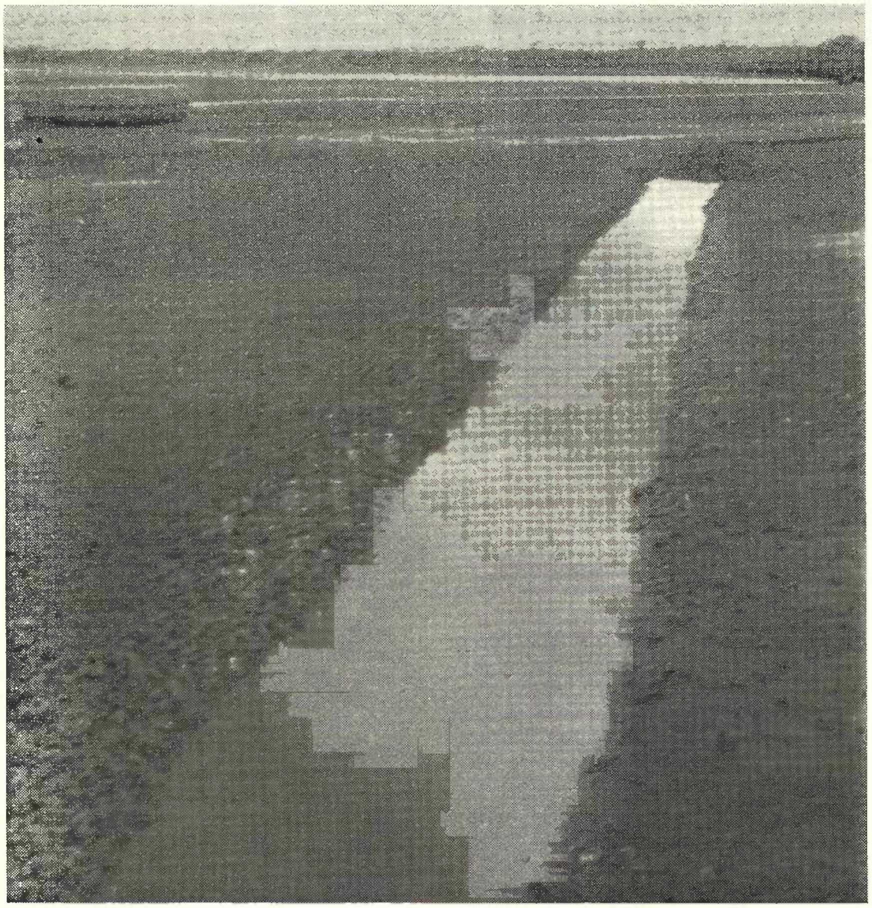


Fig. 5.—Trench through heavily impacted shell.

success, and arrangements were made to obtain two smaller pumps each capable of delivering 12,000 gallons per hour at a pressure of about 120 lbs. per sq. in. Unfortunately, one of these became unserviceable and the work was completed using only one. A total capacity of 102,000 gallons per hour was available, which was still in excess of actual requirements. Experience during the early tests had shown how troublesome a water failure could be, and it was necessary to have an adequate reserve so that in the event of the failure of a pump, the work would not be interrupted and the advantage of the tide would not be lost. A supply of American type fire hose couplings was provided so that the connections could be quickly changed over. In addition a "Y" piece was placed in the feed from the smaller pump and additional water was taken from the large pump on that side to supplement the efforts of the smaller pump. Fig. 3 indicates this arrangement.

Sea water was drawn over the side of the barge and the suction lines were fitted with strainers. Due to large numbers of jelly fish being attracted to these strainers, the water flow was restricted until wire-basket type protectors were fitted over the strainers.

Water Jets. These were standard fire hose branches with an opening of one inch diameter. Two were modified by having the openings enlarged to 1¼ inches, and were called the volume or dispersal jets and were arranged to disperse the sand cut by the two pressure jets. The pressure jets which did the actual cutting of the sand, were so placed in relation to the other jets that the sand was cut and suitably displaced. A fifth jet was placed experimentally half way along the boom, but was only used whilst doing a very deep cut at the Pine River crossing. The original design of the jet angles was fully confirmed as being ideal when a minor test was made. The jets were fitted to curved sections of three inch G.I. pipe, which themselves were screwed to the main supply lines, see Fig. 4.

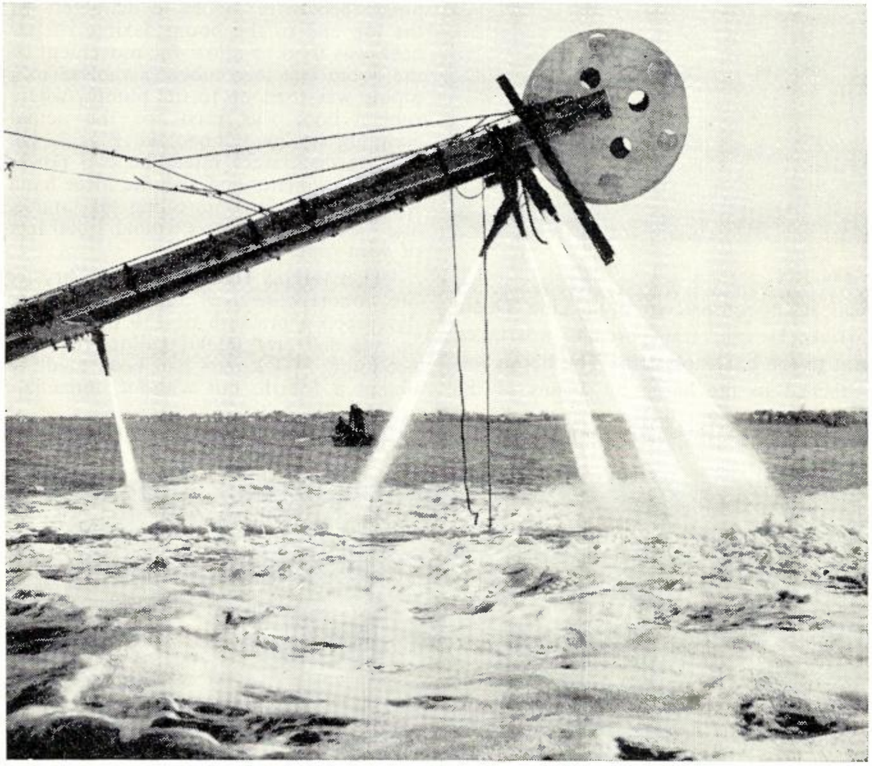


Fig. 6.—Boom raised to demonstrate force of jets.

Application of Water Jets. Investigations made during the preliminary stage showed that it was desirable to cut as long a trench as possible and that the trench should have a bottom sloping gradually to the surface in a forward direction. It was necessary to exploit the weight of the cable in order that the cable would go to the bottom of the trench and certain guides and rollers were fitted to the boom so that the cable would not actually touch the sand until it was within the trench. Actually the cable first touched the sand at the forward portion of the sloping trench, which was approximately ten feet ahead of the boom. This point was blasted by the leading cutting jet, which itself was horizontal to the surface. This jet cut a trench one foot wide and 18 inches deep at its lowest end. The vertical jets that were operating downwards had their angles so adjusted that the trench was cut to its final depth. The leading cutting jet cut and blasted the sand clear and forwards where it was removed by the tide. At full tide it was deposited evenly on each side of the trench.

The vertical jets operating downwards, cut and forced the sand in a backward direction; this directive effect was helped by the drum, and the sand so dispersed served as backfilling to the trench. The sand in this portion of the trench was in a highly quicksand condition and after a few tides the top surface compacted and appeared quite firm.

It was a matter of much interest to note that the walls of the trenches were particularly firm and straight sided, and in one area where the sand was heavily impacted with shell it was impossible to drive a spade into the side of the trench. Even in the quicksand areas the walls were quite firm and it was noticeable over almost all of the route that the trenches had been cut very easily and very cleanly. A picture of the trench cut through the heavily shell impacted area is shown in Fig. 5, whilst Fig. 6 shows the boom raised and with jets working.

Originally it had been decided that the drum would roll the cable into the trench and it was, of course, required while passing over rocks, but after the project had started it was found that the weight of the cable was sufficient to force it well into the trench.

Moving the Barge. The two power winches were used for forward movement of the barge, and as can be seen from Fig. 3 the barge always travelled stern first with the boom trailing behind. Of the two winches, one was a 30 cwt. Sullivan and the other was not identified as its nameplate had disappeared, but it was a particularly fine winch and took most of the load. The winches were wound with 1,000 feet of wire rope, which was later extended to 1,500 feet. The free ends were secured with rope clamps; these were shackled to short slings attached to the anchors. The reason for this was that the anchors, which were of the sand or mud type, tended to bury very deeply and could not be easily tripped. As the recovery of the anchors would take some time, and in the meantime the tide might be falling, it was decided to unshackle the anchors and recover them later, and in the meantime proceed to other anchors already laid 1,000 feet ahead with their slings buoyed so that the rope could be quickly attached.

In most cases one anchor was sufficient for each winch, but on some occasions, particularly when in the quicksand area, it was necessary to use two anchors in tandem for each winch. The barge also carried spare anchors for use during the time when the hauling anchors were being changed. It was not possible to obtain winches large enough to carry wire rope equal in length to the section of submarine cable being laid, and so eliminate the necessity of changing anchors half way along the route, but as

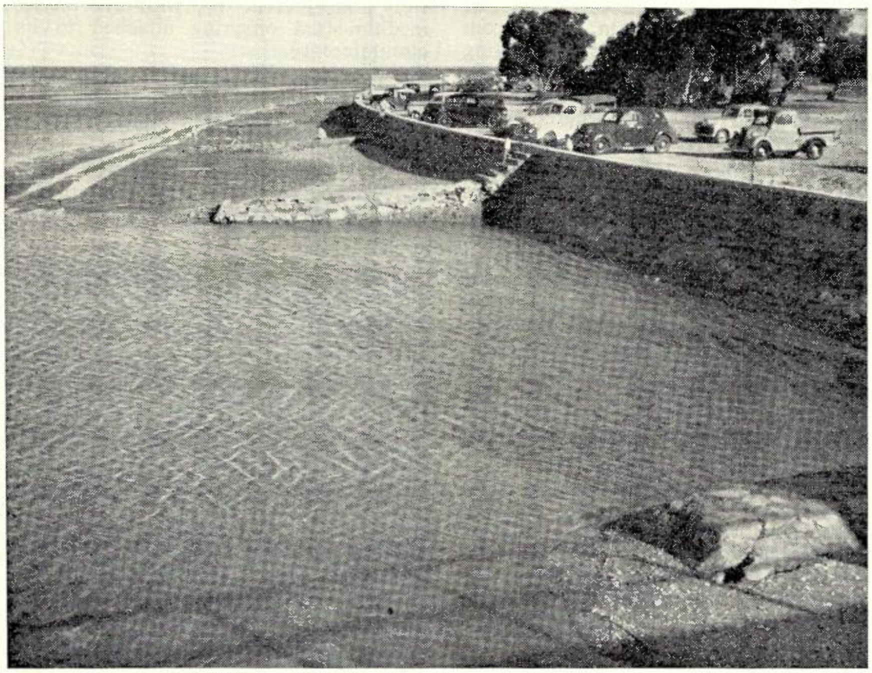


Fig. 7.—Loading dock at low tide.

there was seldom sufficient depth of water to do much more than half a section on each tide, this shortcoming was not a very serious one.

The barge was held in position by two trailing anchors and one beam anchor, this being changed from side to side according to the flow of the tide. The trailing anchors were mainly used to place the barge in position at the start of a run and hold it at the end of a run. During laying it was found that the boom tended to keep the barge on course to such a degree that it was occasionally necessary to "dog-leg" the course in order to provide cable slack as an emergency against any subsequent storms that might erode the sandbank area.

During the time that the barge had to be shifted over to be reloaded it was towed by two fishing craft. It was found that by raising the boom clear of the water, the barge tended to "crab", but by lowering the boom so as to cover the drum, the barge then towed particularly well.

Use of Bulldozers. During the preliminary preparation and during the progress of work use was made of one TD18 and one D4 bulldozer. During the preliminary tests the D4 was placed on the sand to see if it could pull a small plough, but it was found that the tracks tended to slip and cut a trench in which the dozer might become fast. A test with the TD18 indicated the same tendency. It was also found that if a dozer was left in the one position for a long period it tended to sink. These tests showed the impossibility of attempting to lay the cable by a tractor-drawn or winched plough. When it was decided to cut a dock it was feared that the dozers might become stuck in the sand, and as a preliminary test one dozer was positioned on the sand, while the other was kept on the shore close by, the driver being instructed to attempt to get it stuck while shifting sand. The machine quickly became fast in the sand, but was as quickly cleared by means of the winch rope from the other machine. After further test it was found that as long as the machine took a shallow cut and kept its tracks from spinning, there was no sinking. When the machine went over the same track on the next cut it removed the sand cast up by the tracks on the previous run, and there was no tendency for it to become fast. Eventually both machines were put to work, but as a safety measure a heavy transporter, also with a winch attachment, was kept in the area.

Half a mile from the southern shore is the deep channel of the Pine River and, due to various considerations covered later in this paper, it was considered advisable that a small channel be cut at right angles to the main channel. It was decided that the dozers would do this job and, as before, one was to do the job while the other stood by in case of emergencies. The one machine quickly produced a good cutting, during which it was discovered that after the first two feet had been removed the sand was much harder. It is thought that this was due to the presence of small crabs and other marine life, which burrowed through the first two feet of sand and so caused a loose surface to the depth of two feet. Both machines were put to work, and a cutting 100 yards long and 15 yards wide was completed. This cutting was about three feet lower than the surrounding area. The machines worked during the low tide and returned two hours after the turn of the tide in case a mechanical breakdown would cause a machine to be caught in the rising tide. As a precaution, sufficient wire rope was kept available on the transporter winch so that it could, if necessary, winch out the tractor up to a distance of half a mile from the shore.

Laying the cable. At the northern end of the route a conduit party cut a

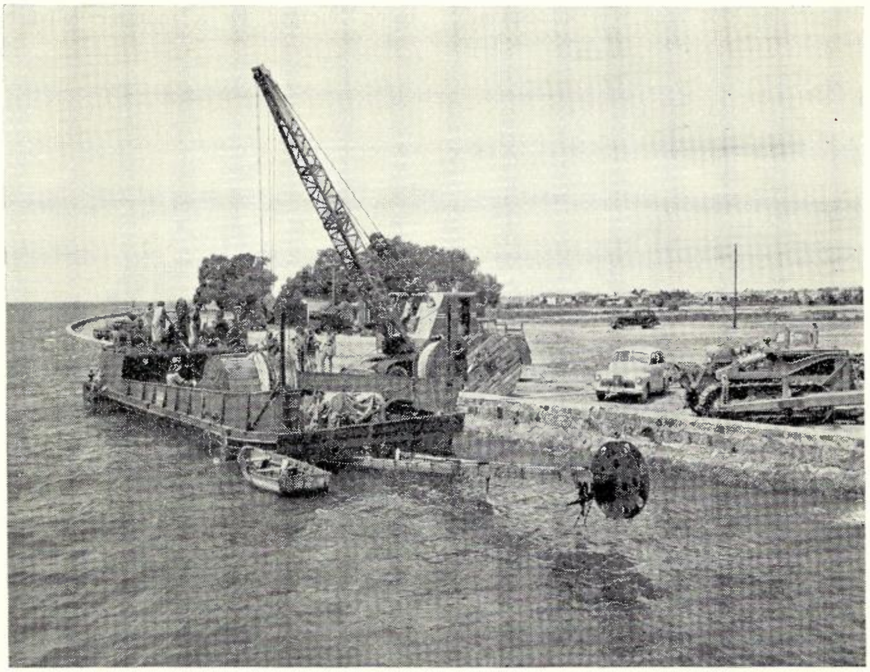


Fig. 8—Loading dock at high tide. Barge being loaded with cable drums. Note use of bulldozer winch.

trench down through the rocks to below low tide mark and as the laying commenced from this shore the cables were hauled ashore by means of the transporter winch. The barge was then placed in position with the boom resting on the end of the trench in which were the cables, the jets were operated and quickly the surface of the water was discoloured with the white clay which was being eroded. Contrary to expectations the jets could not be heard on the surface, although under water the noise was intense. This gave added security to personnel, who might have to enter the water, as it was considered that the noise would effectively scare away any sharks that might be in the area.

As the jets cut lower they exposed rock, and at this moment forward motion was given to the barge and cable laying began. As the barge moved forward personnel on board slowly turned the cable drums to feed the cable freely under the boom. Loose rocks which were two or three feet below the sand were quickly dislodged and for the first hundred yards the boom could be heard rolling over the rocks.

As the barge proceeded into the first channel the rock gave way to sand. During this time progress was made with some difficulty as the power winch anchors kept dragging and after crossing the channel the tide had fallen and the barge was made secure until the following day. In the period of low tide that followed, the writer made a personal investigation by walking along the cable through portion of the channel. This was the area where the cable was laid on rock from which two to three feet of sand had been blasted away. On only one area was there any doubt as to whether the cable might have gone deeper and this area was subsequently blasted by the jets and about six feet of loose rock was washed out. Apart from this small section the cable was resting on solid rock. A later investigation showed that the sand had covered the rocks and the cable was secured under at least two feet of sand.

With the following day's run success was definitely assured, for by this time the barge was past the channel and in the sand that covers at least 95 per cent. of the route. At the edge of the channel the cable was found to be down at least ten feet, this depth was reduced to six feet immediately, and subsequently to between three or four feet on later stages of the route. Once the barge was in position and laying commenced, the work became a routine, and a laying speed of 25 feet per minute was maintained, see Fig. 9.

Some difficulty was experienced when commencing a new section, for then the cable ends had to be brought clear of the barge and laid on the sand with the necessary overlap. At a point where it was proposed to start burying the cable the boom was lowered over the cable and the jets were given a short burst, this effectively buried both the end of the boom and that portion of cable. The cable was then checked for loops or loose sections forward of the jets; these were removed by hauling loose cable back on to the barge. When all was checked the signal for forward movement was given and laying would commence. This work was comparatively simple, but was considerably hindered by the presence of many jellyfish. Certain varieties inflict most unpleasant stings, and many of these varieties were present. While there was little fear of sharks, however, on one occasion a member of the staff received a fright by being bumped by a monster jellyfish fully four feet across, with five or six medium-sized offspring attached to its circumference.

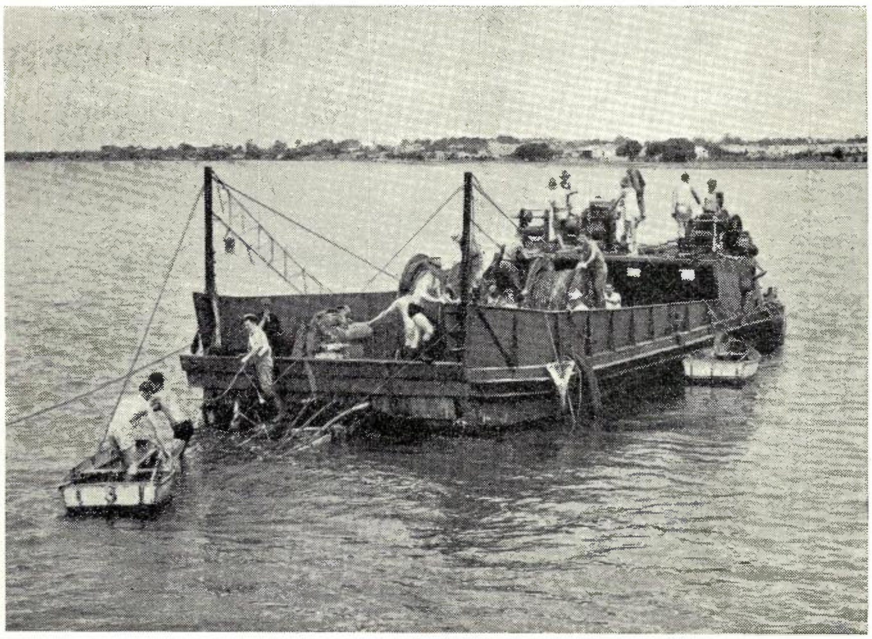


Fig. 9.—Barge laying cable while working in six feet of water.

The laying of the first four sections proceeded with the difficulties of wind and weather, which were, however, considerably minimised due to the stability of the barge, in fact, this type of vessel is preferred to other types of craft, because of its particularly low centre of gravity. It was evident that the boom exerted a great effect in minimising rolling in choppy seas. Each morning the barge was positioned on the first lift of the tide, and as soon as there was sufficient water the run would commence and continue without a break until the barge grounded on the following tide.

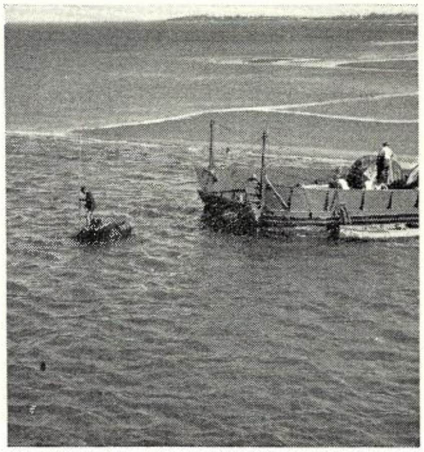


Fig. 10.—Crossing the Pine Channel. Note use of pole for testing trench.

The final section was the crossing of the Pine Channel, and this had been generally agreed as being the hardest section, and was accordingly left to the last, when the crew would be fully experienced. The boom design was based on the assumption that the channel would be crossed on the low tide, when the depth would be somewhere around 20 feet. Due to the greater depression of the boom it was necessary that a different angle for the leading jet should be made; this required a bent section of G.I. pipe of 45°, and when the other sections of cable had been laid the previous 15° pipe was unscrewed and the 45° one fitted. Unfortunately, for this run the tides were not altogether suitable, and it was necessary for a section of the cable to be withdrawn from the barge and laid on the sand in the shallow area. This was bedded in by firehoses working from pumps on the barge which, at that time, was moored in the channel. This method was much less efficient than the boom laying method, but as the length was short, little time was lost.

When the equipment had been in use for some time with all parts exposed to the sea air, it was felt that should any part break it would cause some difficulties, particularly should it happen to the boom lifting equipment. As a precautionary measure a raft was fitted with a small hand winch to which a wire rope was connected to the end of the boom. The raft was allowed to train behind the boom and could be used to lift the boom should any breakage occur, see Fig. 10.

The following day, as the tide fell, the barge was placed in position over the cable. The jets commenced to operate and the cable sank into the sand; when sufficient depth was attained the barge moved slowly forward and out into the deeps of the channel. As the boom went deeper the familiar stain of clay arose, indicating that the jets were operating deeply in the bed of the channel. Trailing behind on the raft was the writer with a long pole testing the trench, and on this survey it appeared that the cable was at least two feet deep in the clay area and about four feet deep in the sand area. The case of cable laying through the deeps demonstrated that the boom design was correct, and that it had adequate margin on its hinges. As the southern end of the crossing was approached the boom was allowed to remain deep in the sand in case of an eventual change of course of the channel. For many reasons it was considered desirable that this section should be laid in one day as it was in a particularly exposed area, and should a gale arise difficulties would be experienced. To forestall any difficulty a small canal was constructed leading into the sandbank area on the southern end. This canal gave approximately three feet of water shortly after low tide, and as the barge came out of the channel it was able to continue laying much sooner than had it to wait for the tide.

It was unfortunate that an off-shore wind slightly delayed the tide in its crossings of the sandbanks, causing a slight delay in the operation, but this was utilised to rearrange anchors and as the tide rose the barge moved off again. As has been stated, the leading jet was changed for the deep crossing, and it is particularly significant that on entering the shallow water the jet, which was still set for deep water work, was very much less efficient in the shallow water. As a result the laying speed was cut by half, but as the remaining distance was short the run was completed without changing the angle of the jet. Up to that time it had been felt that perhaps the attention paid to jet design was unwarranted, but this experience justified the attention that had been given to the design.

Conclusion. After the cable laying was completed the barge was used for minor work, then it was stripped of all its equipment and towed back to where the door had been dropped. This was too heavy to refit while in this area, and was winched up underneath the barge and made secure. The open end of the barge had been closed with heavy wooden skids during the progress of the job; these were made more secure and the barge was towed back to Brisbane. During the return trip very heavy seas were encountered, and both tow-board and barge crews had some unhappy hours.

From experience gained on this project the writer is confident that this method can be successfully employed to lay cable to much greater depths, both in water and in sand cover. Where a smaller single cable is to be laid the present type of boom could be considerably modified. By being attached at the forward end and allowed to trail beneath and behind the vessel it could be made lighter and more flexible, and be up to seventy to eighty feet long for deep water operations.

The laying of the cable was, to some degree, handicapped by the inability to obtain suitable small motor boats for the shifting of the barge anchors, but as they would create inherent disadvantages, such as likelihood of cables being caught in the propellers or the boats being caught in the tide and swamped by the next rising tide, it is possible that it was only a matter of exchange of one handicap for another if the attempts to obtatin suitable craft had been successful.

During the preliminary trials, when a short test section of scrap cable was laid, it was found that by passing the jets along this cable it could very easily be recovered. The adoption of this method could be used to recover faulty or disused existing submarine cables.

POSTAL ELECTRICAL SOCIETY OF VICTORIA ANNUAL REPORT

During the 1952/53 year a bi-monthly lecture programme was arranged, members being able to hear talks by Messrs. D. Brooke, R. Boyle, P. Bethell, J. Coghill, D. Richardson, R. Kerr, J. Brough and P. Warr. Through the courtesy of the Training Section, Engineer-in-Chief's Branch, the Society was able to show four films of general interest to members at a film night.

The meetings of the Society continue to be held at the Radio Theatre of the Melbourne Technical College, to the Principal and officers of which we are again indebted for this facility. We continue, also, to be indebted to Messrs. Permewan and Power, of the College, for their assistance in screening and preparing the illustrations for the lectures.

The difficulties of publishing the Telecommunication Journal have continued to occupy the close attention of the Editors and Committee of the Society during this past year. It is regretted that the Journal continues to be considerably delayed in its appearance, and it would be of some assistance if any member willing to contribute an article were to communicate with one of the Sub-Editors or Editors.

In respect of publishing costs, the rapid rise of prices between one and two years ago left the Society's finances in a serious position at the beginning of the period under review. With the support and assistance of the then acting Director-General, Mr. Vanthoff, it was possible to obtain a Departmental subsidy of £951, which retrieved the Society's financial position. The increased subscription of 10/-, approved at the last General Meeting, made it possible for the Committee to indicate to the Department that, while a subsidy would still be necessary to permit the continued publication of the Journal, the extent of future calls for financial assistance would, it was hoped, be reduced.

During the past year, through the assistance of our printers, the Ruskin Press Pty. Ltd., through careful economy, and an evening out of price trends, it has been possible to hold the cost of publication of the Journal to a level slightly below the maximum which had been reached. However, the financial position, although somewhat improved, must continue to occupy the minds of your Editors and Committee as it must be appreciated that the present subscription rate still implies that the Society must seek an annual Departmental subsidy of some £300.

The circulation of the Journal has, in the past year, continued at some 2,400 copies, of which approximately 150 copies are going to overseas readers.

The Committee, in appreciation of the long service to the Society of the senior member of the Editors, Mr. C. J. Griffiths, has made him a life member of the Society.

The Committee expresses its thanks to the authors of articles, members of the drafting staff who have prepared illustrations, members who have assisted in the collection of subscriptions, and Miss Wright for her task in keeping the records of the distribution of the Journal, for their work during the past year.

AIR TREATMENT IN POSTAL BUILDINGS IN AUSTRALIA

A. F. HALL

Introduction: It was Mark Twain who said, "Everyone talks about the weather, but no one does anything about it." The remark no longer applies, for there is an increasing tendency in all progressive countries throughout the world to introduce into homes, offices and industrial buildings means whereby conditions are made more congenial for occupants, or more suitable to the manufacturing process. It may not be possible to control climatic conditions, but at least restricted areas of occupancy may be provided with precise conditions to meet requirements of physical comfort or of specified industrial needs, provided the need will justify the expenditure.

In the United States, retail sales of air conditioning equipment during 1951 were estimated at one billion dollars, for 1952, 1¼ billion dollars, and this figure promises to be exceeded in 1953. In Australia the field has been exploited to a very limited extent, partly because of the high cost of the necessary equipment and also because of the more favourable climatic conditions in this country. Before examining requirements for physiological comfort or desirable conditions for telecommunication purposes, it would be advisable to consider briefly the prevailing conditions in Australia.

Australian Climatic Conditions: Extending from approximately latitude 10° south at Cape York to 44° south at South-East Cape, Tasmania, the climate ranges from tropical to temperate. Approximately two-fifths of Australia lies within the tropical zone, and its insular position, together with the absence of striking topographical features, provide a more temperate climate than is found in other regions in similar latitudes. Over practically the whole of Australia the temperature range is less than 100 Fahrenheit degrees, although high conditions of temperature prevail in summer in inland areas. The annual rainfall may reach 160 inches in parts of the coastal district of north-east Queensland, 100 inches on the west coast of Tasmania, 40-60 inches in coastal districts of New South Wales, the extreme north coast, the south-west corner of Western Australia and in eastern Victoria. Elsewhere much drier conditions prevail, and the annual rainfall does not exceed 5 inches in the central region. In general, average conditions in spring and autumn are not far removed from the accepted comfort range during daylight hours, but to achieve reasonably comfortable conditions during winter, some form of artificial heating is necessary over practically three-quarters of the continent. Temperatures below freezing point are, however, seldom experienced except over the elevated regions.

Basis of Provision for Postal Purposes: The advantages of ideal comfort conditions are as well recognised as is the need to meet the demands of equipment, but the need for limitation of expenditure has resulted in essential requirements only being provided. The present policy recognises:—

(a) The general need for heating to promote staff comfort.

(b) The provision of essential ventilation and air circulation.

(c) The restricted need for more precise control of conditions in certain areas in buildings in which occur high densities of occupancy with staff rostered over 24 hours.

(d) The requirement for carefully controlled conditions of air cleanliness and humidity in buildings in specified areas where fault incidence in telecommunication equipment would otherwise seriously increase maintenance difficulties.

These diverse requirements are grouped under the common title of Air

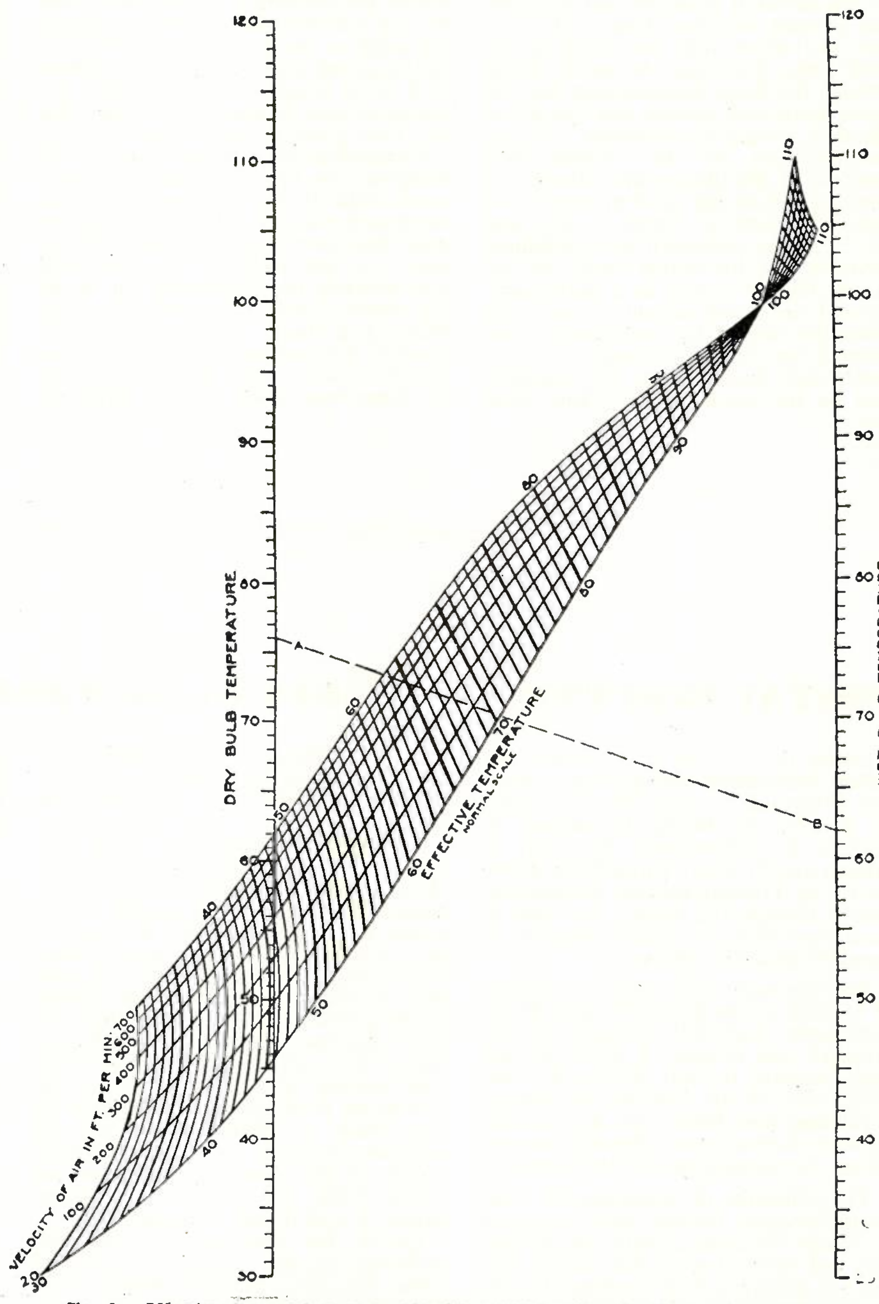


Fig. 1.—Effective temperature chart showing normal scale of effective temperature. Applicable to inhabitants of the United States.

Treatment, but fall into two general groups, Physical Comfort and Equipment Needs.

Physical Comfort. In order to understand the basis of practical air treatment for human comfort it is necessary to study the relationship between the individual and his atmospheric environment. About 375 cubic feet, or approximately 28 lbs. of air, are breathed each 24 hours and therefore five times as much weight of air as of food is taken into the human system. The amount of new air required for purely physiological purposes is very small—about one-third of a cubic foot for one person per minute. Oxygen constitutes approximately one-fifth by volume of the air we breathe and nitrogen accounts for almost the entire remaining four-fifths, but only about 5% of the oxygen inhaled is absorbed in the lungs. The quantity of carbon dioxide present in the air varies from 3.4 parts by volume in 1,000 for pure air to about 8 parts in 1,000 for city air. With 2% of carbon dioxide, lung action increases by 50%. With 6% breathing becomes very difficult. In places of concentrated occupancy as, for example, in picture theatres, the carbon dioxide content would rarely exceed 1 part in 1,000 and it is generally recognised that the quantity of carbon dioxide present is of little practical importance, though it is sometimes useful to indicate contamination due to respiration.

It was formerly thought that the presence of carbon dioxide in ill-ventilated compartments was responsible for the extreme physical discomfort experienced, but the experiments of Leonard Hill resulted in the abandonment of this theory in favour of the present thermal theory. Hill placed subjects in an airtight chamber until the carbon dioxide, temperature and moisture content of the air increased considerably due to respiration, convection and surface evaporation from the subjects. Extreme physical discomfort resulted, but when the air was set in motion by a fan their discomfort was relieved. Other subjects outside the chamber experienced no discomfort when breathing air from within the chamber through tubes, and those within experienced no relief from breathing outside air when the chamber air was not set in motion. When the temperature and humidity in the chamber were controlled to give normal conditions the individuals in the chamber suffered no discomfort due to considerable increase in carbon dioxide content. The experiments indicated that the effect of the atmosphere on the skin is of prime importance and that comfort depends on maintaining proper temperature, humidity and air motion. Unless bodily heat is properly removed, discomfort is experienced.

The presence of impurities may also greatly affect physical comfort and it is desirable to ensure that the air circulated within the treated space is maintained as dust free as the requirements may demand. A human being placed in a room is continually radiating heat from exposed surfaces, including skin and clothing. It has been found that the greatest comfort amongst sedentary workers is experienced when half their excess bodily heat is given off by radiation and the balance by all other methods combined—conduction, convection, respiration and surface evaporation. The latter method uses the principle of latent heat of water and begins to be apparent at about 70° F. for persons at rest and increases as temperature rises. The higher the relative humidity within the occupied space the less effective is surface evaporation and vice versa.

It is now apparent that the three factors principally affecting present theories relating to physical comfort are:
(a) Temperature and radiation.
(b) Air motion and cleanliness.
(c) Relative humidity.

Assuming light muscular movement and normal clothing, comfort zones may be said to lie within the following ranges.—

Summer temperature:
72° F. to 78° F.; R.H. 40% to 70%.
Winter Temperature:
65° F. to 72° F.; R.H. 40% to 70%.

The lower temperature values are associated with the higher relative humidity ranges and vice versa.

In order to assess, conveniently, the sensation of heat and cold felt by the human body due to the combined effects of temperature, humidity and air motion, an arbitrary index has been prepared, and this is termed the "effective temperature index (see Fig. 1). With a fixed dry bulb temperature an increase in relative humidity will produce an equivalent feeling of comfort to that of still air at a higher dry bulb temperature. Similarly, a reduction in relative humidity will produce an equivalent feeling of comfort to that of a lower dry bulb temperature. Under conditions of moderately high temperature and high relative humidity it is more comfortable to raise the temperature and thereby reduce the relative humidity, thus reducing vapour pressure and assisting evaporation of perspiration. The comfort gain is greater than the discomfort which, in normal circumstances, would be associated with the rise in dry bulb temperature. Within the normal conditions of temperature and humidity increased air movement will result in a reduction in effective temperature. Main trunk exchanges and main telegraph operating rooms are areas in which large numbers of persons are employed on exacting work and in which high densities of staff occur. Members of staff are rostered over the entire 24 hours. The need for favourable conditions is recognised as an aid in reducing staff turnover and improving work output. It is expected that, ultimately, conditions within the comfort range will be attained for these activities in all main centres at least. From the viewpoint of unfavourable conditions the order would be Sydney, Newcastle, Brisbane, Perth, Adelaide, Melbourne, Launceston, Hobart.

Equipment Needs. Most telecommunication equipment is designed to withstand a considerable rise in temperature above ambient and if reasonable ventilation is provided excessive heating of apparatus is not a problem. The two factors which should be avoided are dust and excessive humidity—the former greatly increases the wear on working surfaces and the latter brings about conditions of low insulation resistance. It is probable that equipment would operate over a range of ambient temperature 30° F. to 100° F. and with relative humidity ranging from 40% to 70%. Whilst short periods of higher relative humidity may not be serious it is considered that if conditions of humidity above 70% persist for eight hours a day for more than two days in summer, trouble may arise. In buildings constructed of materials with a low co-efficient of heat transmission the summer temperature in daylight hours within the building is lower than that which might be recorded outside in a Stevenson screen, and in these conditions the relative humidity within the building would be somewhat higher than outside. At night in summer, and almost continually in winter, the warmer conditions within the building will usually reduce the relative humidity to a safe value so that dew point will not be reached. Even in the most adverse circumstances experienced, a rise of 13° F. above ambient will probably result in a safe value of relative humidity.

Much of the equipment dissipates a considerable amount of heat, which must be removed by increasing the quantity of air admitted to the space. Increased air supply means increased dust unless filters are provided to remove impurities. If conditions of high relative humidity prevail in the locality it is necessary, before admitting the air, to reduce its relative humidity to a safe value. In winter this may usually be done by heating but in summer this method would create most unpleasant conditions for staff, and it is often necessary to resort to full air conditioning, which includes refrigeration. By this means the temperature of the entering air may be reduced below dew point, in which circumstances surplus moisture will be deposited on the cooling coils. The air, saturated at the low temperature, may then be mixed with re-circulated air or warmed before being admitted to the space at the specified temperature and humidity.

The main activity in which the above circumstances apply is in the automatic telephone exchange switchroom. The most important localities are the coastal regions of New South Wales, Queensland, and Western Australia, particularly when proximity to the sea front results in presence of salt spray in the atmosphere. Several additional problems may arise in these exchange buildings. If large areas of glass are a feature of the architecture the heat load is increased in summer and more heat is lost from the building in winter. With the cooling load extensive air treatment is often unavoidable and refrigeration plant of considerable capacity may be necessary. The capacity of refrigeration plant depends on the locality and the particular conditions but, for a 10,000 line automatic exchange, plant of capacity in excess of 20 tons refrigeration may be required.

Referring to Fig. 2, the general methods of air treatment to maintain reasonable conditions in the specified areas are as follows:—

Areas A and B:
Mechanical ventilation or circulation and air filtering.
Area C:
Mechanical ventilation or evaporative cooling and filtration.
Area D:
Cooling to the comfort zone will not usually be possible without refrigeration, but cooling to 10° or 15° F. below ambient, may be possible with lesser provision.
Area E:
Refrigeration will be necessary, usually to meet equipment needs.

Heating for several months of the year will be necessary south of the heating line.

Psychrometric Chart. Since relative humidity is so important from the points of view of physical comfort and equipment needs, it is necessary to establish quickly its actual value at any time. The branch of physics relating to the measurement or determination of atmospheric conditions and particularly regarding the moisture mixed with the air is termed psychrometry. Relative humidity is established by simultaneous reading of wet and dry bulb thermometers, and the chart which, inter alia, relates these readings with relative humidity is termed a psychrometric chart, see Fig. 3.

Strictly speaking, the relative humidity readings should be taken with an air velocity of 1,000 feet a minute, and to achieve this condition a suitable means is provided for rapidly whirling the thermometers before reading. The device is known as a Sling psychrometer.

Heating. From the point of view of Departmental policy, we are concerned mainly with the heating of buildings. Table 1 gives a comparison of temperatures in various areas.

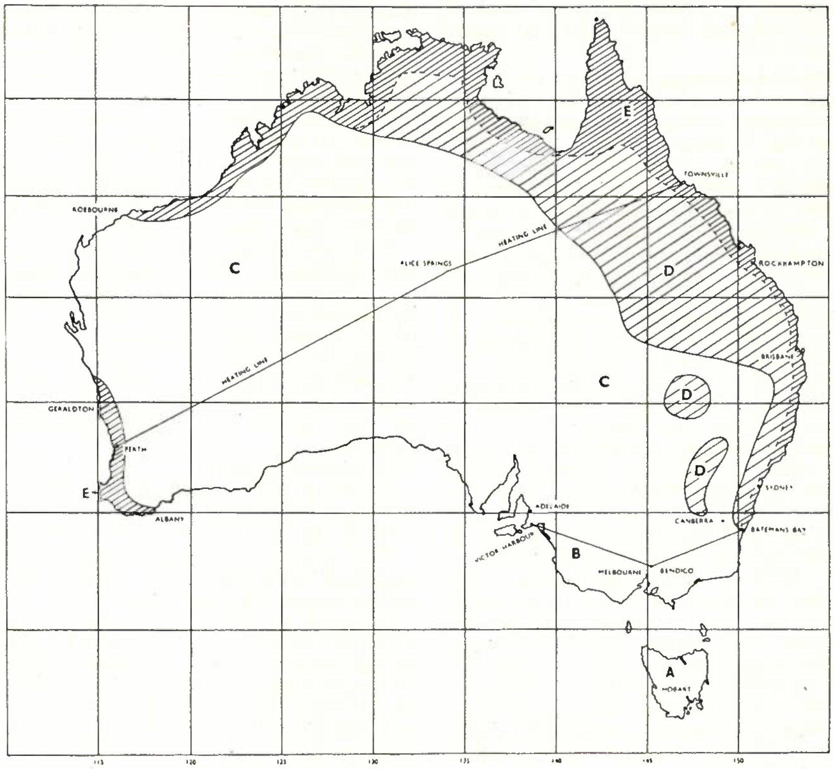


Fig. 2.—Air treatment zones in Australia.

between the mean temperature for the day and 65° F.

There are two main types of heating installation:

(a) Warm air heating.
(b) Radiant heating.

With either type a furnace may be provided. Oil or solid fuel may be used

Place	9 a.m. temperature: No. of months below 55°F.	9 a.m. temperature: Mean temp. of coldest month.	Minimum temperature: No. of months below 55°F.	Minimum temperature: Mean temp. of coldest month.
Lithgow	5.6	40.9	12	32.2
Ballarat	6.2	42.8	12	38.3
Hobart	6.2	44.2	12	39.5
Geelong	4.1	48.4	9.5	41.7
Melbourne	4.4	47.0	9.1	41.9
Broken Hill	3.2	48.7	5.8	40.7
Adelaide	2.9	50.6	6.8	44.7
Sydney	2.9	50.3	5.2	45.9
Newcastle	2.5	51.7	5.0	46.6
Perth	1.7	53.8	6.2	47.7
Brisbane	0.	56.3	3.9	48.5

The capacity of heating plant in British speaking countries is based on the British Thermal Unit, the quantity of heat required to raise the temperature of 1 lb. of water one degree Fahrenheit, the exact value depending on the initial temperature. When estimating fuel consumption and specifying the nominal heating load of a building in winter, a unit, based upon temperature difference and time is used. It is termed the degree-day. For any one day when the mean temperature is less than 65° F. there are as many degree days as there are Fahrenheit degrees difference in temperature

in the furnace, the former being more adaptable to automotic control, cleaner and more convenient for fuel storage. The operating costs, for fuel, are usually considerably higher when oil is used.

With warm air heating, the furnace, if desired, may be placed in the enclosed space and a fan provided to recirculate the air continually to maintain an acceptable temperature. The quantity of fresh air added is carefully controlled to reduce operating costs. Should the zone be partitioned, air ducts will be required to provide a uniform distribution. This method of heating, being convenient and reasonably cheap, is very popular in the United States, and its use is likely to increase in this country. Where ventilation plant is in use it is sometimes convenient to place finned heating coils in the air duct to heat the air. The heaters may be supplied with hot water or, if limited heating only is required, electric strip heaters may be used. Generally the running cost of electric heating is prohibitive.

An interesting application of electric heating which has been employed with success, though to a limited extent, is off peak thermal storage. Large concrete blocks, each enclosing a heating element, are distributed over the working space and connected to a special circuit which is controlled by a time switch and energised during "off peak" hours at a favourable tariff rate. The blocks are at maximum temperature in the early morning and impart their heat to the space during the working hours.

Radiant heating is provided by the well known cast iron hot water radiators which have been installed in many of the larger public buildings. The term is misapplied, as about 50% of the heating is obtained by convection of air. An oil-fired or solid fuel furnace is usually located in the basement. The installation is expensive and the system is somewhat inflexible but, provided sufficient radiators are properly located in the building and discretion is exercised when partitioning is arranged, reasonable results for the majority of occupants may be achieved.

Steam as the medium for heat transfer is not extensively used in this country, being more applicable to colder countries where temperatures below freezing point are common. Much may be done in buildings to conserve the heat within the space with great advantage to operating costs of heating equipment. The use of thermal insulation such as "Insulwool" or "Thermostop" in ceilings and in wall cavities of framed structures should always be considered where heating is provided. Diagrams indicating methods of connecting radiators in hot water heating systems are shown in Fig. 4. A warm air space heater of the plug-in type available in a capacity of 100,000 b.t.u. and fully automatic in operation is shown in Fig. 5.

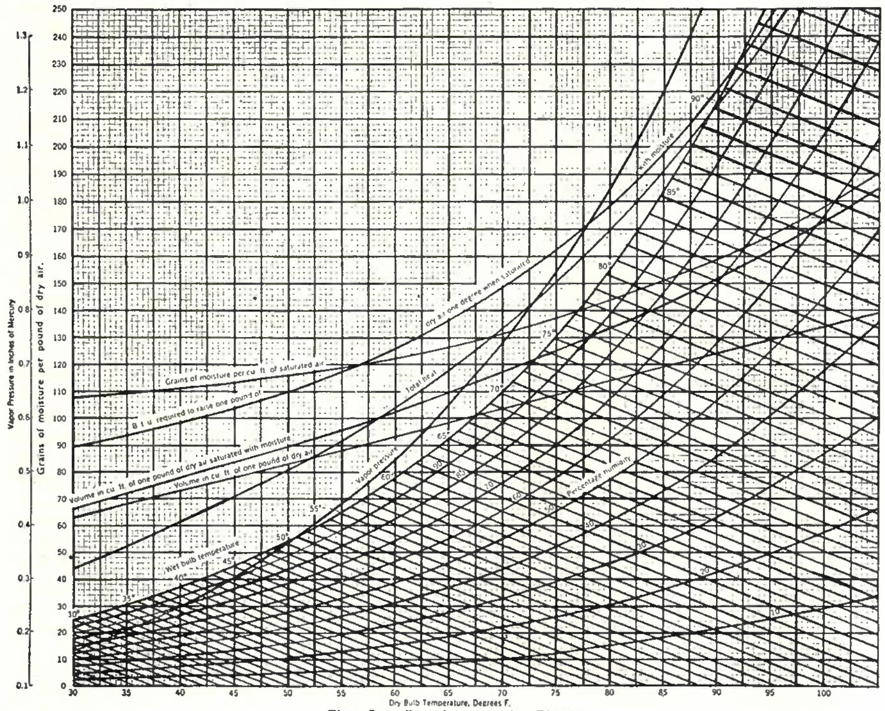


Fig. 3.—Psychrometric Chart.

Ventilation. Natural cross ventilation may be employed satisfactorily in many buildings provided the obvious rules, based on wind forces and temperature differences, are intelligently used. It is not intended, however, to discuss natural ventilation, but to refer briefly to forced ventilation provided by a fan or blower. There are two general classes of fans, namely, centrifugal and propeller.

The former consists of an impeller rotating in a spiral or volute housing. Energy is imparted to the air by centrifugal force, the housing serving to convert part of the kinetic energy of the air into potential energy to overcome friction. Centrifugal fans are used when it is necessary to overcome resistance and may be used under conditions varying from zero resistance to 20 inches water gauge and higher. There are three general types:—

(a) Forward curved blades.

(b) Backward curved blades.

(c) Radial tipped blades.

Each has its own particular field, but, in air treatment, fans with backward curved blades or multivane fans with small curved blades are generally used. Fans with forward curved blades are more prone to overload the driving motor should resistance of the air distribution system be suddenly decreased.

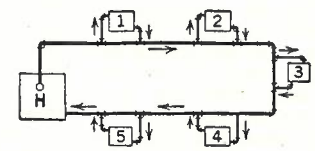
The propeller fan operating within a cylindrical housing imparts energy to the air propulsively. Propeller fans are designed to move large volumes of air against low resistance. They should not be used against resistances above about $\frac{3}{8}$ inch water gauge. For constant speed the horsepower consumed is a minimum when the fan is delivering against free inlet and discharge, and reaches a maximum with zero volumetric delivery. This is important, as many propeller fan motors will burn out when operating against resistance.

In air treatment drafts must be avoided. Air movement up to 25 feet a minute is regarded as still air and the maximum air movement which can be tolerated by persons at rest is about 120 feet per minute. The quantity of air supplied to enclosed spaces in which forced ventilation is provided in the Postal Department varies from 3 to 8 air changes an hour. By far the largest application of fans in the use of small propeller fans for air circulation only.

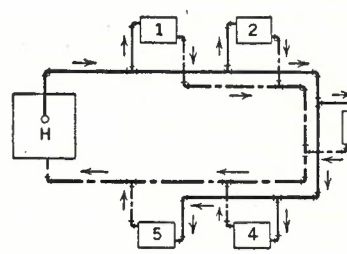
Cooling. Where the air supplied to working spaces must be cooled one of two general methods is usually adopted, namely, evaporative cooling or refrigeration. The former method consists of passing the incoming air through a recirculating water spray chamber in which it is not only washed to remove portion of the dust, but evaporates some of the spray water. The latent heat of evaporation of the water taken up in the process is largely drawn from the air stream, the sensible heat of which may also be reduced in the chamber. With a well designed spray chamber the temperature of the issuing air may be reduced to within a few degrees of the dry bulb temperature, but the air will then be in a condition of almost complete saturation.

If the dry bulb temperature is not too high and the heat load within the treated space is not too great, the saturated air may be mixed with recirculated air to give acceptable conditions of temperature and humidity. It is only in areas where a considerable differential commonly exists between dry and wet bulb temperatures that straight evaporative cooling can be employed with any degree of success, and even in these locations humid days will occur in summer when no benefit, except that due to air motion, will be obtained from the installation.

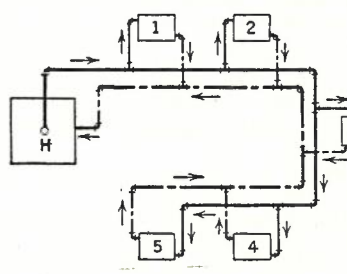
A variation of this method uses two evaporative coolers. The primary cooling unit circulates atmospheric air which, due to the evaporation in the spray chamber, cools the spray water to almost wet bulb temperature. This water is circulated, in the secondary cooler, through a finned coil which reduces the sensible heat of the air entering the secondary spray chamber on its passage to the treated zone. Since dew point has not been reached the absolute humidity remains constant and the dry bulb and wet



(a) One pipe system



(b) Two pipe system reversed return



(c) Two pipe system direct return

Fig. 4.—Hot water heating connections.

bulb temperatures are both lower than that which would obtain in a straight evaporative cooling system. The following illustrates the operation of this system:—

Outside air, 95° dry bulb, 68° wet bulb, 24% relative humidity, 59% absolute humidity.

Primary cooler water, 68°F.

Difference, dry and wet bulb, 27°F.

Finned coil temperature, 68°F.

Allow a reduction of 80% due to the finned coil, then—

$95 - (27 \times 80/100) = 73°$ dry bulb.

73° dry bulb, 59% relative humidity = 60.5° wet bulb, 48% relative humidity.

The wet bulb temperature has therefore been reduced by 7.5°.

If a source of cool water is available to enable the entering air to be cooled below its dew point moisture will condense out of the air and conditions tending to approach those under cooling by refrigeration may be achieved.

Cooling by Refrigeration. The capacity of cooling plant is based on the ton of refrigeration, which is the removal of heat at the rate of 200 b.t.u. per minute or 12,000 b.t.u. per hour. The ton referred to is the U.S. ton of 2,000 lb. In air treatment, when the term refrigeration is employed, the installation of full air conditioning plant is usually implied. The term air conditioning is often loosely applied when heating and ventilating only are provided in an area. True air conditioning is the simultaneous control, in an enclosed space, of the temperature, humidity, purity and movement of the air. An installation which is not capable of regulating all four factors is not an air conditioning plant in the correct sense of the term. Since the heating and ventilating plant will not control the temperature in summer, it must be classed as a partial air treatment plant only. The air conditioning plant will perform the following functions in the enclosed space.

1. Regulate temperature by cooling in summer and heating in winter.
2. Regulate humidity by removing moisture when humid conditions prevail and adding moisture should excessively dry conditions obtain.
3. Remove dust from the air.
4. Maintain acceptable air movement—adequate but without drafts.

The controls may be arranged to operate automatically over precise ranges of temperature and humidity. Since the controls react to the condition of the air the ventilating plant will run in summer and in winter, though in autumn and spring conditions may often be such as to permit the plant to be closed down. The air conditioning plant will, in general, comprise the following equipment provided either as separate units or wholly or partly combined into unit construction.

(a) A boiler or other heat source to enable supply air to be heated.
(b) Refrigeration compressor and evaporator coils which, either directly or by chilled water or other medium, will enable the supply air to be cooled, below dew point, if necessary, to reduce its humidity.
(c) A condenser, often an evaporative condenser, to cool the liquefied refrigerant.
(d) A conditioning chamber in which the air may be treated, heated, or cooled as required, and washed or surplus moisture removed.
(e) A filter chamber in which most of the dust content will be removed.
(f) A fan system to impart motion to the air.
(g) A system of ductwork and regulating baffles to provide control of the air supplied to the space.
(h) A more or less complete system of automatic regulation comprising thermostats (heating and cooling), hygrostats (high and low), and damper motors.

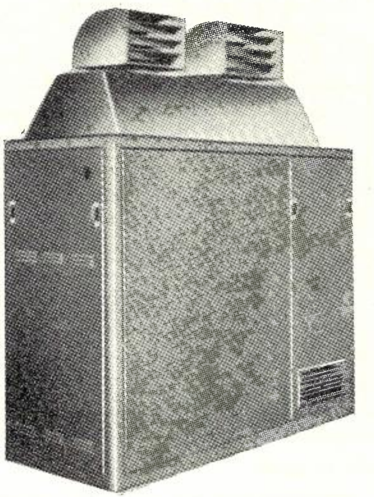


Fig. 5.—Automatic warm air space heater.

The Heat Pump. An interesting development of the application of refrigeration to air treatment is in the use of the heat pump, sometimes somewhat erroneously referred to as reverse cycle refrigeration. With this system the arrangement is to make use of the refrigeration coils when supply air requires cooling and, at such times, to discard the heat drawn from the air and dissipated in the condenser. When it is necessary to warm the supply air the heat from the condenser is used for the purpose. The source of heat at such times is either water or, if ambient temperatures are not below about 40°F, the atmospheric air external to the building. Several installations using this method are in use in automatic telephone exchanges, as for example, Cronulla (9 tons), Pymble (20 tons), Kogarah (12 tons), in Sydney and Ashgrove (6 tons) in Brisbane. The system has most favourable application in areas where the cooling load is greater than the heating load and where the use of atmospheric air as a heat source is favourable. When serving the heating load the heat pump is capable of a coefficient of performance of 4 to 1, that is, for 10,000 b.t.u. heat equivalent of electrical power to drive the compressor 40,000 b.t.u. of heat energy may be delivered to the building from the outside air or other heat source. This is possible because there is a favourable ratio between the heat energy used to drive the pump and that delivered to the building. The former is obtained by conversion to electric energy in an efficient power station where the energy is liberated at high temperature. The air delivered to the building is relatively very close in temperature to the temperature of the reservoir of low grade heat source such as atmospheric air, and therefore it is a question of heat flow to the building rather than conversion of energy.

Many hundreds of installations of heat pump air conditioning are in service in the United States in localities in which less favourable conditions exist than obtain in many areas of New South Wales and Queensland. Although at present the system is somewhat more expensive it is certain that the application of the heat pump will continue to receive increased development in the future.

Air Filtration. In the Department the most commonly used filter is the viscous impingement type, in which cellular metal deflecting surfaces enclosing metal wool or stampings coated with a viscous oil are interposed in the path of the entering air. Dust particles become trapped on the oil film. The filters are arranged in sections for ease of handling and cleaning. Regular cleaning is essential. The resistance is less than that of the "air mat" type and reasonably successful results are obtained except in localities in which heavy concentration of industrial smoke occurs. For air filtering to automatic exchange switchrooms in such areas electric precipitation filters have been found to be effective. Owing to the high cost of these units, however, installation has, so far, been limited to the worst cases. A self-cleaning precipitator is now being manufactured in this country and the self-cleaning feature may offer possibilities which will help to overcome the high cost of filtration by this method.

Conclusion. In a short article which endeavours to embrace the broad field of air treatment little detail can be included, but it is hoped that sufficient information has been given to indicate the basis of the requirement from the viewpoints of physical comfort and equipment needs.

There is little doubt that modern ideas on working conditions will place increasing emphasis on comfort conditions in industrial buildings and the experience which is gained in this Department will provide useful information for the application of increased air treatment to postal activities.

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EXCHANGE INSTALLATION METHODS — QUEENSLAND

C. M. LINDSAY

Introduction

A survey of existing stocks of exchange equipment in Queensland at the end of World War II showed that switchboard cable and ironwork components sufficient for the installation of a number of exchanges were available, but that the limited number of racks in stock made the application of normal methods of exchange installation difficult. As a result, an examination was made of the practicability of installing the ironwork and cabling for an exchange without equipment racks to support them. This showed that such an arrangement was feasible and that a considerable saving in the installation time of the equipment could be obtained. In addition, the cabling could be carried out on the assembled tie-bar and runway system in readiness for installation of the racks.

A trial installation, based on the foregoing was made at the Toowong exchange of 3,600 lines, where the building was ready and cable and ironwork were available, but the exchange equipment had not been delivered. After erection of the runway and tie-bar system, the cabling was run, laced, stripped and formed in advance of the delivery of the equipment. In this installation the runways and cabling were erected in their permanent location near the ceiling. Portable frameworks designed to represent a group of racks were used to locate the ironwork at the 10′ 9½″ level. The method adopted was to complete a section of the overhead ironwork on the supporting framework and, when completed, move the portable framework to a new position, the completed section being supported by temporary pillars and drop tie-rods inserted in the ceiling. Upon completion of the overhead ironwork the cabling system was then installed, and all cable drop lengths stripped and formed out. This work was completed before the delivery of racks took place. Over 100 racks were installed subsequently in this exchange, the first rack being delivered early in August and the last rack terminated in the latter part of November. This represented an appreciable saving in the time that would normally have been involved in the installation of the equipment, and thus considerably advanced the date of cutover.

Subsequent to the Toowong installation, and arising from the experience gained, a further improvement in practices was developed. This provided for the construction of the runway system on the floor of the exchange room, with subsequent alteration to a height of about 3′ 6″ where the cables could be conveniently run and laced. When the cabling is completed the framework is lifted to the required height, and the racks placed in position and terminated. The switches are fixed in position, after adjustment in a switch checking centre. The assembly of ironwork on the floor of the exchange and the running and lacing of cables at a convenient working height saves time, and is less fatiguing to the staff. The saving is appreciably greater with this method than that used in the initial trial at Toowong. On one installation at Camp Hill exchange, which provided for 1,500 lines of equipment on a 4,900 layout, the ironwork was assembled in one day. The total time in lifting of the ironwork, including the first and second stage, was less than a day; all cabling required for this exchange was placed in situ and laced within a fortnight. The methods employed on this installation have since been used for all subsequent major installations in Queensland, with further improvement being made on each new installation. Work at high level on ladders has been eliminated for running cables and assembling the ironwork, and the accident risk has been reduced. During the whole of the assembly of the ironwork and the running in and lacing of cables, the freedom of movement of the installing staff has been greatly increased and restricted areas for working reduced.

Cabling on the raised platform of ironwork is simplified, due to the fact that the cables can be placed in position wherever required. The adjustment of any length of cable is simple compared with previous methods, in which cables are drawn through the runway slat system and men, located at each turning point, prevent the fraying of the braiding and adjust the cables to the correct length. In a companion paper in this issue, by G. E. Dixon, a description is given of the main features of the installation of the Edison exchange in the Central Exchange Building, Brisbane, where the area and quantity of equipment installed was approximately equal to half a large main exchange. In this paper it is shown that the construction methods outlined in the foregoing are equally effective when applied to main city exchanges. Two of the important advantages are that damage to the rack equipment by men climbing over the racks to run and lace cables or assemble ironwork is avoided, and that the dust created by the running of cables is avoided.

A more detailed description of the methods used is given in the following:

(a) Installation of wooden plinths.
(b) Assembly of tie-bar and runway details.
(c) Methods of raising the completed iron work.
(d) The running and lacing of cables.

Installation of Wooden Plinths.

Reinforced concrete floors, due to different degrees of shrinkage in drying out, are never accurately level; variations of up to half an inch can be expected. To overcome these variations in floor level the following practices have been adopted for the installation of the plinth system.

Fig. 1 shows a grid which is based on the layout of 2,000 type racks in an exchange formed by chalk lines along the centre of each row of racks, and a second set of parallel lines at 2′ 3″ centres. Fig. 1 also includes a typical reading of the various rises and falls taken at the intersections of each of the chalk lines, these readings being obtained by the use of a surveyor's level. If the highest reading is expressed as "5.000" datum, then all other readings can be referenced as "falls" to this "5.000" reading. The greatest difference in levels in concrete floors is generally not more than half an inch. The use, therefore, of a plinth shaped as shown in Fig 2, finished 4″ x 2½″, together with packing pieces of timber of varying thickness to adjust to the various falls shown on the level diagrams, will reduce the time required for their installation.

The fixing holes for the plinths are first drilled and the sections of plinth, shaped as shown in Fig. 2, are loosely locked in position. Pieces of timber packing of the required thickness, and about 12″ long, are inserted under the junctions of each side member of adjacent racks, that is at 4′ 6″ centres, and all fixing bolts then tightened to give the first level of the plinths, see Fig. 3. The rebates shown in the sides of the plinths illustrated in Fig. 2 are finally filled in with scantling timber after scribing to the floor contour, thus presenting a flush elevation of the plinth system.

Assembly of Tie-bar and Runway Details.

An assembly drawing is first prepared showing the location of all tie-bars, position, length and types of runways, and associated clamping and fixing members. A typical assembly of portion of the tie-bar and runway details is shown in Fig. 4. A complete assembly of the overhead structure before lifting is shown in Fig 5. For the actual assembly of the ironwork, templates of various types are used, and these are:—

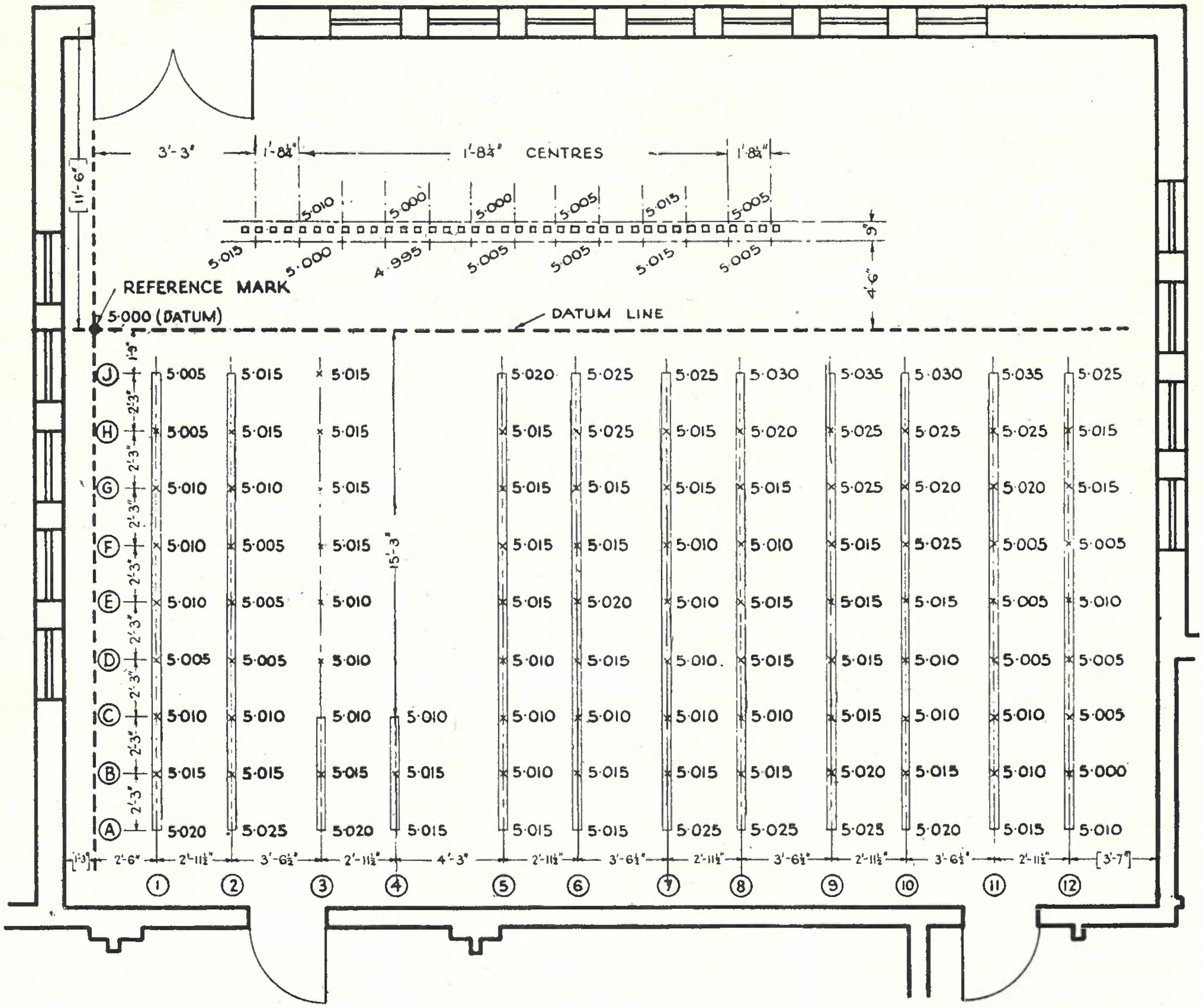
(a) A slotted piece of 5″ x 1″ packing timber to details shown in Fig 6A. This template is used to space the tie-bar system.

(b) Slotted pieces of 3″ x 3″ hardwood to details shown in Fig 6B, used as a lifting beam in subsequent raising operations.

(c) A template of the assembly of a length of tie-bar showing the various clamping pieces used in one complete length, as shown in Fig. 4.

(d) Height gauges for the location of the runway details in both the low level and high level systems, see Fig. 7.

After the plinth system is fixed in position, the 3″ x 3″ hardwood members used for subsequent lifting operations are placed in the centre of the equipment



PLINTH No.	LENGTH REQUIRED	DIMENSION								
		A	B	C	D	E	F	G	H	J
1	18'-0"	1 15/16"	2"	2 1/16"	2 1/16"	2 1/16"	2 1/16"	2 1/16"	2 1/8"	2 1/8"
2	18'-0"	1 7/8"	2"	2 1/16"	2 1/8"	2 1/8"	2 1/8"	2 1/16"	2"	2"
3	4'-6"	1 15/16"	2"	2 1/16"						
4	4'-6"	2"	2"	2 1/16"						
5	18'-0"	2"	2 1/16"	2 1/16"	2 1/16"	2"	2"	2"	2"	1 15/16"
6	18'-0"	2"	"	2 1/16"	2"	1 15/16"	2"	2"	1 7/8"	1 7/8"
7	18'-0"	1 7/8"	2"	2 1/16"	2 1/16"	2 1/16"	2 1/16"	2"	2"	1 7/8"
8	18'-0"	1 7/8"	2"	2 1/16"	2"	2"	2 1/16"	2"	1 15/16"	1 13/16"
9	18'-0"	1 7/8"	1 15/16"	2"	2"	2"	2"	1 7/8"	1 7/8"	1 3/4"
10	18'-0"	1 15/16"	2"	2 1/16"	2 1/16"	2"	2"	1 15/16"	1 7/8"	1 13/16"
11	18 - 0"	2"	2 1/16"	2 1/16"	2 1/8"	2 1/8"	2 1/8	1 15/16"	1 1/8	1 3/4
12	18'-0"	2 1/16"	2 3/16"	2 1/8"	2 1/8"	2 1/16"	2 1/8"	2"	2"	1 7/8"

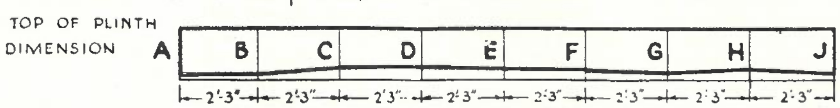


Fig. 1.—Floor levels and plinth details.

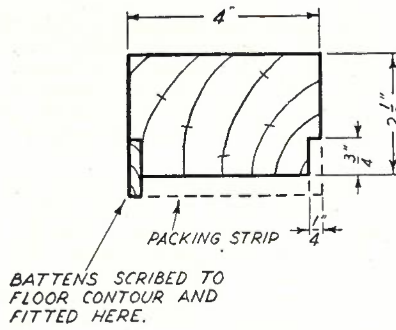


Fig. 2.—Fitting of plinths.

aisle. The 5" x 1" slotted templates for spacing of the tie-bars are nailed to the side of the plinths, the templates being spaced at the first, fifth and ninth line of plinths, etc. The template used to assemble one length of tie-bar system (generally made out of pieces of packing timber joined together) is nailed to the end of the plinth system extending from the front to the rear of the exchange. The individual lengths of tie-bar and all associated clamping pieces are then sorted out in heaps where the assembly of the parts can be carried out with a minimum of movement by the staff.

As each complete length of the tie-bar system is assembled, it is carried over to

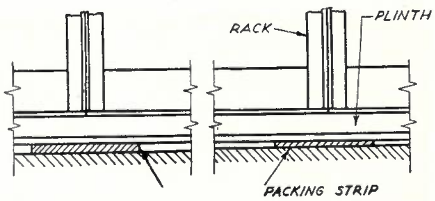


Fig. 3.—Arrangement of plinth packing strips.

the slotted templates, Fig. 6A, which have been nailed to the plinths and placed in the slots provided. There it is adjusted for correct position from gauging marks previously placed on the floor. When all the tie-bar assemblies have

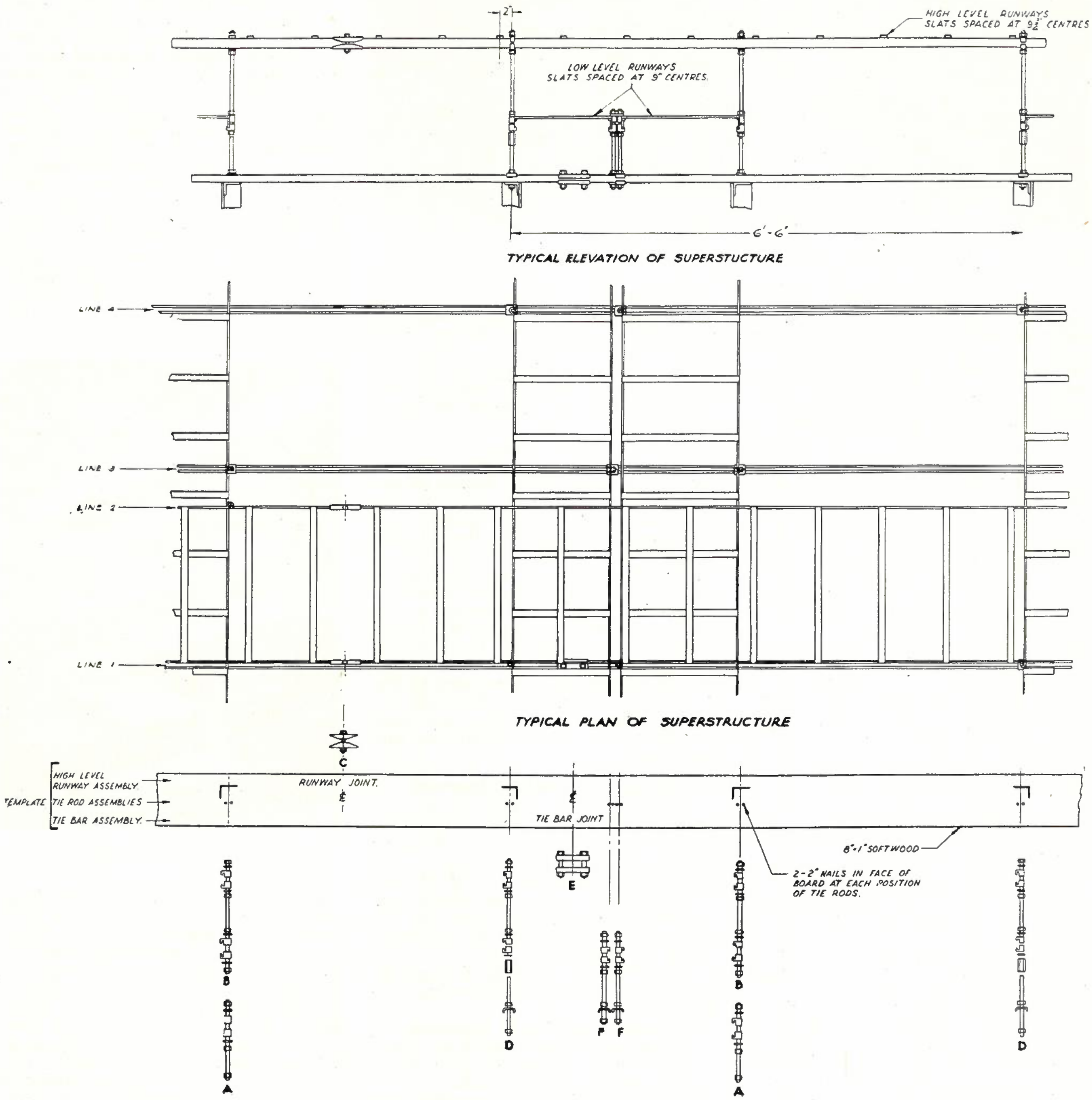


Fig. 4.—Assembly of tie-bar and runway details.

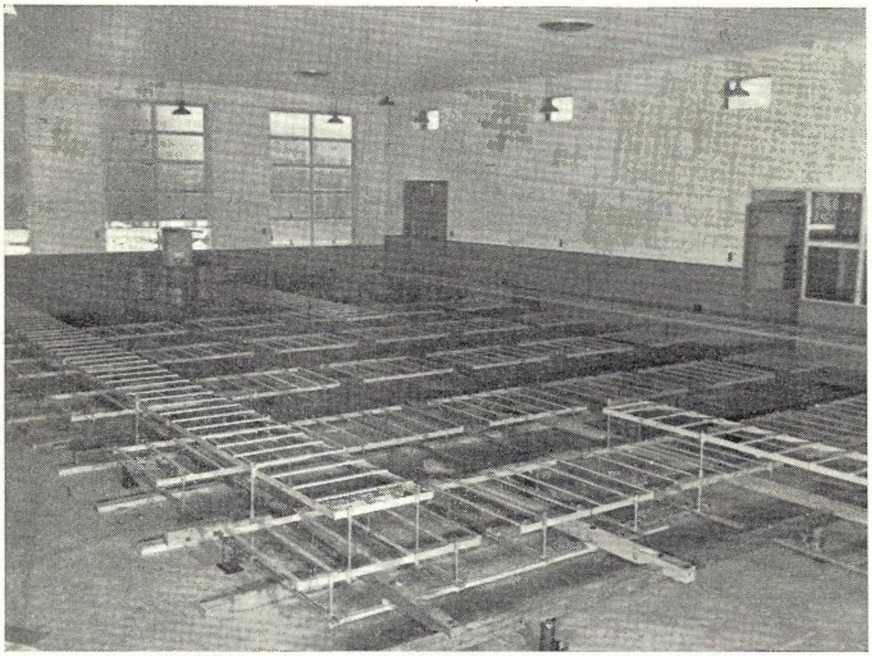


Fig. 5.—Assembly of tie-bar and runway ironwork at floor level.

been located in the slotted templates, the 3" x 3" hardwood lifting beams, which had previously been placed in the equipment aisles, are then bolted to the under face of the tie-bars using clamping plates on the top edge of the tie-bars for a rigid assembly. The wiring and aisle runways are sorted out on the floor of the exchange parallel to the last row of plinths. All longitudinal lengths of runways are sorted out in the aisle at the end of the plinth system. Wiring aisle runways are then carried to their correct location and are clamped in position, being adjusted for height by using the templates shown in Fig. 7.

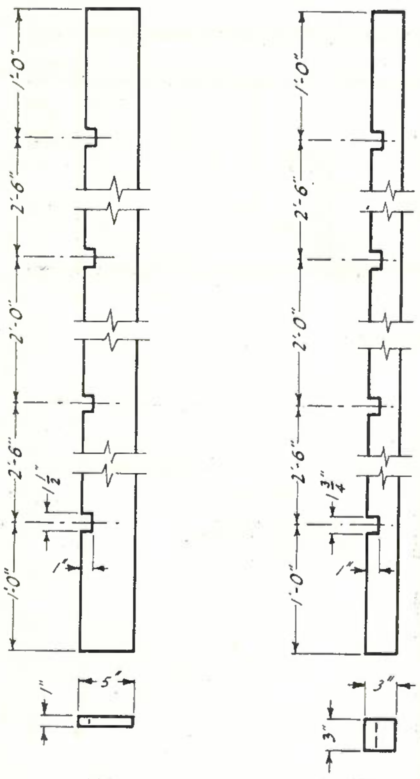


Fig. 6.—Templates for spacing tie-bar system.

When all of the wiring aisle or low level runway sections are finally fixed in position, the longitudinal lengths of runway are moved from the side aisle and clamped and adjusted for height, using the templates supplied for this purpose. Diagonal bracing members of 3" x 3" hardwood, if required, can be fixed in position at this stage. Systems which use continuous lengths of runway in the wiring aisle will not require the use of diagonal bracing members, but it may be necessary in some instances where short lengths of runway, as illustrated in Fig. 5, are used. When all of this work has been completed, preparations are made for the raising of the tie-bar and runway system.

Raising of Completed Ironwork

In this section a description is given of the methods adopted to raise the completed overhead ironwork from its position at ground level to:

(a) a position approximately 3' 6" from floor level where the switchboard cables are laid in and laced; and
(b) the correct height for the positioning of the 2,000-type racks.

The lifting arrangements through the various stages require the following components:

(i) The use of a 3" x 3" hardwood lifting beam fixed centrally in the equipment aisles and bolted to the under face of the tie-bar system.
(ii) Vertical lifting points comprising two tubular steel posts approximately 1' 9" apart. The two posts are placed at right angles to the lifting beam with the beam located in the centre.
(iii) Hydraulic jack support platforms made from a two feet length of tubular steel to which is welded a 6" x 4" steel plate.
(iv) Lifting beam support bar made from a two feet length of tubular steel.
(v) Hanging bracket shown in Fig. 8.
(vi) Hydraulic jacks, each having a lifting capacity of three tons.
(vii) A gauging template made from 3" x 1" timber marked off in one inch sections.
(viii) An index pointer.

A complete assembly of these items, excluding item (v), is shown in Fig. 9. The lift is made with a suitable number of three-ton capacity hydraulic jacks in conjunction with a tubular steel frame work generally assembled as shown in Fig. 10. These lifting points are spaced approximately seven feet apart in each equipment aisle. The tubular steel frame work is leased from firms who generally prefer to assemble their own components. These firms take all necessary details of the staging required and supply and fix in position the various lifting columns and other bracing members. This type of scaffolding is quickly assembled, but care must be taken to ensure that all lifting columns are trued for vertical.

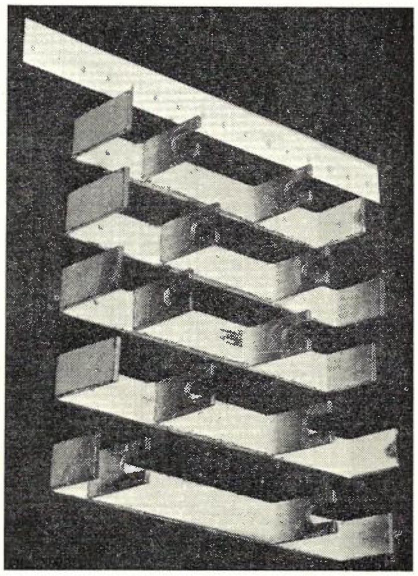


Fig. 7.—Runway spacing gauges.

During the various stages of lifting some of the bracing members are taken down and repositioned. This work is best carried out by Departmental labour to avoid delays, and subsequently when the scaffolding is no longer required, it is best dismantled by Departmental labour since it is only removed piece by piece as the various types of 2,000 type racks are positioned. After the tubular steel scaffolding is in position the raising of the assembled ironwork superstructure is commenced. This involves the appli-

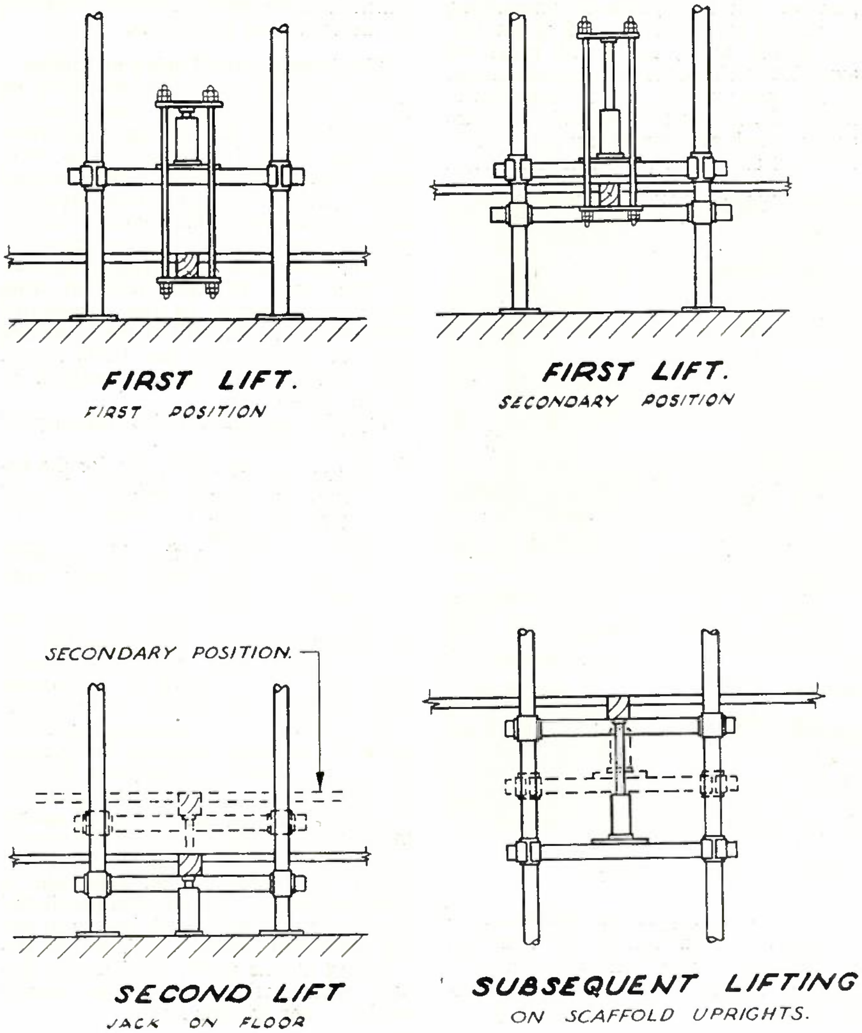


Fig. 8.—Lifting arrangement.

cation of three different lifting methods as follows:—

Stage 1—to lift the ironwork initially from the floor level to permit stages 2 and 3 to be applied;

Stage 2—to lift the assembly to the height where cabling is carried out, that is, 3′ 6″ from floor level;

Stage 3—final lifting stage to a point where the under face of the tie-bars is 10′ 6″ from top of plinth.

Stage 4—Dismantling of scaffolding and erection of racks.

Stage 1. The initial lift from floor level is made with the assistance of hanging brackets as illustrated in Fig. 8. The hydraulic jack platform is temporarily clamped to the lifting columns above the 3″ by 3″ hardwood lifting beam and the hydraulic jack is compressed and set up on the platform. The hanging bracket is made up of a short length of 3″ by 3″ hardwood with two half-inch rods which extend from this hardwood member to approximately two inches below the main support member, and on each side of it. The fitting in position of a half-inch piece of steel below this hardwood beam completes the hanging bracket. Sliding the platform pipe upwards until the slack is taken up and then locking this support to the scaffolding post, enables the first stage of the lift to be carried out. When the hanging supports are in position, all of the hydraulic jacks are pumped at the same time and the superstructure is lifted approximately eight inches over its complete area. At this stage the supporting bar is clamped to the lifting columns directly underneath the hardwood lifting beam and is locked in position. The hydraulic jacks are now released and removed, and the hanging brackets are dismantled. The hydraulic jacks are then located immediately under the main 3″ by 3″ hardwood beams, using the floor as the supporting base. Small pieces of packing timber may be required to take up the variations in floor level and to enable the full lifting range of the jack to be used. With all hydraulic jacks in position, they are again pumped until fully extended, the ironwork superstructure then being approximately 1′ 4″ from floor level. The support pipe is unclamped and moved up to the underside of the hardwood beam and again clamped.

Stage 2. The platform bar is removed from the scaffolding post and located approximately eight inches below the supporting beam so that the compressed hydraulic jack can be inserted in this space. The pumping of all hydraulic jacks at the same time raises the ironwork superstructure a further eight inches. The support pipe is unclamped, slid upwards to the underside of the hardwood beam and reclamped. These two steps are repeated until the ironwork is located at a reasonable working height for the running in and lacing of cables. In order that the support platform and the support bar will not interfere with each other, they are located on opposite sides of the lifting columns throughout the whole stage of the lifting operations. Apart from the initial lift the sliding bar is located above the platform bar in all stages of the lift. When the under face of the tie-bar system is approximately 3′ 6″ from the floor level, a 3′ 6″ template is used to gauge the height from the plinth face so that a uniform and level surface is obtained throughout the whole structure. At this point the cabling work required for the exchange is carried out.

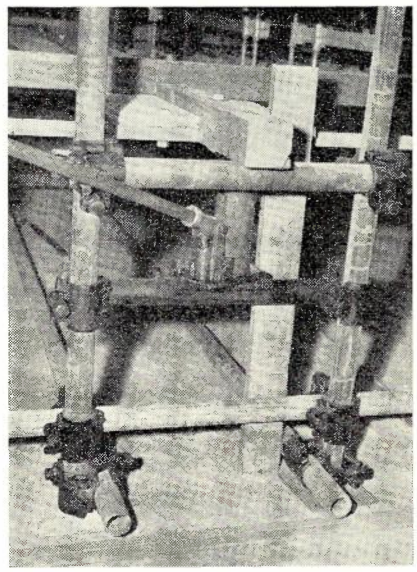


Fig. 9.—Lift in progress.

Stage 3. The final lifting stages of raising the superstructure together with the cable system required greater care to prevent flexing of the whole structure while this lift is in progress. So that the lift is made uniformly, coloured templates, marked off in one inch sections coloured alternately red and blue, are fixed to the support beam and hang vertically. Index pointers are fixed to the lifting columns and the officer controlling the lifting operations issues instructions as to the amount of lift required at all points. The order is given to pump the height equivalent to one blue section on the template, and each jack moves the structure up until the pointer just enters into the red marking. The order then is given to lift the height of one red span and this procedure is continued so that the lift is made uniformly and continuously to a blue or a red until the whole ironwork assembly is lifted to the full extent of the hydraulic jack. The support bar is then moved up below the support beam and clamped in position. The hydraulic jacks are released and the support platform is moved up so that the compressed jacks can be inserted. The lifting is carried on again as described earlier until, finally, the whole structure is positioned with the under face of the tie-bar system 10′ 6″ from the top face of the plinths. A 10′ 6″ gauging template is used to prove the level over the whole area. Before the final lifting stage s completed, it may be necessary to remove part of the bracing system of tubular steel from above to below the runway system due to the fact that the scaffolding posts may not be sufficiently high to permit the top level of cable to be raised to its correct height.

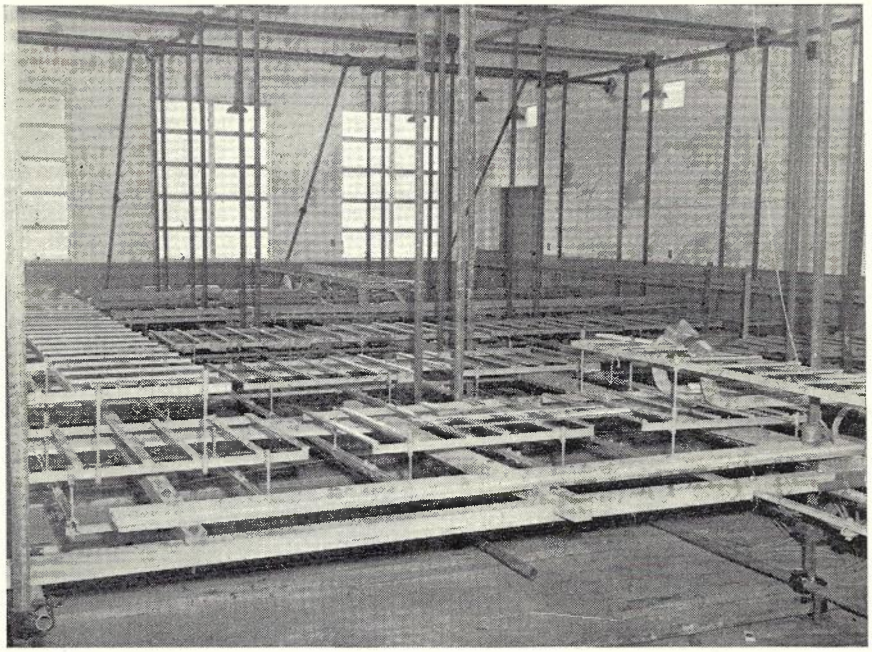


Fig. 10.—Structure lifted to cabling height and cabling commenced.

Stage 4. It is necessary to dismantle the tubular steel scaffolding, so that the racks required for the installation can be placed in position. This can be carried out by removing the scaffolding from one end of the floor area and by replacing it at selected positions by 3″ by 3″ hardwood posts placed vertically under the support beam. These are packed up as required so that the true 10′ 6½″ level is not disturbed. As one set of lifting columns in an equipment aisle is removed, the racks can now be brought into position and placed on the plinths. The lifting columns in the next equipment aisle can then be removed, supporting the main hardwood member with the 3″ by 3″ hardwood posts, and the racks brought into this line. This process can continue until the complete racking system is in situ. It is not imperative that the system of dismantling be carried out from one end of the layout to the other, but if all racks are available it offers the greatest advantage. If the racks available are not sufficient to permit the removal of the superstructure as described, sections at any part can be removed and racks placed in situ. When all racks are in position and the scaffolding has been completely removed, the tie-bar system, which extends beyond the first and last row of racks, is completed by the addition of small pieces which lock the whole overhead structure to the front and rear walls.

The Running and Lacing of Cables.

The running and lacing of cables on the runway and tie-bar superstructure, which is located at standing height from the floor level, introduces a new technique, due to the fact that the racks are not in position for the determination of cable length from the runway to terminating points. To run cables under this system, statements are prepared indicating the length of cable required from the runway system to the terminating point on the racks both at the beginning and end of each run. See Table No. 1. The running of the cable is assisted by the use of:—

(i) special cradles for the forming of cable sections,
(ii) two measuring sticks, one for the beginning of the run and one for the end of the run, to mark the drop lengths of cable,
(iii) labels attached to the side members of the runways where cables drop through the slats.

The cable is drawn from the drum and the length of drop at the end of the run is first marked with an indelible pencil. The cable is then fed on to the runway and let into its correct position in cradles which are located at selected points. The cable is fed down between the runway slats at the indicated drop point, and the indelible marking, showing the length of the feed down the rack, is held against the slat. The cable is adjusted for correct length back to the point where it first enters the runway system. This point is then marked with an indelible pencil and the second measuring stick is used to add the additional length required for termination at this point. Cradles are also used where cables leave one runway level to enter another level.

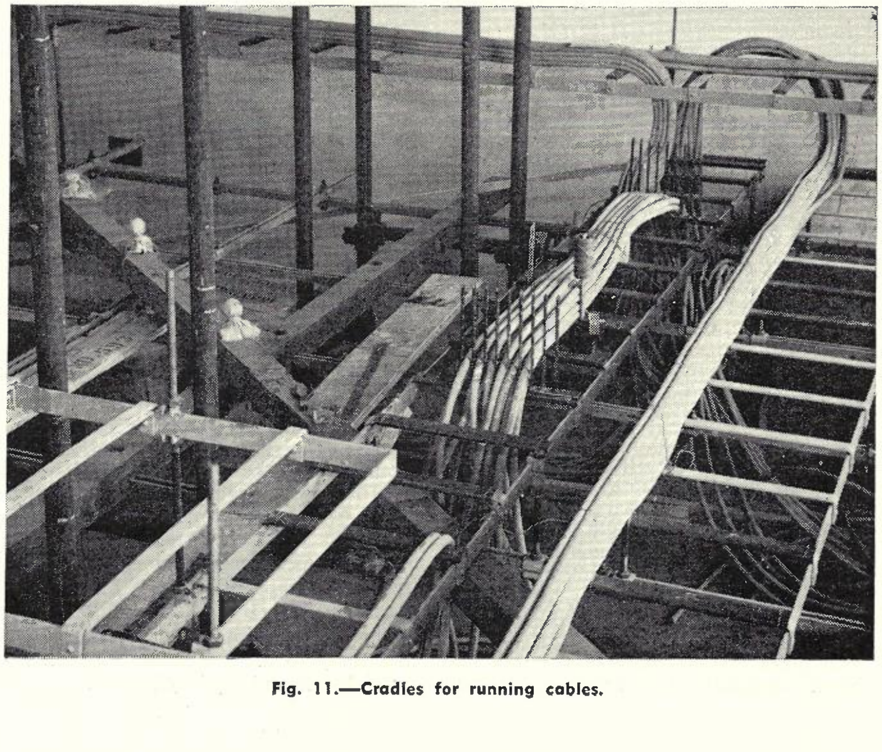


Fig. 11.—Cradles for running cables.

Table No. 1
Cable Run U.S. to T.D.F.1 78 Wire

Uniselector rack cable drop lengths			T.D.F. rack cable drop lengths		
Designation	Terminated on	Length	Designation	Terminated on	Length
T.D.F. S/ 1	U.S.1 A-D	10′	U.S.1 A-D	T.D.F.1A. S1 1	12′ 6″
,, ,, 2	,, E-H	7′	,, E-H	,, 2	12′ 6″
,, ,, 3	,, T-M	4′	,, T-M	,, 3	12′ 3″
,, ,, 4	U.S.2 A-D	10′	U.S.2 A-D	,, 4	12′ 3″
,, ,, 5	,, E-H	7′	,, E-H	,, 5	12′
,, ,, 6	,, T-M	4′	,, T-M	,, 6	12′
,, ,, 7	U.S.3 A-D	10′	U.S.3 A-D	,, 7	12′ 9″
,, ,, 8	,, E-H	7′	,, E-H	,, 8	11′ 9″
,, ,, 9	,, T-M	4′	,, T-M	,, 9	11′ 6″
,, ,, 10	U.S.4 A-D	10′	U.S.4 A-D	,, 10	11′ 6″
,, ,, 11	,, E-H	7′	,, E-H	,, 11	11′ 3″
,, ,, 12	,, T-M	4′	,, T-M	,, 12	11′ 3″
,, ,, 13	U.S.5 A-D	10′	U.S.5 A-D	,, 13	11′
,, ,, 14	,, E-H	7′	,, E-H	,, 14	11′
,, ,, 15	,, T-M	4′	,, T-M	,, 15	10′ 9″
,, ,, 16	U.S.6 A-D	10′	U.S.6 A-D	,, 16	11′ 6″
,, ,, 17	,, E-H	7′	,, E-H	,, 17	11′ 6″
,, ,, 18	,, T-M	4′	,, T-M	,, 18	10′ 3″
,, ,, 19	U.S.7 A-D	10′	U.S.7 A-D	,, 19	10′ 3″
,, ,, 20	,, E-H	7′	,, E-H	,, 20	10′
,, ,, 21	,, T-M	4′	,, T-M	,, 21	10′
,, ,, 22	U,S,8 A-D	10′	U,S,8 A-D	,, 22	9′ 9″
,, ,, 23	,, E-H	7′	,, E-H	,, 23	9′ 9″
,, ,, 24	,, T-M	4′	,, T-M	,, 24	9′ 6″
,, ,, 25	U.S.9 A-D	10′	U.S.9 A-D	,, 25	9′ 3″
,, ,, 26	,, E-H	7′	,, E-H	,, 26	9′ 3″
,, ,, 27	,, T-M	4′	,, T-M	,, 27	9′
,, ,, 28	U.S.10 A-D	10′	U.S.10 A-D	,, 28	9′
,, ,, 29	,, E-H	7′	,, E-H	,, 29	8′ 9″
,, ,, 30	,, T-M	4′	,, T-M	,, 30	8′ 9″
,, ,, 31	U.S.11 A-D	10′	U.S.11 A-D	,, 31	8′ 6″
,, ,, 32	,, E-H	7′	,, E-H	,, 32	8′ 6″
,, ,, 33	,, T-M	4′	,, T-M	,, 33	8′ 3″
,, ,, 34	U.S.12 A-D	10′	U.S.12 A-D	,, 34	8′ 3″
,, ,, 35	,, E-H	7′	,, E-H	,, 35	8′
,, ,, 36	,, T-M	4′	,, T-M	,, 36	8′
,, ,, 37	U.S.13 A-D	10′	U.S.13 A-D	,, 37	7′ 9″
,, ,, 38	,, E-H	7′	,, E-H	,, 38	7′ 6″
,, ,, 39	,, T-M	4′	,, T-M	,, 39	7′ 6″

A shaped block is clamped in position where major changes in level take place so that the roll of the cable is smooth and free from kinking. If layers of cables are changing from a vertical to a horizontal position in the cable block, or from a high level to a low level runway, spacing pins can be placed in the cradles to keep the cables in their correct position. The use of the cradles for positioning the various lengths of cable avoids the use of temporary lacing twine ties. A complete block section of cable can be run before the block lacing of the cables is necessary. The identity of the rack cable in the block is retained throughout its length of run. Fig 11 illustrates the use of these positioning cradles throughout various stages of the running in of the cables.

Design of Cabling System

A typical cabling plan and a cross section of the cables on the runways, is shown in Figs. 12 and 13. The preparation of these details, if based on the general practice of pencilling in positions of each cable group on prepared layout of the exchange, is both tedious and time-consuming. The allocation of the positions of cables on runways, found necessary when checking the preliminary plan, can only be obtained by rubbing out and redrawing. If the installation being planned is for a major exchange, then much trial and error is necessary before a suitable plan can be finally obtained.

Most of this tedious preparation of the cabling details by the engineering and drafting sections and, later by the installing staff, can be avoided if the methods detailed hereunder are applied. The planning of the cabling system for an exchange can be simplified if a large scale drawing of the floor plan, generally one and a half inches to a foot, is first prepared. Details required on the plan are:—

(i) The outline and title of all racks used in the installation.

(ii) A single line indicator of the locations of the various runways used.

The outline of cable runs can be quickly assessed by the use of narrow width paper streamers of various colours to represent each individual run. The streamers are pinned initially into position without attempting to locate them correctly in respect to each individual cable run; the main idea being to block out with the coloured streamers on the plan an outline of the different runs required. When this preliminary colour streamer plan has been completed it is then a simple matter for the correct placement of each group of cables to be determined. An inspection of the plan will show where runs of cables are likely to interfere with other runs and by simply withdrawing the pins and repositioning the paper streamer to correct position, the full outline of the cabling system is quickly determined. When the preliminary outline cabling plans have been prepared in this manner the widths of the runways required for each section of the system can then be selected. By referring to a chart, which lists the size of the cable, the number of conductors, grouping of the conductors, the number of wires in each individual circuit, and the number of circuits to be connected, initially and ultimately, the designing officer can prepare the cable block sections and from this determine the width of runways required. Noting these various cable block widths at selected points on the preliminary plan, and adding the width dimensions of the various cable sections, the width of the various runway sections can be readily assessed.

Instructions for the installation of the cables in the field are also simplified if a directional cabling chart for each individual run is prepared of a cable block, showing full details of change in position of runway, drop off points and change of level, together with details of each rack feed. A typical drawing, Fig. 14, shows a completed section of cables for one individual run. These sectional running charts enable the installing staff to locate quickly the cables in position and replaces all field work preparation of cable running details.

Handling of Racks.

The handling of heavy racks of equipment has been considerably simplified by the use of mechanical aids. All racks of equipment required for installation in exchanges are uncrated in the storage area and are delivered to the exchanges as required ready for erection. The mechanical aids used in the storage area are:—

(i) a travelling gantry,

(ii) a cradle for extracting racks from the cases,

(iii) a cathead and travelling hoist for unloading and loading of racks,

(iv) a racking area where the uncrated racks are stored in a vertical position prior to their delivery to the exchanges,

(v) a tilting devise for vertical storage of racks.

In Fig. 15 the travelling gantry is shown positioned over an opened crate, and the cradle is shown fixed to the sides of the rack which has been removed from the case.

Delivery of Racks to Exchanges. Three slotted hardwood members are

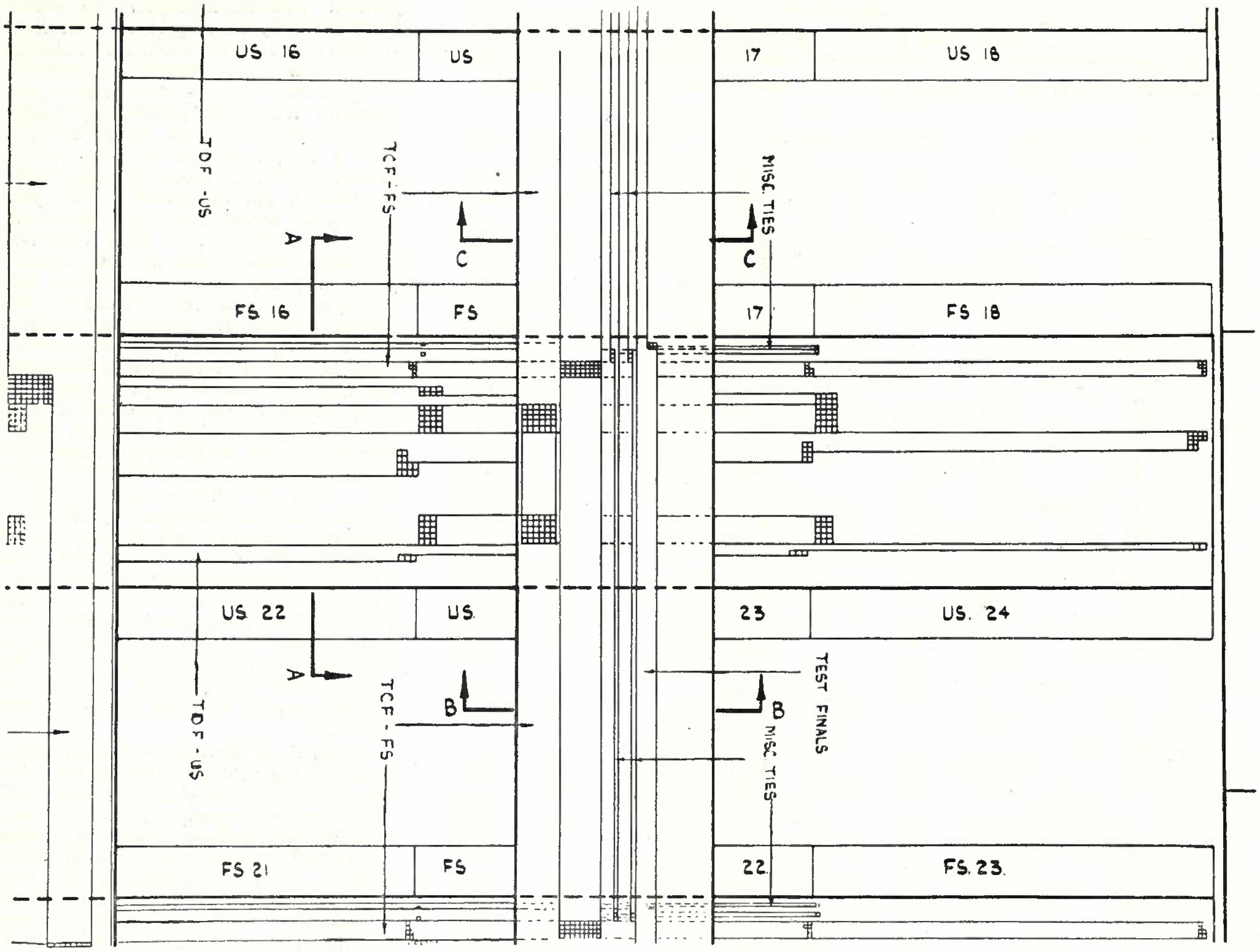


Fig. 12.—Part of cable plan for an exchange.

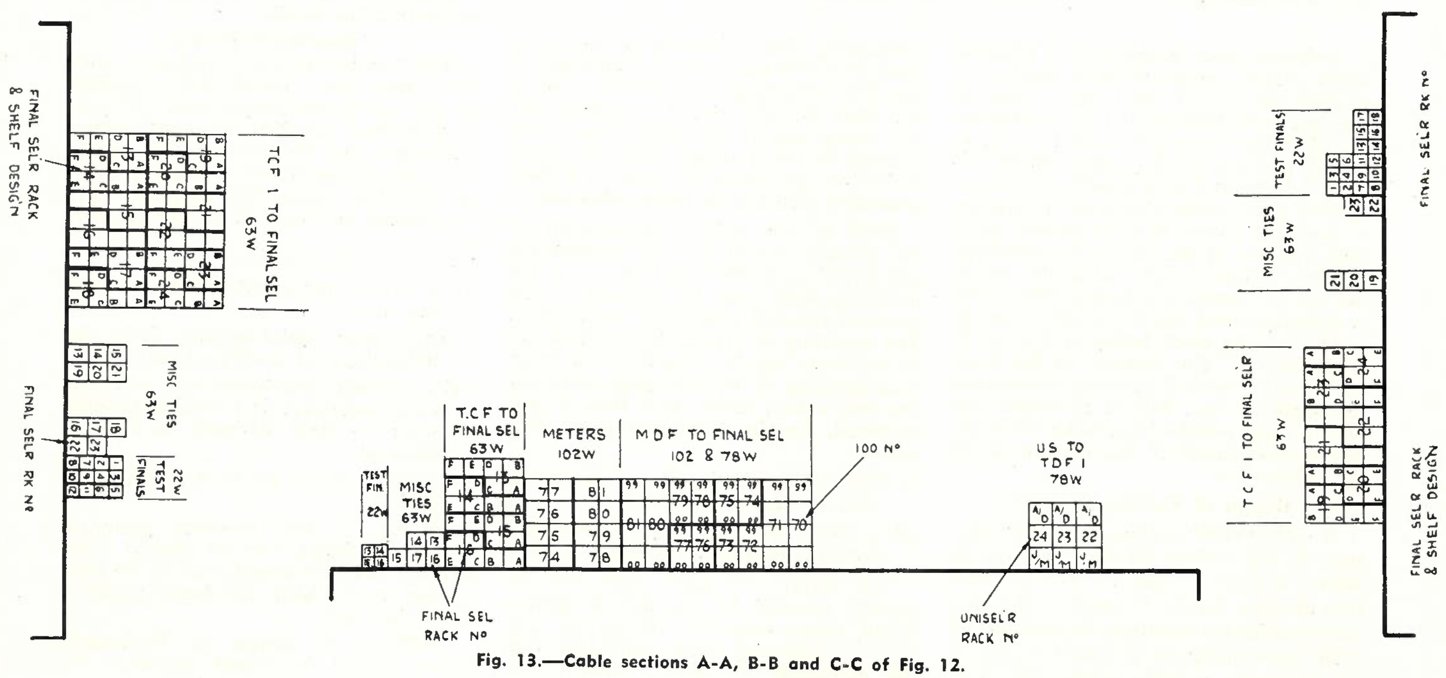


Fig. 13.—Cable sections A-A, B-B and C-C of Fig. 12.

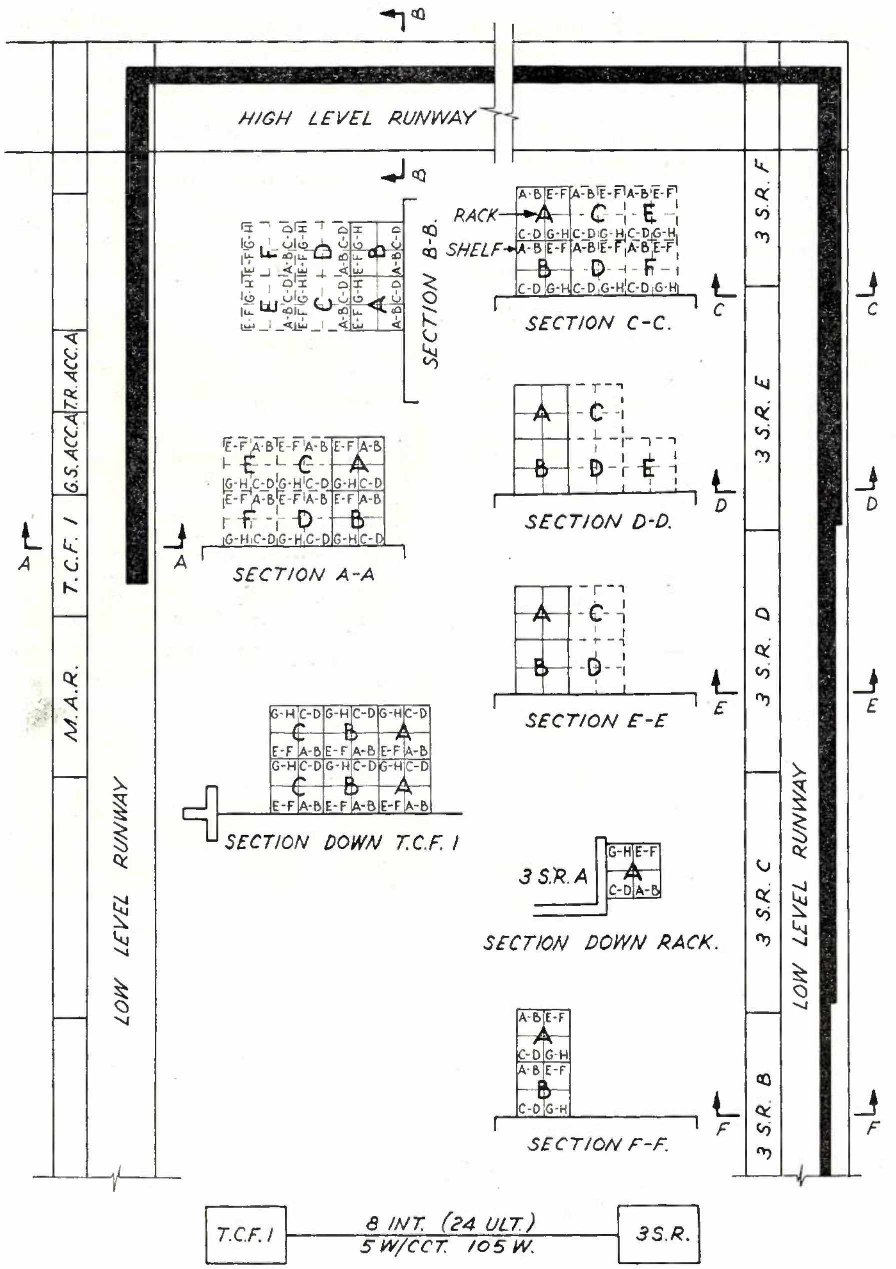


Fig. 14.—Cabling chart.

laid on the lorry deck spaced about four feet apart and three 4′ 6″ racks carried on edge are taken on each trip, a set of clamping members being used to brace the racks during transport. See Fig 16. The loading operation is: rack one is lowered from the cathead to one set of slots in the hardwood members and an offset bracket, fixed to the hardwood member, is bolted to the fixing holes on the top edge of the first rack. Rack two is then lowered into position in the second set of slots and small braces are tied from it to the first rack. The third rack is braced to the second in a similar manner and the second set of offset brackets again fixed from the latter to the hardwood members. The three racks are covered with a tarpaulin to prevent damage due to weather and dust during transport.

Handling of Racks in Exchanges. The design of the mechanical aids used to position the racks in the exchanges was based on the use of not more than three men for any one operation. The main items used for mechanical handling of racks are:—

(i) A device which is used to transport the rack from the cathead to selected positions in the exchange and subsequently to permit the rack to be tilted from its horizontal carrying position to a vertical plane, see Fig. 17.

(ii) A set of 4″ x 2″ channel irons fixed to the side of the racks for wheeling into the equipment aisles.

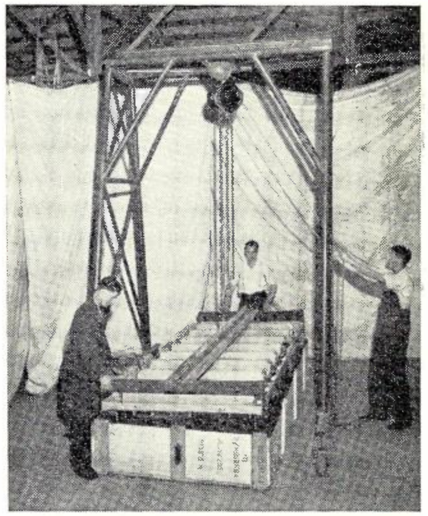


Fig. 15.—Travelling gantry.

(iii) Lifting jacks fitted in these channel irons for raising the rack about one inch from floor level, see Fig. 18.

(iv) Inclined rollers used to position the base of the rack on the plinths, see Fig. 19.

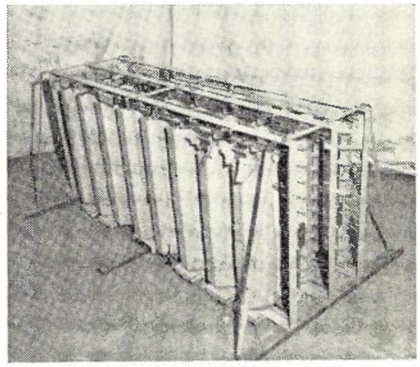


Fig. 16.—Transporting of racks.

(v) Rolling devices fitted to the tie-bar system for anchoring the head of the rack.

In conjunction with these aids, the following items are also used:—

(a) A set of posts which are fitted temporarily to the racks to avoid crushing of the wiring forms when racks are lowered to floor level, with the wiring side facing the floor.

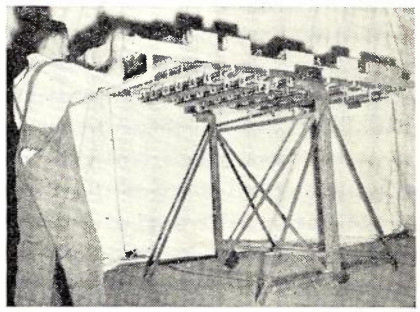


Fig. 17.—Rack transporter.

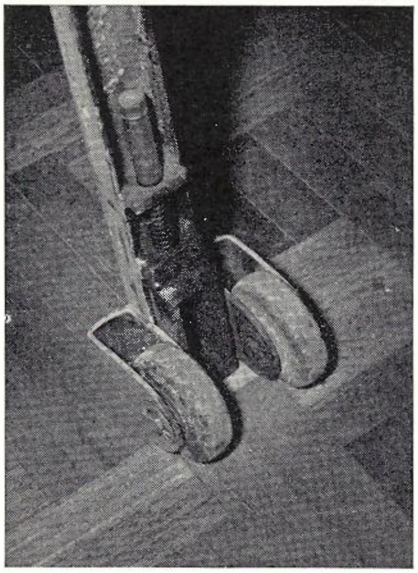


Fig. 18.—Lower end of channel iron showing lifting jack.

(b) A special track used to guide the head of the rack along equipment aisles.

(c) Two bolts of special construction are used in the top angle for holding the rack in a vertical plane. They are held in position by keeper plates which permit easy extraction.

Procedure in Exchanges. When the racks are delivered to the exchange, each rack is lifted from the lorry decking and taken into the exchange by the normal hoist and cathead provided for this purpose. The various stages of handling in the exchanges are:—

(i) Before lowering the rack to floor level, four metal posts are fixed to the four corners of the rack so that when the rack is finally lowered, wiring side down to the floor, crushing of the forms is avoided.

(ii) Two wire slings are next fixed to the four corners of the rack and the rack is lifted in a horizontal plane approximately five feet from the floor level.

(iii) The tilting device is wheeled under the rack and it is then lowered into the two side clamping plates and fixed in position, using the holes which are centred on the side of the rack. Special high tensile steel bolts are used to avoid shearing.

(iv) The slings are now removed and the rack, in a horizontal plane, is wheeled into one of the side aisles at the end of the rows of equipment and positioned so that when the rack is finally tilted into a vertical plane it is standing central and opposite to an equipment aisle.

(v) With the two special guide bolts, see Fig 20, in the top angle of the rack, it is tilted, and with the gates in the special tracking open, the two bolts can enter into the centre of the channel. The closing down of the two gates holds the rack in a vertical plane. The tilting device is next unbolted from the rack and removed. One of the cross bracing members which joins the extremities of the side bracing members of the tilting device is a detachable unit and its removal permits it to be wheeled away from the rack.

(vi) The two 4" x 2" channel irons are clamped to the side of the rack. The top fixing hole in these side members is so located that it is approximately ⅜" higher from floor level when standing in a vertical position compared with the centre hole in the side of the rack. By fixing the channel irons first with the two top bolts to

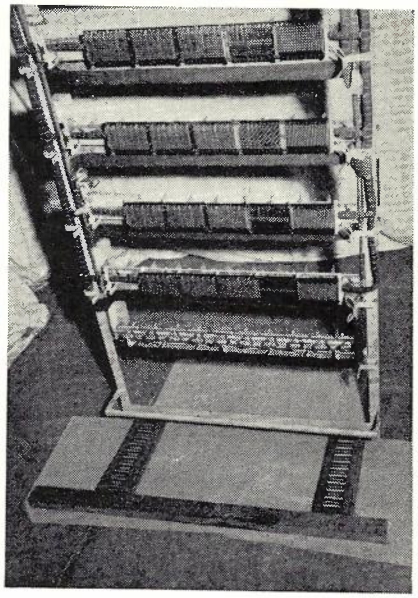


Fig. 19.—Inclined rollers.

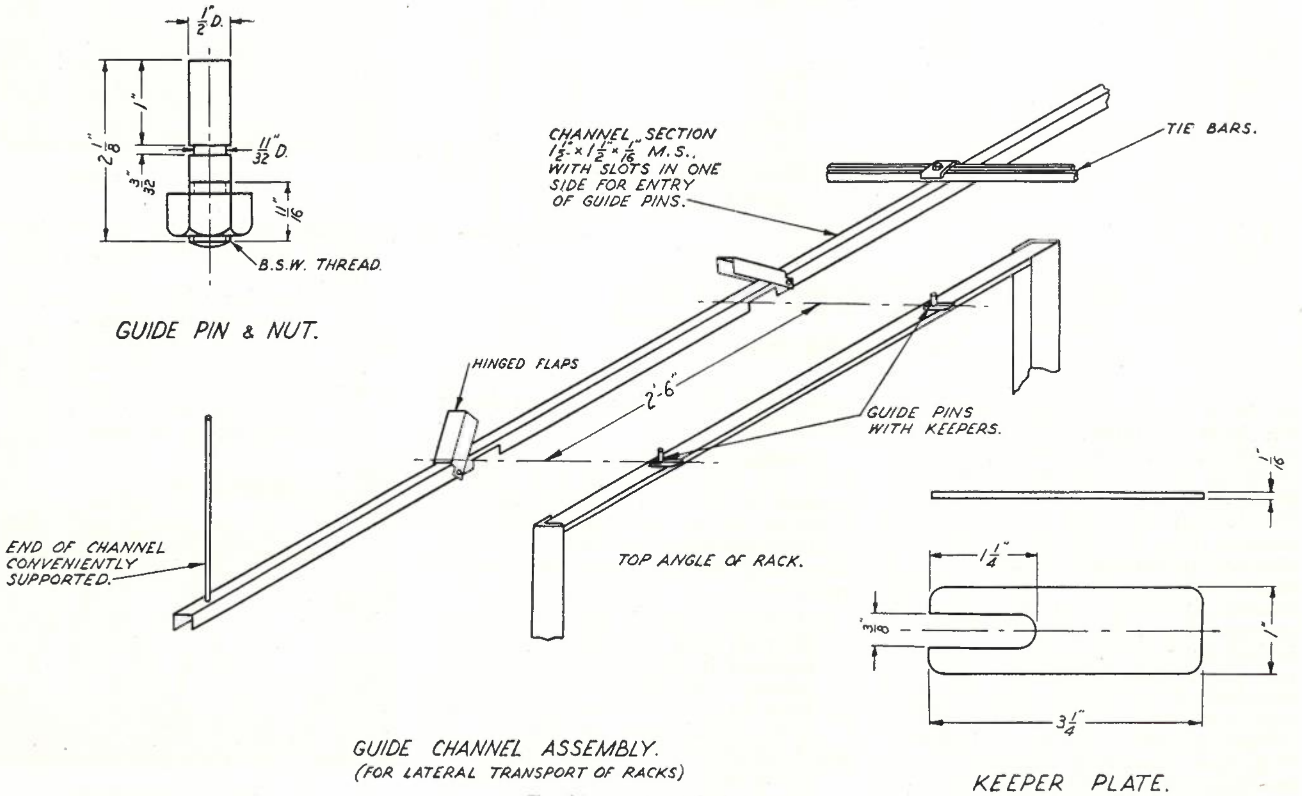


Fig. 20.—Rack guide bolts.

the side of the rack and forcing the lower ends inward to the face of the side angles of the rack, the rack is raised approximately ⅜" from the floor level. The rack can now be wheeled along the equipment aisle to its ultimate position along the plinth system.

(vii) The two special fixing bolts shown in Fig. 20 are withdrawn from the top angle of the rack and the head is moved so that the fixing bolt in the tie-bar rollers enters the tie-bar hole in the top angle and locking the holding nut, enables the rack to be held vertically.

(viii) The two jacks in the side channel member are now used to raise the base of the rack approximately one inch from the floor level.

(ix) The two special rolling devices used at floor level, Fig. 19, are now positioned under the rack. The head of the rack is held back against the small channel fixed to the tie-bar system, the base of the rack is forced up the inclined roller plane with the result that the rack quickly slides into position on the plinth. The head of the rack is then forced over until it is standing vertically on the plinth. The two rolling devices are removed, the tie-bar fixing bolts are placed in position and the rack is clamped to the tie-bars.

The selection of the racks required in any particular row, and the delivery of these in sequence from the storage area, enables the greatest use to be made of the tracking system which is only removed when the equipment has been located on the plinths on the opposite sides of the equipment aisle. The dismantling of the overhead guide track, and repositioning in the next equipment aisle permits the next series of racks to be positioned.

EXTENSION OF EDISON EXCHANGE, BRISBANE

G. E. K. DIXON

In the associated paper in this issue by C. M. Lindsay a description is given of the design and trial of a new method of installation of exchange equipment. In this paper a description is given of the method as applied to the installation of additional equipment in the Edison Exchange, in the Central Exchange building, Brisbane. The description of the installation will deal with some aspects of the principles described earlier, but also includes particular problems associated with an extension to the original installation.

The Edison Exchange, which is the "F" main switching centre, is located on the ground floor of the Brisbane Central exchange building, and occupies a floor area of approximately 100 feet by 40 feet. An initial part of this exchange was brought into service in August, 1949, the equipment being installed in the manner described in the accompanying article. The actual area occupied by the racks was 34 feet by 24 feet and thirty 4′ 6″ racks and fifteen minor racks were provided. The extension equipment is installed in an area approximately 40 feet by 60 feet, and provides for the ultimate installation of 134 racks made up of 103 4′ 6″ racks and thirty-one minor racks. The racks in the present installation totalled ninety-seven, comprising sixty-six 4′ 6″ racks and thirty-one minor racks, and the cabling was provided for the ultimate number of racks. Those cables not required for the initial cutover were tied back under the runway system. This installation introduced the problem of linking up with an existing section, with the additional problem of installing some cables on the new section, which ultimately had to feed to or from various equipment units in the original area and also to the M.D.F. The installation has shown, however, that the principle involved in this type of installation can be applied to either an initial installation or to a major extension.

The extension to the Edison exchange equipment provides for 2400 lines of small P.B.X. services, and includes twenty-four racks of large P.B.X. final selectors. The installation of the equipment was commenced in April, 1951, in an area encumbered by a number of partitions and other exchange service equipment which had to be removed before the assembly of the ironwork at ground level could take place. On 1/5/51, the assembly of all ironwork and lifting bearers was completed. The clear ceiling height in the switchroom is 15′ 9″, and this permitted the use of fifteen feet lengths of tubular scaffolding for the uprights. The high ceiling also enabled the longitudinal and transverse top braces to be fitted at fourteen feet from the floor level, that is, above the top level of the cabling, and this avoided changing the top bracing to the midway position during the main lift, as is required in switchrooms which only have a 13′ 6″ ceiling height.

After the erection of the tubular scaffolding, the assembly was lifted to cabling height, that is, 3 feet 6 inches from the floor, to the under face of the tie-bars, and cabling commenced, see Fig. 1. Particular attention was paid to cable lengths, charts being supplied to the staff showing the lengths to reach the terminal strips on all types of racks. As the cables were finally laced in position on the runway, bends were formed and all spare lengths from the drop-off were coiled and fastened to the under side of the tie bar to prevent distortion of the bend during lifting. This is illustrated in Fig. 2.

A problem arose at the outset in connection with the cables from the final selector and 2nd selector Trunk Con-

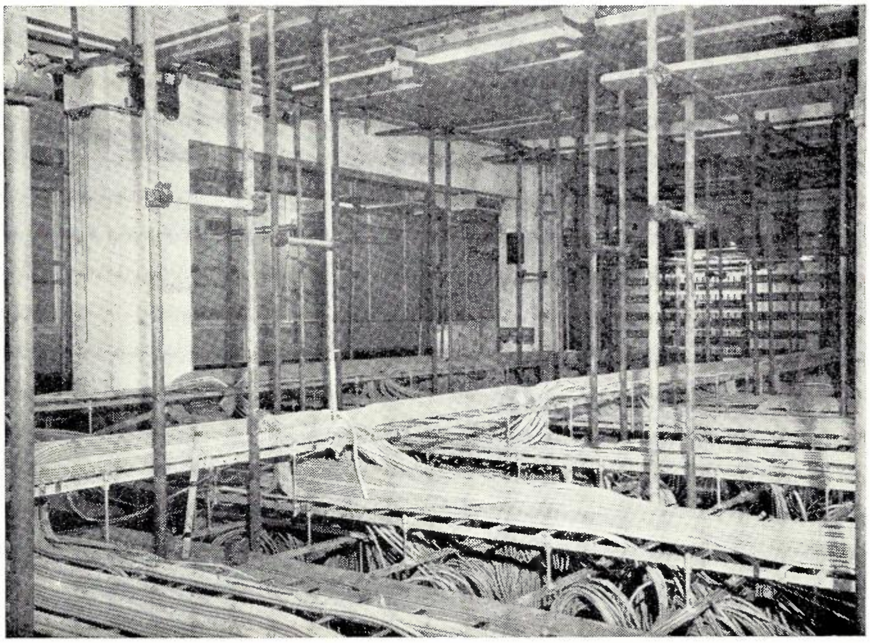


Fig. 1.—Assembly lifted to cabling height.

necting Frame to the M.D.F. The main frame and the switchroom are located on the one floor of the building, and an average length of forty feet had to be left on all of these cables to allow for the run from the switchroom assembly to the M.D.F. This additional length was turned back along the high level runway, resulting in a load of 100 lbs. to the foot in this section of runway. This was considered to be too great a strain on the normal tie bar assembly, and auxiliary tie bars were added as temporary supports along this side. Similar action was required for cables feeding to equipment in the initial section of the exchange.

Preparations for the Main Lift: A careful check was made of all joints in the hardwood bearers. On the day prior to the main lift, plumb bobs were placed at the four corners of the structure, and all tie bar bolts and tie rods were checked for tightness, gauge sticks and hydraulic jacks were placed in position and lifting points were numbered for identification, see Fig. 3. A number of small racks such as routiners, routiner access and meter racks were moved in and temporarily stored close at hand ready to be placed in position when the structure was lifted. Finally, the staff was briefed on the procedure to be followed and stations were allotted to all persons engaged on the lift.

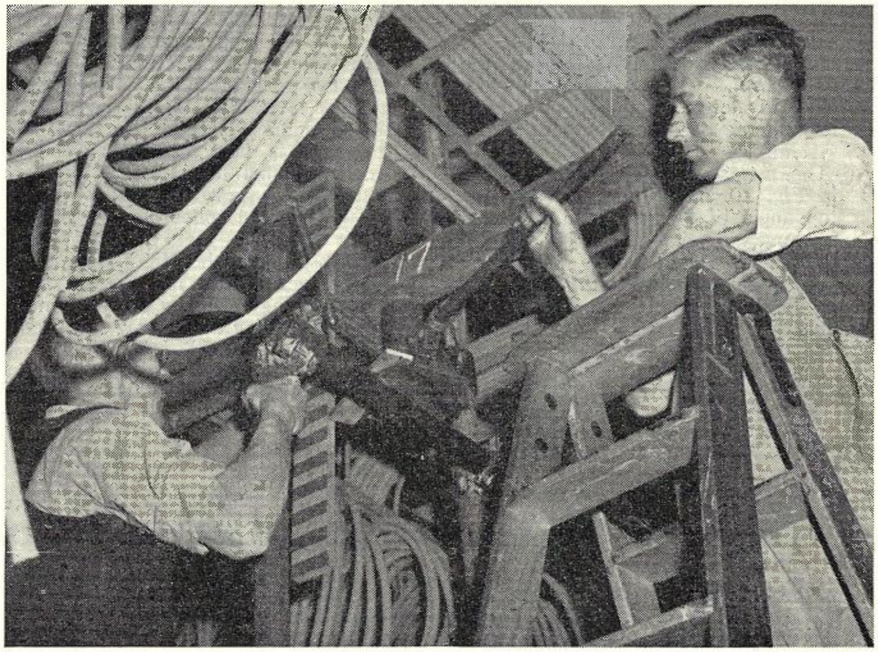


Fig. 3.—Lifting procedure.

The Main Lift: As the lift was to be made over a fairly large area, effective supervision of the thirty-seven lifting points by one person was not practicable and one man in each row was appointed as a leader. He was required to give an "all clear" signal to a control officer at the end of the row as each stage of the lift was completed. An emergency stop signal was arranged by giving the controlling Engineer a press button switch attached to a wandering lead of sufficient length to allow him to move about at will. The switch when operated caused a six-inch trembler bell to ring, and all staff was instructed to cease work immediately on hearing the bell. The Supervising Technician in charge of the installation was stationed well above the tubular scaffolding, where he could survey all lifting points and at the same time could see each control officer. It was his responsibility to determine the stages of the lift, each new stage being commenced only after the "all clear" signal had been received from the controlling Engineer.

The all-up load on the structure was calculated to be seventy tons, and the main lift was commenced at 8.0 a.m. on 27/6/51. Each stage of the lift was limited to five inches in steps of one inch. This resulted in a small amount of extra labour in changing the position of the supports more frequently, but was considered to be necessary because of the variety of jacks in use. The plumb bobs located at the four corners revealed any tendency of the structure to drift, and when this did occur, a correction was obtained by causing the jacks at one end to be operated a few pumps in advance of the remainder on each movement.

The complete assembly was lifted to about 10 feet 4 inches from the floor without incident. At this point it could be seen that the structure had moved bodily towards one end of the room for about half an inch. Since the runways on the new equipment were required to join on to the existing runway system, it was necessary to exercise care at this point. The lift was concluded to the 10 feet 9½ inch height and correction for the drift applied by placing three jacks horizontally at the northern end of the building to slide the assembly back into its correct position. Levelling off at all points was then proceeded with by three men, one of whom moved a 10 foot 6½ inch gauge stick along each plinth, while the other two operated the hydraulic jacks at each lifting tower where variation of height was required. These two men also moved the support pieces to hold the assembly when adjusted to its correct height, and finally removed the jack from each lifting tower.

The work was completed at 12.50 p.m. on the same day, and the light

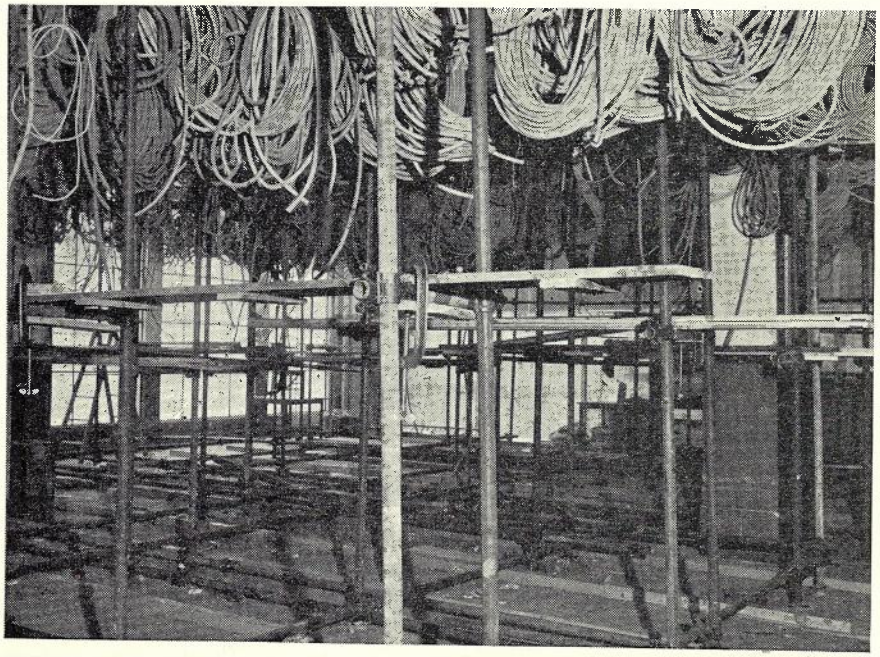


Fig. 2.—View of under-side of cable assembly.

racks which were stored nearby were immediately moved into their respective positions. At 5.0 p.m. sixteen racks had been bolted into position and screwed to the plinths. The positions in which these racks were placed were chosen to be those requiring removal of the least number of scaffolding braces. Wherever possible, the vertical lifting towers were removed as the racks were placed in position. Using the method outlined in the accompanying article, shifting in of the heavier racks was commenced next day, and on 6/7/51, the full complement of ninety-seven racks was in position, exactly twelve weeks from the time that the room had been made available. It is noteworthy that during the progress of the job to this stage, there had been no accident to personnel.

Employment of the low level cabling practice in this case resulted in an estimated saving of 6,200 manhours. Up to the stage where all racks were placed in position, a total of 8,800 manhours was recorded against the job. This compares more than favourably with the time required for erection by the normal methods. Some idea of the size of the Edison installation can be gained from the details given and the use of 44,544 yards of cable on this installation. The first 900 lines of large P.B.X. services connected to the Edison exchange were brought into service on 29/9/51. The remaining portion of the installation was cutover on 2/12/51.

INFORMATION THEORY AS APPLIED TO COMMUNICATIONS

W. O. GIBBERD, M.Sc., A.M.I.E.Aust.

Introduction

The theory of communication, as developed in recent years by Shannon and others in America, is an attempt to find a relationship between the rate of transmission of information, band-width and signal to noise ratio.

The theory enables a clear picture to be obtained of the various types of modulation and the relative advantages of each. It also helps in the appreciation of noise as a signal error and gives a meaning to the term "signal to noise ratio" in the case of quantised signals, such as those obtained in pulse code modulation where the channel may be perfectly quiet in the absence of signal. The relationship between noise and error is very real in the case of radar work, and the theory has been used by Woodward and Davies in determining the natural limits of radar systems.

The theory should be of use to those engaged on telemetry work, as it connects band-width, rate of transmission of information, error, and the signal to noise ratio in the radio frequency medium, all of which quantities are important in this field.

After experience with communications such as carrier telephony and telegraphy or radio, one feels that there is some principle akin to the conservation of energy applicable to the use of band-width for transmission of information. For instance, any attempt to reduce band-width of a voice frequency telegraph system results in a consequent fall in maximum speed of signalling. That the maximum rate of transmission of information is proportional to band-width or that the total amount of information transmitted is proportional to the product of band-width and time may be proved crudely by the example of a gramophone record. If the whole record is played at half-speed the same total amount of information is transmitted, but the band-width (W) has been halved and the time (T) has been doubled. The product W x T, therefore, remains constant as also does the amount of information transmitted.

The idea of the connection between transmission of information and signal to noise ratio was taking shape in 1924. In this year Nyquist proved that with a limited band-width the speed of signalling could only be increased by using more possible states than the two normally obtained by the "on" and "off" positions, (mark and space) of a telegraph key. Obviously a higher signal to noise ratio is required as we increase the number of possible states so that a connection between rate of transmission of information and signal to noise ratio appears.

It cannot be said that the theory has as yet produced any radically new system of modulation. Frequency modulation and the various forms of pulse modulation were introduced independently. Pulse code modulation provides perhaps the nicest example of the application of information theory to communication, but this method of modulation was not produced as a result of the theory. In fact, the reverse is more nearly true, as the advent of pulse code modulation has stimulated interest in information theory. It is now recognised that the improvement in channel noise obtained by frequency and pulse code modulation have been obtainable at the expense of radio frequency band-width.

Before proceeding to a discussion of communication theory, it is important to define certain terms which are commonly used to describe a communication channel used for telephony or programme. The principal characteristics of such a channel are band-width, operating level, over-load point, signal to noise ratio, and distortion. These characteristics are defined briefly as follows:—

Band-width: The band-width is defined as the difference between the maximum and minimum steady tone frequencies effectively transmitted by a channel. The meaning of the term "effective transmission" will depend to some extent on the purpose for which the channel is required.

Operating Level: The normal signal level at any point of a channel is the level at that point when zero reference level is applied at the switch-board in the case of a telephone channel, or at the studio in the case of a programme channel. It represents the level at which the channels are lined up and operated.

Over-load Point: As the level of the input to the channel is increased, a point is reached where a rapid increase in distortion occurs with further increase in level. This level is the over-load point and is greater than the normal operating level by a fixed number of decibels.

Signal to noise Ratio: The noise level is generally taken to mean the actual level measured at the receiving end in the absence of signal at the sending end. The signal to noise ratio is the ratio between the operating level and the noise level and is normally expressed in decibels.

For pulse code modulation and on channels using noise suppressors, it has become necessary to regard the noise voltage as an error voltage between the true sent signal and the actual received signal. The signal to noise ratio is defined as the ratio between the R.M.S. value of the operating level and the R.M.S. error voltage.

Distortion: Three types of distortion commonly occur in a communication channel; amplitude, phase and harmonic. These three terms are suitably defined in many text books, for example, "Everitt, Communicating Engineering".

It will be seen that when we adopt the idea of noise as an error voltage, it is no longer possible to differentiate clearly between noise and distortion.

Hartley's Unit of Information

The fundamental purpose of any communication channel is to reproduce at any one point a message selected at another point, with a specified degree of accuracy. In general, the message will consist of a sequence of selections from a group of possible symbols, for instance, a sequence of selections from the 26 letters of the alphabet. All of the possible symbols will not necessarily have the same probability of selection and generally, the probability will differ.

Assume that at any instant a selection may be made from s symbols and that any of the s symbols may be selected with equal probability. Let a message consist of a sequence of n selections from these s symbols. The message then becomes one out of a possible s^n selections. It is logical to regard the amount of information, H, as a function of s^n, in fact, H depends on the whole range of rejected messages, not only on the one selected. There are also reasons why we should regard H as being proportional to the length of the message or to n. We know, for instance, that a telegraph channel has no greater difficulty in passing the (N + n)th symbol than in passing the n th symbol.

The information H is, therefore, a linear function of n and we adopt as a definition for the amount of information

$$H = \log s^n = n \log s. \quad \text{———(1)}$$

If the logarithm is taken to base 2 the units are defined as binary digits (bits). Thus the selection of "yes" or "no" represents one bit of information. This logarithmic unit is intuitively suitable. For example, two relays each with an on/off position will provide twice as much information as one.

If the logarithm is taken to base 10 the information content is defined in decimal digits, one decimal digit = 3.32 bits.

In the 5 unit code used by a teleprinter or teletype, each letter is determined by a sequence of 5 selections from the mark or space possible conditions of a telegraph line. Thus the character is actually determined from 2^5 possibilities and the selection of a character conveys 5 bits of information.

The information content of one selection from s symbols is given by $H = \log s = -\log 1/s$.

In the above case the probability that a particular symbol will be selected is 1/s. In the case where the probability of selection is not constant for all symbols, an intuitive definition for information content is

$$H = -\Sigma \; p_i \log p_i \quad \text{———— (2)}$$

Where H is the information content of a selection of a symbol, and pi is the probability of selection of the i th symbol. In the case of equal probability this formula reduces to that given above. This definition was proposed by Shannon and is referred to in more detail later.

The definition of information as given above by Shannon is not the only possible concept. Gabor has proposed an alternative unit based on the fact that the amount of information contained in a message is proportional to the maximum allowable frequency band-width and to the time. He proposed the term logon for this unit and defines it as the product $\Delta f \; \Delta t$.

The Capacity of a Channel

The capacity of a communication channel is the rate at which it can transmit information. In the simple case of s symbols all equally probable and all occupying t seconds for transmission the rate is $(\log_2 s)/t$. In the case of teletype s equals 2 and five selections are needed per character.

If t is the length of a signal element the rate of information is given by C = 1/t bits per second. But each character needs 5 bits of information and 1/5t characters per second may be transmitted.

Where the time is not equal for each symbol Shannon defines

$$C = \lim_{T \to \infty} \left\{ \frac{\log N(T)}{T} \right\}$$

where N(T) = number of allowed signal sequences of duration T.

The Communication Channel with Noise

The general communication channel, as shown in Fig. 1, consists of the following components:

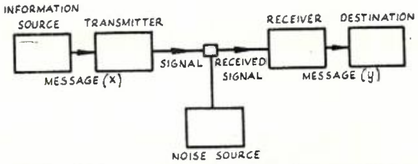


Fig. 1.—The general communication channel.

A message source such as a speech source, telegraph transmitter, or instrument, etc. This source will generate a message x.

A transmitter, which can be a radio system, voice frequency telegraph channel, etc., will encode the message into a signal suitable for transmission to the distant terminal.

A noise source which mixes a certain noise voltage with the signal during transmission.

The signal receiver which converts the signal plus noise into a received message (y).

A destination such as the human ear, telegraph sounder, etc., which receives the restored message.

Information Theory Using Inverse Probability

In Fig 2 the column x represents a set of possible messages. Column y represents the set of possible received messages. Owing to the fact that noise is present in a communication channel, there is some uncertainty in the received message. The arrows in Fig. 2 show that there will be a distribution of probable values of y for any fixed value of x, and vice versa.

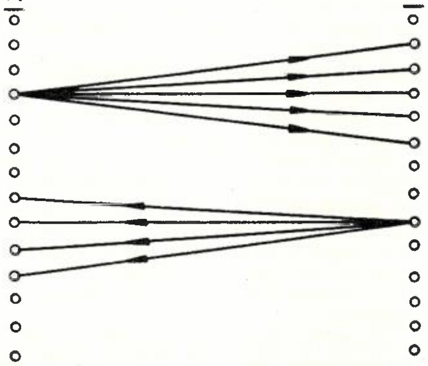


Fig. 2.—Probability representation of the conversion of a message x to a received signal y.

The following terms may be defined:

p(x) is the probability that a message x will be selected and is defined as the prior probability.

$p_x(y)$ is the probability that a given message x will produce a received message y.

p(y) is the probability that a received message y will occur.

$p_y(x)$ is the probability that a given received message y was caused by a message x.

Obviously the above probability functions are not independent of one another and, in fact, we have from first principles the following equation:

$$p(x, y) = p(x).\, p_x(y) = p(y).\, p_y(x) \quad \text{— (3)}$$

where p(x, y) is the probability of a joint occurrence of a message x and a received signal y. From this we have a formula for the posterior distribution in terms of the prior distribution

$$p_y(x) = \frac{p(x).\, p_x(y)}{p(y)}$$

The above formula is an application of the disputed Baye's theorem and is valid only when the prior probability p(x) is known. In communication we can assume that this distribution is known. For instance, we know the probability of selection of the letters of the alphabet in the English language.

The term $p_x(y)$ (that is the probability of a received message y for a given message x) is really an expression of the effect of the noise present and in particular cases should be capable of evaluation.

The Information Content of a Communication

Up to now we have been concerned with the information resulting from the selection of one message from a set of possible messages. It is now intended to evaluate the information resulting from the selection of a message and communication of it along a channel. This value is denoted by I and a formula for it may be obtained by using the above inverse probability formula in conjunction with the following two axioms, which may be postulated about the information content of a communication.

(a) If two communications representing the same message are sent, and the observer regards the posterior probability after the first as the prior probability before the second, the total gain of information is equal to the sum of the gains from each communication.

(b) If two communications representing two independent messages are sent the total gain in information concerning them is the sum of the gains obtained when each communication is considered separately.

Using these two axioms and the inverse probability formula we obtain:

$$I = H(x) - H_y(x) = H(y) - H_x(y) \quad . . (4)$$

where $H(x) = -\int p(x) \log p(x)\, dx$ . . (5)

$H(y) = -\int p(y) \log p(y)\, dy$

$H_y(x)$ = Avge. for

$$y \text{ of } -\int p_y(x) \log p_y(x)\, dx$$

$$= -\int\int p(y)\, p_y(x) \log p_y(x)\, dx\, dy$$

$H_x(y) =$ Avge. for

$$x \text{ of } -\int p_x(y) \log p_x(y)\, dy$$
$$= -\int\int p(x)\, p_x(y) \log p_x(y)\, dy\, dx$$

It will be seen that H(x) represents the information gained by the selection of a message and it represents the limiting case of the finite distribution originally conceived by Hartley.

The term $H_y(x)$ represents the average information still to be gained from the selection from the set having the distribution $p_y(x)$ after the message has been sent. Obviously when there is no noise present there is a one to one correspondence between a sent message x and a received message y, $H_y(x)$ is zero and the information gained by the communication is equal to that gained by the selection of the message originally, which is equal to H(x).

Because of the similarity between the formula for H in information theory and that for entropy in statistical mechanics, the quantity H is often referred to as entropy. The similarity between the two quantities is only formal in a mathematical sense because entropy represents our knowledge of the statistical behaviour of a physical system at a given temperature, whereas H represents our knowledge of the statistical behaviour of a distant sender.

However, using the term entropy, equation (4) can be stated in terms of the following theorem:

> "If in a continuous channel, the signal and noise are independent and the received signal is the sum of the transmitted signal and the noise, then the rate of information is equal to the entropy of the received signal less the entropy of the noise."

The Message as a Time Function—The Sampling Theorem.

Let a message of length T consist of a function of time f (t) as shown in Fig. 3.

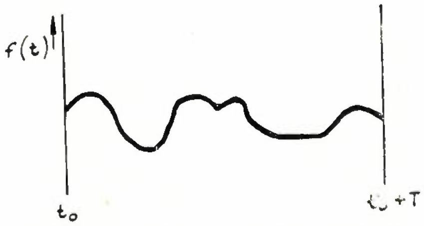


Fig. 3.—Message length as a fraction of time.

Let the Fourier series for the function be

$$f(t) = \sum_{n=0}^{\infty} a_n \cos n\,\omega\, t + \sum_{n=1}^{\infty} b_n \sin n\,\omega\, t$$

where $\omega = \dfrac{2\pi}{T}$

Now suppose that the message is limited to a band-width W, that is

$$n\,\omega \doteq 2\,\pi\, W \text{ or } n \doteq \frac{2\,\pi\, W}{\omega}.$$

f(t) becomes

$$\varphi(t) = a_o + \sum_{n=1}^{WT} a_n \cos n\,\omega\, t + \sum_{n=1}^{WT} b_n \sin n\,\omega\, t.$$

This would be the form which f(t) would take if it were passed through an ideal low pass filter with cut off W.

This function $\varphi(t)$ is defined completely by the (2WT + 1) constants

a_o, a_1, a_2, ———— a_N
b_1, b_2, ———— b_N

If the interval T is divided into 2WT equal intervals and we specify the amplitude at those points plus one additional piece of information such as the slope $\varphi^1(t)$ at t = o, we can solve for a_n and b_n.

If a function f(t) contains no frequencies greater than W cycles per second it can be specified by giving its ordinates at a series of points spaced 1/2W seconds apart. This is one consequence of the sampling theorem.

Note that the function can be specified by either a time or frequency spectrum and in either case it has 2WT degrees of freedom.

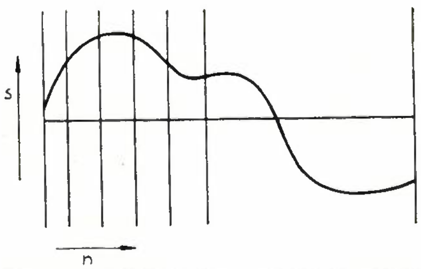


Fig. 4.—Function of time sampled at uniform intervals.

Fig. 4 shows a function of time sampled at uniform intervals separated by ½W seconds. From this, a connection with the original definition of information is evident. The value of the amplitude at any instant of sampling represents a choice from a set (in this case a continuum) of possible values. Consecutive sampling points represent consecutive choices.

As the number of choices is equal to 2WT it is apparent that the information content must be proportional to the product of band-width and time. If the band-width of a channel is limited to W cycles we can fix the value of the variable every ½W seconds, but not more often. This fact was realised in the early days of telegraphy, and Nyquist in 1924 pointed out that the speed of working on a telegraph channel could not be increased unless either

(a) the band-width was increased, or
(b) the number of possible states was increased.

The latter improvement could be achieved, for example, by using a three unit code instead of the two unit (on/off or mark/space) normally used in telegraphy.

The Capacity of a Channel with Noise

The capacity of a channel, such as that shown in Fig. 1, may be derived in a simple though not rigorous manner by considering the number of possible amplitudes which may be selected in the presence of noise. Let the signal power

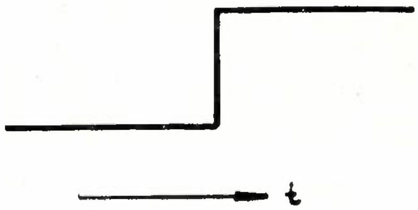


Fig. 5.—Output of initiating circuit.

be P and the noise power N. Then on a linear channel the received power is P + N. The noise voltage represents an error voltage and therefore it is possible to detect $\sqrt{(P + N)/N}$ possible levels. As choices from these levels may be transmitted at the rate of 2WT per second, we obtain by the use of equation (1) the following formula for the capacity:

$$C = W \log (P + N)/N \quad \ldots \ldots (6)$$

If it is assumed that the probable values for both signal and noise amplitudes obey the Gaussian probability distribution, the above formula may be proved by means of equation (4) above. The value of H(x) for a signal of length T, of average power P, band-width W and whose amplitude follows the Gaussian probability distribution is

$$H(x) = WT \log 2\,\pi e P \quad \ldots \ldots \ldots (7)$$

The formula shown in equation (6) follows very simply from equations (4) and (7).

The implications of equation (6) are obvious as it relates the maximum information capacity of a channel to band-width and signal to noise ratio.

The Operation of a Simple Trigger Circuit

As a simple example of the application of equation (6), consider the case of instruments with two states (on and off) operated by the application of a definite voltage. This is the case, for example, in the operation of a kinetheodolite lamp by a pulse. Suppose that the output of the initiating circuit (timing equipment) is a step function of the form shown in Fig. 5.

Also suppose that the lamp is required to operate within one millisecond. One bit of information must be transmitted in one millisecond and a channel of capacity 1,000 bits is required. Suppose that the equipment will operate reliably with a maximum signal to noise ratio of 3, that is (P + N)/ N = 4.

Using equation (6) we obtain

W = 500 c/s.

The usual method of deriving the band-width required for this purpose is to consider the shape of a received step function after passing through an ideal low-pass filter and as would be expected when this method is used the result again comes to a required band-width of 500 c/s.

The Relationship between Band-width and Noise in some forms of Modulation.

Consider the general case of a radio frequency transmission. We have an audio (or video) signal of band-width b which it is desired to transmit over a medium which may be line, cable or radio path. In the medium the audio signal will occupy a band-width B (often not clearly defined) and noise will be introduced. Finally, the signal is demodulated to yield the original signal, of band-width b, plus noise. The signal to noise voltage ratio in the output is n. Such an arrangement is shown in Fig. 6.

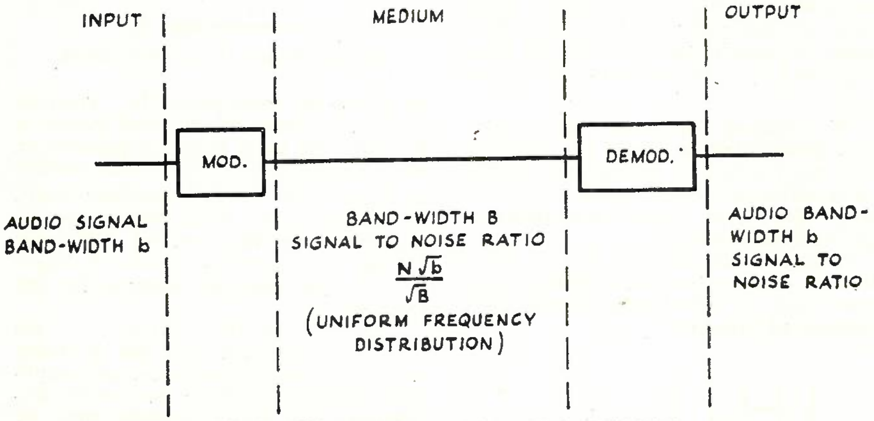


Fig. 6.—General case of radio frequency transmission.

The noise power introduced in the medium will in general be evenly distributed over the frequency band (white noise). If the signal to noise voltage ratio for band-width b is N, for a band-width B the signal to noise ratio will be $N\sqrt{b/B}$.

The most efficient means of transmitting a signal and conserving band-width is frequency division multiplex (amplitude modulation) which for multichannel working usually takes the form of single sideband transmission. For this reason this method is universally used where it is desired to send the maximum amount of information over a given band-width and where the signal to noise ratio allows the demodulated signal to meet the required performance standards. Examples are the use of carrier systems on open wire lines, underground cable, coaxial cable, wide band radio bearer circuits, etc.

Where the medium is subject to too much noise for frequency division multiplex (for example, radio paths) some other forms of modulation enable a better signal to noise ratio to be obtained in the channel at the expense of a greater band-width in the medium. Examples of this are frequency modulation and pulse code modulation. The latter enables quite a large improvement to be obtained and has the significant feature that by means of reshaping, the final signal to noise ratio can be made substantially independent of circuit length.

Other methods (for example, pulse time modulation and pulse amplitude modulation) are being developed largely because conservation of band-width is not important in the functions for which they are intended and their use enables a saving in equipment costs compared with frequency division multiplex.

The characteristics of the noise in the demodulated signal vary with the system of modulation. In single side-band the noise has the same frequency-level characteristic in the output as it has in the medium. In frequency modulation a uniform frequency distribution in the medium is converted to the triangular characteristic in the output in which the noise voltage amplitude varies linearly with frequency. With pulse code modulation the channel is perfectly quiet in the absence of signal and the noise appears as a signal error. The error voltage may assume any value up to one-half of a signal step.

The method in which a given modulation system improves noise by the use of large band-width cannot be derived directly from equation (6) because no system other than frequency division multiplex makes full use of band-width. The method of trading band-width for noise is not 100 per cent efficient.

Earp in "Electrical Communications" for June, 1948, details the following formulae for some common types of modulation:

(a) **Amplitude modulation**

$$n = N \quad \ldots\ldots\ldots\ldots$$

(b) **Phase modulation**

$$n = N \times B/b \times 1/2\sqrt{2}$$

(c) **Pulse time modulation**

$$n = N \times \pi/2\sqrt{6} \times \beta/b$$

Here β is used to represent the effective band-width in the medium, and is equal to the true band-width divided by the number of times the same band-width may be used again by other transmissions of the same effective band-width without crosstalk between the various systems.

(d) **Pulse code modulation**

$$n = \left(\frac{N}{p\sqrt{r}} + 1\right)^r - 1$$

where $r = B/b$

$$p = \frac{\text{peak noise voltage}}{\text{R.M.S. noise voltage}}.$$

(e) **Frequency modulation**

$$n = N\sqrt{3}\, m$$

where m = index of modulation.

But $B = 2\,(m + 1)\,b$

$$\therefore n = N\sqrt{3}\,(B/2b - 1).$$

These formulae are approximate and apply only to the case where N is significant, that is, the signal level is greater than the noise by a factor of, say, 10. Using the same assumptions, the formula which an ideal system would obey is given aproximately by:

$$n = (N/\sqrt{B/b})^{B/b}.$$

Comparison of Improvement with that of an Ideal System

The improvement obtained with existing systems may be calculated from these formulae. If we assume a single side-band noise of 30 db (20 log N = 30) and a band-width expansion of 4(B/b = 4) the following signal to noise ratios would be obtained with the respective systems:

Phase modulation	33 db	improvement	3 db
Pulse time modulation	38 db	,,	8 db
Pulse code modulation (assume p = 3) . . .	60 db	,,	30 db
Frequency modulation	35 db	,,	5 db
Ideal system .	96 db	,,	66 db

It will be seen that none of the systems of modulation provide the theoretical maximum improvement calculated from Shannon's formula. Pulse code modulation approaches most closely to the ideal and in this case the improvement depends also on the frequency of errors allowed. With an allowable error frequency of 1 in 10^5 a signal to noise ratio improvement within 8 db of the ideal may be obtained.

Coding

Why is it that for a given band-width expansion in the medium a signal to noise ratio in accordance with Shannon's formula is not obtained. The answer lies in the method of coding. Equation (6) gives the maximum capacity for a channel and this maximum is obtained only when the channel is correctly "matched" to the medium from a coding point of view. Amplitude modulation is 100 per cent efficient and pulse code modulation nearly so. Other forms such as frequency modulation, phase modulation and pulse time modulation have much lower efficiencies. One piece of apparatus commonly used on noisy channels, namely the compandor, is in fact an elementary code matching device. The compressor rearranges the probability distribution of the level of the incoming speech so that the probability of the occurrence of high levels is greater in the medium than it is in incoming speech. An ideal compressor would rearrange the speech in such a way that all levels were equally probable. The expandor, of course, must have exactly opposite characteristics to the compressor so that the original speech is restored in the channel output. Efforts are being made to form a theory of coding.

Conclusion

Because most of the work to date in information theory has been done in the communication field, it has been approached mainly from this angle in the foregoing. However, the general theory of information covers a larger field and includes the field of scientific information.

References

So much has now been written on Information Theory and related subjects that a complete bibliography would be too large for such an article as this. However, the following have been selected as suitable references for those wishing to become more familiar with the subject. Most of those mentioned have bibliographies.

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PREFERENTIAL ACCESS WITH NON-HOMING UNISELECTORS

G. A. PROVAN

Introduction: Early type rotary subscribers' uniselectors, practically all of which are still in service, are of the non-homing type. As the name implies, they have no "home" position for the wipers, which move only if standing on a busy trunk when a call is originated. The starting point of search for a free trunk can, therefore, be any one of the 25 outlets with which these uniselectors are provided. Owing to the random seizure of free trunks, the outlets from non-homing uniselectors are not graded, but are generally trunked in small full availability groups.

With homing type uniselectors, the wipers return to the home position when the switch is freed. The starting point of search for a free trunk is, therefore, from the home position, and the first free outlet from there is the trunk that is seized. Thus the late choice trunks carry traffic only during the peaks. Early homing type uniselectors have 24 outlets and the home position, but modern homing uniselectors have 23 outlets, a home position and a "busy" position.

The main advantage of homing type uniselectors is that their outlets can be arranged in a grading, and this results in a large saving in the number of trunks which are required. As an example, 2000 subscribers' lines terminated on 23 outlet homing type uniselectors and with an originating traffic per line of 0.03 T.U. during the busy hour, would require only 96 trunks when graded, whereas 115 trunks would be required if they were trunked in five separate full availability groups of 400 lines. This represents a saving of more than 16 per cent. in the number of trunks required and as these trunks must terminate on either first selectors in a main exchange or discriminating selector repeaters in the case of a branch exchange, the saving in equipment is an important consideration.

A further advantage in the grading of the outlets of subscribers' uniselectors is that the traffic from the first selectors or D.S.R.'s to which these uniselectors are trunked, is smoothed, and the number of trunks required to carry this traffic is considerably reduced. This results in a saving in junctions. As an example of this saving, if the 2000 subscribers' uniselectors are trunked to D.S.R.'s and the traffic to the main exchange from the junction hunters is 48 T.U., only 70 junctions would be required for the smooth traffic, whereas 78 junctions are required for the pure chance traffic resulting, when D.S.R's are trunked from small full availability groups of uniselectors.

Control Circuit to Permit Grading of Non-Homing Uniselectors: As there are more than 33,000 non-homing subscribers' uniselectors in the Melbourne network, it was evident that savings in equipment and line plant would result if the outlets from some of these uniselectors could be graded. Conversion to homing type, by means of a cam and off normal springs was considered in the absence of spare wipers and a homing arc, but as each uniselector had to be altered, the cost was considered prohibitive. Furthermore, the conversion of these uniselectors to homing type could increase the fire risk, as the drive magnets are not of the "self protecting" type.

An experimental control circuit which gives preference to early outlets to provide a similar order of search to that of the homing type uniselector has been developed. The outlets of the non-homing uniselector can be effectively graded by the application of the circuit arrangement. See Fig. 1. This control circuit ensures that a trunk individual to a grading group will be seized if one is free, and, if the latter are busy, that the least common type of free trunk will be seized. This is achieved by busying all common trunks when a uniselector is engaged, and by progressive removal, at a suitable timing rate, of the busy condition from early commons, later commons, and, finally, from the full common trunks. This arrangement has been tried out in several exchanges and has proved effective and reliable in operation.

Circuit Description: A typical arrangement for the control circuit is shown in Fig. 1, and the associated grading pattern is shown in Fig. 2. Relays B, C, D E are normally operated. When a subscriber's line is looped, the L relay and the SG relay (one of which is provided per gate on non-homing units) are energised. Relay SG operates before L, which is slow to operate. SG 2 operates relays A, AA, AB, AC and AD. SG 2 also lights the supervisory lamp.

A1 opens the circuit of B relay, which is slow to release (80 milli-seconds). A2 opens the chain circuit to prevent false operation of the GCO relays. A3 with contacts of relays AA, AB, AC and AD places a busying earth on the privates of all common trunks. The 1/12A rectifiers prevent the earthing of meter pulses which may occur whilst the busying earth is applied. If the uniselector is standing on a common trunk or a busy individual trunk, it will hunt when L relay operates.

When B relay releases, B 1 opens the circuit of C relay, which is slow to release (140 milli-seconds). B2 releases AA and B3 with contacts of AA removes the

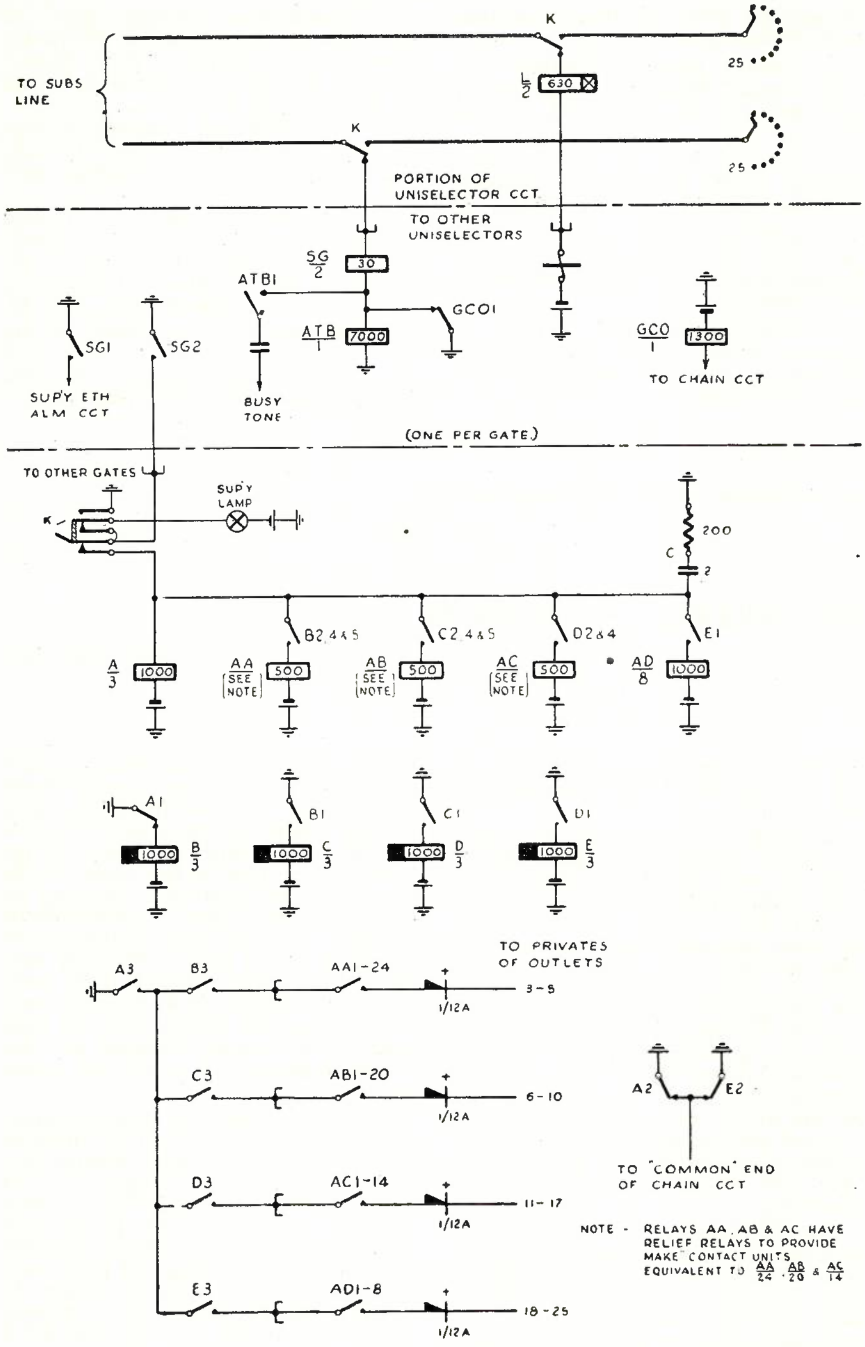


Fig. 1.—Control circuit to give preferential access to non-homing uniselector.

busying earth from outlets 3-5 of all uniselectors.

When C relay releases, C1 opens the circuit of D relay, which is slow to release (220 milli-seconds). C2 releases AB and C3 with the contacts of AB, removes the busying earth from outlets 6-10 of all uniselectors.

When D relay releases, D1 opens the circuit of E relay, which is slow to release (280 milli-seconds). D2 releases AC, and D3, with the contacts of AC, removes the busying earth from outlets 11-17 of all uniselectors.

When E relay releases, E1 releases AD, and E3 with contacts of AD, removes the busying earth from outlets 18-25 of all uniselectors. E2 closes the chain circuit.

When the uniselector seizes a trunk, SG relay is released by the K contacts. SG 2 releases A relay and extinguishes the supervisory lamp. A1 operates B relay, B1 operates C relay, C1 operates D relay, and D1 operates E relay. A2 makes the chain circuit independent of E2. The control circuit is then ready for the next call.

In most cases the uniselector finds a free trunk without the control circuit functioning for the full timing cycle. This depends on where the hunt commences, and if the uniselector is standing on a free individual trunk, it will not hunt at all. In practice it has been found that the majority of uniselectors are standing on individual trunks, having been diverted there on previous calls.

The flashing of the supervisory lamp as calls originate, serves as an indication that the circuit is functioning correctly. Operation of the key disconnects the control circuit and lights the supervisory lamp.

Calculation of the Release Lags of Relays: The timing of relays B, C, D and E should be such that no matter on what outlet the uniselector is standing when a call originates, a trunk of the individual type will be seized if one is free. If the individual trunks are all in use one of the least common type of free trunk must be seized. The calculation of the timing necessary is based on the fact that the release lag for each timing relay must be sufficient for the wipers to step from the second of the preceding type of outlet, to the first outlet beyond the type of common controlled by that relay.

Taking the grading pattern shown in Fig. 2 as an example, and allowing 20 milliseconds per step, B relay must have sufficient delay for the uniselector to step from outlet 2 to 6, that is, 4 steps of 20 milli-seconds = 80 milli-seconds. C relay must have sufficient delay for the uniselector to step from outlet 4 to 11, that is 7 steps of 20 milli-seconds = 140 milli-seconds. D relay must have sufficient delay for the uniselector to step from outlet 7 to 18, that is 11 steps of 20 milli-seconds = 220 milli-seconds. E relay must have sufficient delay for the uniselector to step from outlet 12 to 1, that is 14 steps of 20 milli-seconds = 280 milli-seconds. If these relays have greater release lags, the only disadvantage is that the hunting time of the uniselectors is increased. If the release lags are insufficient, full control will not be given and it is then possible for trunks to be seized out of their correct sequence.

If a second call originates during the timing cycle of a previous call, the degree of control exercised over the second call will be proportional to the proximity of the two calls. The probability of this occurring is fairly remote, and in practice it has been found that the one control circuit can cope with a grading of 2000 uniselectors, the number of trunks seized out of sequence being practically negligible.

If the originating density of calls is such that the one control circuit cannot cope with them, two or more control circuits could be used, one for each portion of the grading. To obtain the number of make contacts necessary on relays AA, AB and AC, special relays such as the "claw" type must be used. Alternatively, more than one standard type relay may be used to perform the functions of each of relays AA, AB and AC.

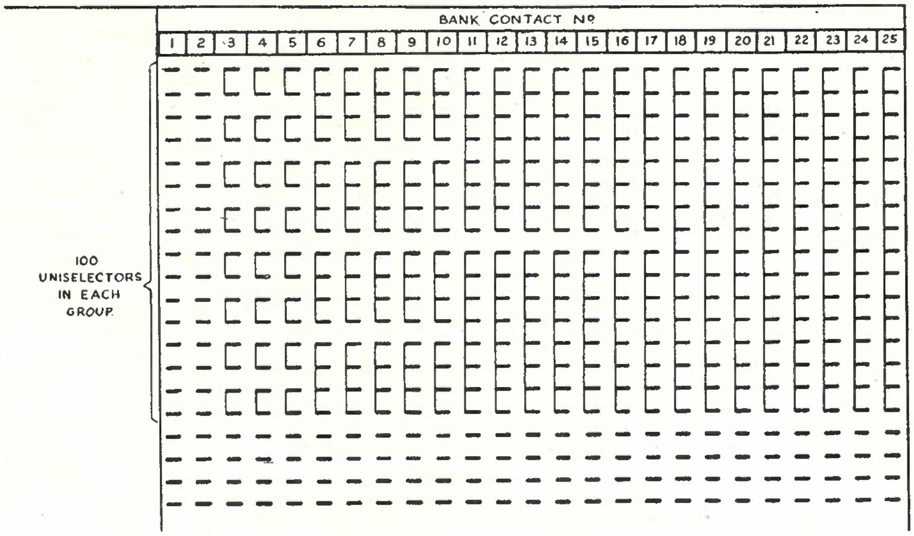


Fig. 2.—Grading pattern associated with control circuit.

BASIC PRINCIPLES OF MANHOLE DESIGN AND CONSTRUCTION

I. McDOWELL, B.A., B.Sc.

Introduction.

Manholes are necessary in cable runs to permit and facilitate installation of cable into ducts, to provide facilities for jointing of cable and housing of joints, and to allow access to cables for maintenance purposes.

These are the main considerations affecting principles of design, apart from those involved in construction procedure. These principles are given hereunder, permissible variations indicated, and construction methods discussed.

Size, Shape and Depth of Manholes.

Size and shape. To facilitate construction, a constant cross section in the horizontal plane is usual. Fig. 1 indicates the basis of dimensioning on plan views of ideal manholes, there being two main cases:

(a) for 1 to 3 ducts inclusive, a small manhole; and

(b) for 4 to 12 ducts inclusive, a larger manhole.

Manholes in runs involving more than 12 ducts are given special consideration. The following table lists the principal dimensions of the interior of the manhole and comments relevant thereto.

From the table the total manhole lengths can be obtained for any particular case.

Dimension	Part of manhole	Sizes (a)	Sizes (b)	General Comments
A	Jointing wall	4′	5′	See (iii) under "Principal Modifications." Cable Joints are housed on bearers on this wall.
B	Length of bell	1′ 6″	2′	These are usual lengths; but the wall of the bell, which is shaped to conform to the natural sweep of the cable through the manhole, should make an angle of not less than 159 degrees with the jointing wall.
C	Width of manhole	2′ 6″ 3′	4′ 4′	For depth not exceeding 3′ 6″. For depth exceeding 3′ 6″. To provide room for handling and jointing of cables.
D	Width of conduit entering manhole	Depends on type		
E	Length of end wall beside conduit	3″	3″	This is the normal minimum, and is usually exceeded in practice.
F	Radius of curve of wall if required by alteration in angular alignment of conduit run	1′ 6″	1′ 6″	Conforms to natural sweep of cable entering ducts at new alignment.
G	Remaining wall in manhole involving 4′ 6″ radius bend	4′	5′ 6″	4′ is the minimum length, to allow room for rodding of ducts. The wall should be parallel to the alignment of adjacent ducts, and meet the continuation of the jointing wall; that is, no bell is provided at this corner.

Depth. The depth is governed by:

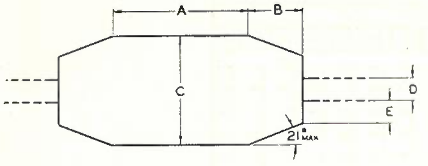
(i) the depth of the pipe or conduit; the floor should be not less than one foot below the bottom of the bore of the lowest pipe or conduit; or

(ii) the depth required for cables to be housed relatively to one another, and the clearances to be maintained between cables and ceiling, and cables and floor;

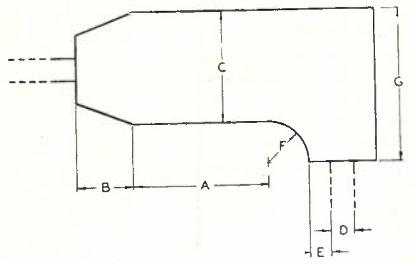
whichever is the greater. One exception is that, in the case of a single pipe run, the floor may be only three inches below the bore of the duct. The minimum vertical separation of cable bearers is six inches. If more space is available, the bearers are separated accordingly.

Hence, for a 4-duct run with minimum cover over the conduits, the depth would be:

Thickness of top and extent of cover over roof (say)	8″
Standard separation between ceiling and first bearer	9″
To second bearer	6″
From lower bearer to floor (to permit a convenient working height for jointing operations) .	1′ 8″
Total depth	3′ 7″



(a) STRAIGHT THROUGH MANHOLE



(b) MANHOLE AT 90° CHANGE IN CONDUIT ALIGNMENT.

Fig. 1.—Plan views of ideal manholes.

Cables are, of course, housed on both sides of the manhole, each wall in this example having two sets of bearers. If the conduits were laid to provide the bottom of the bore of the lowest duct at, say, three feet from the surface, the depth of the floor would be four feet. It is obvious that ducts must be provided before the depth of any corresponding manhole is known. Only in special cases should manholes be built before conduits are installed.

Principal modifications to foregoing basic measurements. It is difficult in practice to provide in all cases for the basic dimensions set out in the foregoing. The following are some of the factors which require variations to these measurements.

(i) For a run of single pipe of 3½" or 4" diameter, where the depth of the bottom of the bore at the pit is not more than two feet, a No. 6 pit (usually prefabricated) is used.

(ii) Where obstructions occur (and this is often the case) the ideal shape must be varied. However, the sizes of jointing wall, width, total length of hole, radius and minimum depth should not normally be interfered with. It might be necessary, rather, to relocate a manhole.

(iii) For a run of 4-duct conduit, the jointing wall should preferably be four feet only. However, as prefabricated formwork for the four feet wide manhole does not cater for this, the jointing wall in the 4-duct case is usually made five feet long.

(iv) Where appreciable changes in depth or alignment of conduit runs occur at either side of a manhole, consideration must be given to increase of the length to allow proper handling of the cable.

(v) Interpretation of the principles will indicate the shape of the manhole at points of alteration of angular alignment or offset of the line of a conduit run.

(vi) If further duct provision is a possibility, the manhole should be offset from the centre line of the existing ducts to provide for the entry of the new ducts in the end walls. The effect of this possibility on the depth of a manhole must also be taken into account.

(vii) Unusual cases, as for loading coil manholes, are given special consideration. These should be of rectangular cross section in the horizontal plane to allow the housing of loading coil pots in the corners.

(viii) It is desirable to position a manhole so that the longitudinal axis is parallel to the adjacent building line.

Preliminaries and Excavation of Manhole.

Material and equipment. Sand and screenings are set out as close as possible to their point of use. Typical quantities for an average case (b) manhole would be 1 cubic yard of washed sand and 2 cubic yards clean ¾" screenings (involving 13 bags of cement and 45 gallons of clean water). Equipment is disposed, having regard to the locality of other adjacent work and the necessity of providing traffic lanes; protecting the site, equipment, material and later the spoil, with barrier posts and rails, 72-hour red lamps and warning signs as required.

Setting out. When the shape of the manhole and its position relative to duct alignments have been ascertained, the extent of the excavation is set out accurately on the surface. In normal circumstances, a thickness of wall of four inches is allowed.

Excavation. The manhole is excavated to the depth from the surface to the floor plus three inches (the thickness of the floor in normal cases), providing for a slight fall towards the lower ducts, and a sump for drainage purposes. Care must be taken:

(i) to keep the sides vertical and trim them to as smooth a finish as is practicable;

(ii) to prevent by timbering collapse in whole or part of the sides. In bad ground, it may be necessary to back-timber an excavation completely;

(iii) to prevent at all times, by plugging ducts and providing temporary drainage, ingress of foreign matter (such as mud, sand, and other rubbish) into the ducts;

(iv) to dispose spoil safely and conveniently pending removal, bearing in mind the tendency of the weight of spoil to collapse the sides if placed too closely to the excavation;

(v) to cut any pavement neatly;

(vi) to prevent the disturbed ground of the conduit trench falling into the manhole; a vertical surface against which the concrete will be poured is formed around and above the ducts with brickbats.

Fig. 2 shows a typical excavation prior to the setting up of the formwork; for clarity, barrier posts and rails have not been shown.

Construction of Manhole

Formwork. When excavation has been completed (except in special circumstances, as when walls are to be constructed in two stages or more, see later) the wall formwork is set up. Such formwork could consist of any one of a number of types of prefabricated sets of formwork (see later) or 6" by 1½" timber, or some combination of both, depending on the departure of the manhole from standard shape and size.

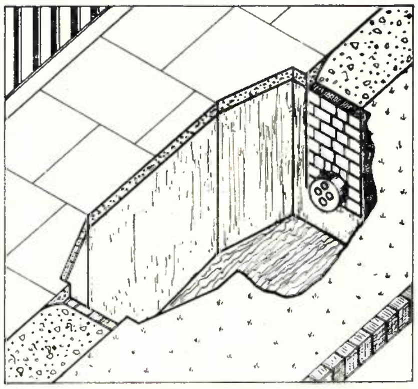


Fig. 2.

Prefabricated wall formwork. This must be vertical with the outer face at a distance of four inches from the inner wall of the excavation. It is retained at this separation until the concrete is poured, by means of wedges at the top and pegs at the bottom, rigidity being obtained by a system of toms within the formwork. Nails should not be used on formwork pieces.

Manhole walls constructed before the floor. In some circumstances it is preferable to construct the walls before the floor, these being where:

(i) it is not otherwise possible to obtain a proper seal between wall and floor (to prevent ingress of water, etc.);

(ii) floor (and top) should provide support for the walls against pressures in the ground; and

(iii) working in poor ground, it is desirable to construct the walls as soon as possible after excavation, to prevent the sides falling in and avoiding the inconvenience of timbering.

Placing of Concrete. Good quality concrete is mixed as close as practicable to the job (see "Mixing of Concrete" later) and the walls poured, care being taken to secure a dense concrete by thorough agitation and tapping of the former boards and pieces. In one-stage pours, the walls must be constructed in one operation, since horizontal joins otherwise resulting, allow the ingress of water and tree roots into the manhole.

Walls poured in two or more stages. It is sometimes necessary to pour walls in two or more stages, either in vertical sections, or, say one side wall at a time, for the following reasons:

(i) where the manhole is to be provided in bad ground; in which case, if depth is a factor, the first three feet at the top are constructed at first.

(ii) in the vicinity of conditions, such as pressure from building foundations, which might collapse one side, when that side is to be constructed before the whole manhole is excavated; or

(iii) in a very large manhole, when insufficient shuttering is available to enable all walls to be poured at once.

Ready-mixed concrete. This may be used if arrangements can be made for its supply. Its advantages are that it is good quality concrete and it may be cheaper, but it has the following disadvantages:

(i) ready mixed concrete cannot always be obtained at the precise time required, as this cannot always be predicted accurately in time to give necessary notice to the suppliers;

(ii) it is not easy to estimate the quantity required. It is essential that sufficient be ordered for a given job; disposal of excess economically, presents a problem; and

(iii) ready mixed concrete cannot always be brought to the site of a job.

Reinforcing Rods. These are not normally used in the walls of footway manholes since sufficient strength is obtained from the mix, the thickness of the walls, and the keying at top and bottom, to stand all strains encountered in practice. There is danger in the use of rods in walls, in that should they rust, the concrete will crack, Furthermore, it is difficult to position them in thin sections so as to gain any material benefit.

Completion of walls and construction of floor. The formwork wall can usually be stripped with safety after 24 hours. The walls are not rendered, but any appreciable irregularities are removed and rough places such as where the conduits enter, or where the formwood pieces are joined, smoothed with mortar. The floor is poured in three inches of good concrete, and finished very slightly domed and smooth, with a slight fall in the direction of the lowest duct entering the manhole.

A drain (formed with a special trowel) is provided at the base of the walls to the sump adjacent to the lowest duct or drain. A sump is moulded around a special form when the floor is poured, and must be placed in such a way relative to the drain and floor that water must pass through it before leaving the manhole; thus as well as providing facilities for final baling of the manhole, the sump provides a trap for silt. Fig. 3 shows a manhole with walls and floor finished, prior to erecting formwork for the top.

Construction of roof. Prefabricated sets of formwork have been designed to enable the roof to be poured simultaneously with the walls; these can only be used, however, when the depth of the hole corresponds to the depth of the wall formwork. As this is not usual, roofs are constructed as a rule subsequently to the walls. As manhole shapes vary considerably from manhole to manhole, it is not practicable to use prefabricated formwork for the roofs themselves; thus each manhole roof is timbered in 6″ by 1½″ hardwood. Fig 4 shows a typical manhole timbered prior to pouring the roof. The formwork rests on timber frames resting in turn on the horizontal floor; and should itself be horizontal. The forming timber for the plinth is placed in position after the roof itself is poured. Fig. 5 shows the completed manhole.

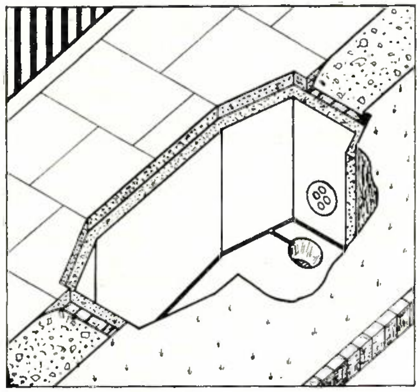


Fig. 3.

The upper surface of the covers and frame should conform to the slope and level of the footpath. If necessary, information in this connection should be obtained from the local Authority, as subsequent alteration is costly. The top is poured in four inches of good concrete, regard being paid to the following points:

(i) a four inch wide plinth, properly finished, and in the plane of the surface of the covers is to be provided around the frame, as part of the top, in one pour;

(ii) where the top of the hole is under grass, four inches of cover should be allowed for replacement of soil;

(iii) formwork should be set up such that the top keys into the walls to the extent of one inch;

(iv) reinforcing, if used, should be one and a half inches from the lower surface of the concrete, and rails, if used, totally enclosed. This is to avoid cracking through rusting of the reinforcement;

(v) while the top is poured, the covers should be set in their frame to allow the frame to be checked for distortion, which would spoil the subsequent fit of the covers; and

(vi) where concrete footpaths adjoin the manhole, these should be finished to a high standard integral with the top.

Drainage of manholes. Where the conduit route is drained by the lower duct, the bottom 12″ (that is, below the duct) of manholes are drained where possible to open or closed storm water drains or gutters to an extent depending on the importance of the route. A manhole at the lowest point of a conduit run should always be drained in this way. The bottom of the bore of any outlet pipe should be two inches below the floor of the manhole, a grating fitted over the opening, and a non-return valve provided if necessary. Water should enter the drain from the sump only, not from the manhole floor.

Where the conduit route is drained, such drains should leave the manholes in the same manner as above; but an entry to a manhole should be provided only for the purposes of inspection and cleaning of the drain, the water being routed under the floor using two "T" pipe sections and two 90 degree bends (with ordinary drain pipe).

Manhole covers and frames. The two types in most frequent use are:

(a) the checquer plate double cover and frame (Ser. 75/12), 4′ by 3′ 9½″, is used on most large manholes;

(b) the double cover and frame or its equivalent (Ser. 75/5), 4 ′ by 2′ 6″, is used on smaller manholes.

A variety of cover and frame types are used in special cases.

Other factors in construction. These include those involved in operations over existing plant, viz.:

(i) when an existing manhole is rebuilt, the same principles apply; it may be possible in practice to use part of the old hole, in which case adequate support is required during construction for that part which is used;

(ii) special equipment is available for removing G.I. pipe protecting cables which will appear in the rebuilt manhole; and

(iii) any existing cable must be firmly supported during construction, moved to a minimum extent during operations, and afterwards cleaned of all concrete and supported pending rehousing by personnel trained in the handling of cable.

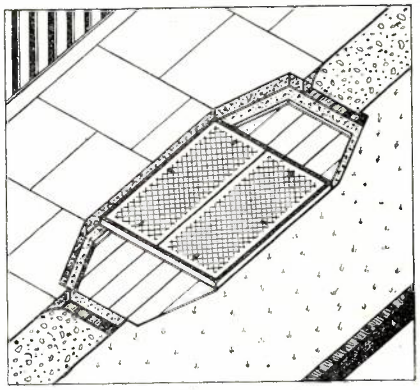


Fig. 4.

Finishing off. Care is necessary to leave surroundings at least as well as these were found; and the following points apply:

(i) concrete footpaths should be finished to a high standard integral with the top of the manhole;

(ii) other surfaces pending reinstatement should be well consolidated by ramming and surfaced temporarily with brickdust or ashes well watered in and rammed with a 6″ by 6″ flat iron rammer; except that

(iii) all grass surfaces should be replaced and firmed carefully into position; and

(iv) all formwork should be cleaned and treated with sump oil; all surround-

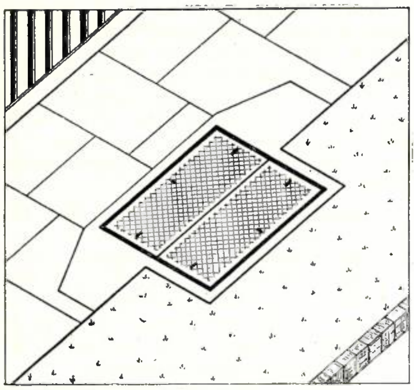


Fig. 5.

ings should be cleaned up, particularly where concrete was mixed. Arrangements should be made for removal of spoil immediately following excavation. In addition

(v) any cables existing in the manhole must be left adequately supported and clean.

Mixing of Concrete.

Two grades of concrete are used, corresponding to a 4: 2: 1 mix where strength is particularly required, and 5: 3: 1 mix where the strength aspect is less important. For the stronger concrete (say) the following procedure would apply:

Hand Mixing. Hand mixing is not desirable, since large quantities of concrete are usually involved in manhole construction. The procedure is:

(i) two measures of sand are placed on a mixing board. If the sand is lumpy all lumps must be removed;
(ii) one measure of cement is placed on the sand;
(iii) the heap is turned over with a shovel until a uniform color of materials is obtained;
(iv) four measures of screenings are placed on the heap, and turned over until a uniform mix is obtained;
(v) water is gradually applied and the mix turned over. Excess water must be avoided (to prevent voids in the concrete resulting from water not taken up by the cement, drying out) the mix being only wet enough to be worked into compaction when placed.

Measurement of quantities will relate, of course, to the amount of concrete to be placed. Mixing should take place adjacent to the manhole.

Mechanical Mixing. Materials are added to the mixer (which will contain a little water) in the same order and proportions as for hand mixing. Overmixing is to be avoided and the material should if possible, be placed direct from the mixer itself.

Prefabricated Manhole Formwork

Wall Construction. Wall construction is facilitated greatly by the use of prefabricated formwork sets. Timbering a manhole is tedious and a waste of timber (as to short ends) and a better finish to the walls is obtained from formwork faced with iron. In addition, the completed dimensions conform more accurately to standards. Prefabricated formwork should be strong, light and durable, sufficiently versatile to be applicable to any variation of the ideal manhole usually encountered in practice, and simple and speedy to set up, strip and clean.

Types of Sets. The types of former sets in use include the following:

(i) pieces of varying size depend on the versatility of the set (the basic set forming walls for a standard straight through hole up to six feet deep) constructed rectilinearly as to frame and surface from timber, and faced with light iron sheet. These are joined with bolts; on a straight wall piece to piece, and at an angle, with iron angle pieces. A radius piece (more or less common to all types of set) forms the curved wall if required. This type is the most useful in practice in Victoria at the present time. The type is readily usable in conjunction with timber, and is exemplified by that shown in Fig. 6.
(ii) rigid iron pieces capable of being joined at angles or straight by iron plates. These are slower to set up and strip, but give a better finished wall at the joints of the formers;
(iii) simple tongue and grooved timber pieces cleated together, held rigidly in relation to one another by external means (toms and wedges). These sets are light and cheap, but not durable; and
(iv) other types; the essential differences being in the method of joining them rigidly at angles in the walls (which vary from manhole to manhole) and in size and shape (in the quest of better versatility). The metal facing is usual to prevent damage to timber and ensure a smooth finish on the wall.

Tools and Equipment in Manhole Construction

The most important tools and equipment used by a manhole builder include the following:

Personal. A hut (for shelter and safeguarding of material, etc.), tool box, wash basin, working reports, attendance book, receipt book.

Safety. Barrier posts and rails, reflectors, caution and danger signs, and 72-hour lamps.

Excavation and backfilling. Shovels, spades, picks, bars, rammers iron 3″ by 3″ and 6″ by 6″; compressor and tools temporarily as required.

Setting Up. Rule, level, prefabricated formwork, timber, hammers, saws and bench, chisels.

Mixing and Placing Concrete. Mixing board or mixer, measure, hydrant and coupling, hose, bucket and barrow.

Concrete work. Trowels (various), floats (wood and iron), and sump mould.

Miscellaneous. Manhole keys, spanners (for assembling formwork), hatchet, bolt cutters, heavy hammers, cold chisels, etc.

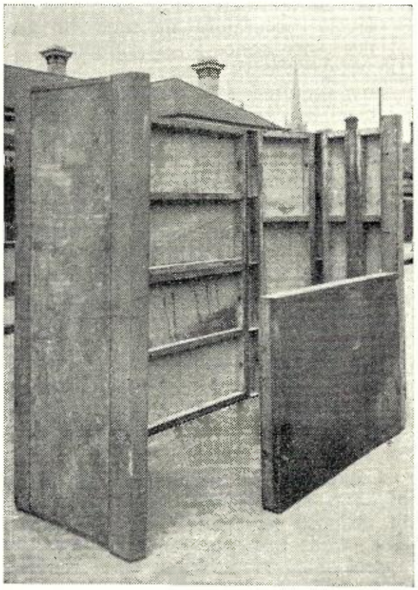


Fig. 6.—Prefabricated steel formwork.

Possible Future Developments.

Practical methods remaining to be developed more fully as to the construction of manholes include either prefabrication in totality, in which instance the major disadvantage of lack of necessary versatility would be, in metropolitan areas at least, impossible to overcome, or prefabrication in sections (for example of corrugated fibro-cement) which are sufficiently versatile to build variations of the common standard shapes and sizes usually encountered in practice, and joined together in such a way as to prevent ingress of water and other foreign matter. Some research as to this is in progress at the present time. Whatever the future techniques, these should be developed and materials obtained to enable manholes to be built more rapidly and economically than at the present time, in that such techniques are clearly possible and obviously desirable.

A DRY CELL BATTERY-OPERATED TRANSMISSION MEASURING SET

F. A. CELLIER

There are many different types of transmission measuring sets at present in use in the Department. Generally, a type is available to suit the requirements of any specific job. Most of the portable sets, however, are not capable of direct measurements where the losses involved are greater than 8 or 10 db. It is common, also, for the meter scales to be cramped, which leads to inaccuracy when readings exceed 4 or 5 db. These limitations are at times a considerable disadvantage and in general, restrict the field of application of portable instruments.

With the foregoing in mind, an attempt was made some time ago in Adelaide to develop a portable instrument free from the disadvantages mentioned. The instrument envisaged was to be robust, but light in weight, and capable of measuring losses or levels with a fair degree of accuracy down to –40 db in the frequency range 35 c/s to 50 kc/s. It was, in fact, required to do the work of the now standard A.P.O. Transmission Measuring Set, at centres where A.C. or 24/130 volt power supplies were not available.

An experimental set was made up, and after modification was found to meet the above requirements in all respects. This instrument, although designed primarily for use on open wire measurements, was found to possess a number of advantages, and its field of application has since been considerably enlarged. These now include carrier equipment installation and maintenance, country telephone maintenance, and transmission laboratory use. The instrument is readily portable, and as such is particularly useful for fault finding in that it can be connected to equipment in situ which is suspect, and observed while adjustments are made. This facility is of some advantage, for instance, when clearing faults on carrier systems fitted with panel mounted transmission measuring sets which cannot be observed from the rear of the racks.

Regarding the design of the experimental set, the modifications found necessary were the result of field trials, and later instruments were wired to the schematic shown in Fig. 1. Fig. 2 gives an idea of the general appearance of the instrument. Brief specifications are as follows:—

Approximate size:
: 12 inches high, breadth and depth 7 inches.

Weight:
: 18 lbs., including batteries.

Meter scale:
: 5 inches, graduated +2 to –30 dbm.

Input pad switching:
: 50 db in 5 db steps.

Measuring limits:
: +22 to –60 dbm inclusive of switched pad and meter scale.

Frequency response:
: Flat within ± 0.1 db, 35 c/s to 50 kc/s.

Calibration:
: 0 db = 1 milliwatt in 600 ohms.

Switched pad accuracy:
: ± 0.2 db all scales.

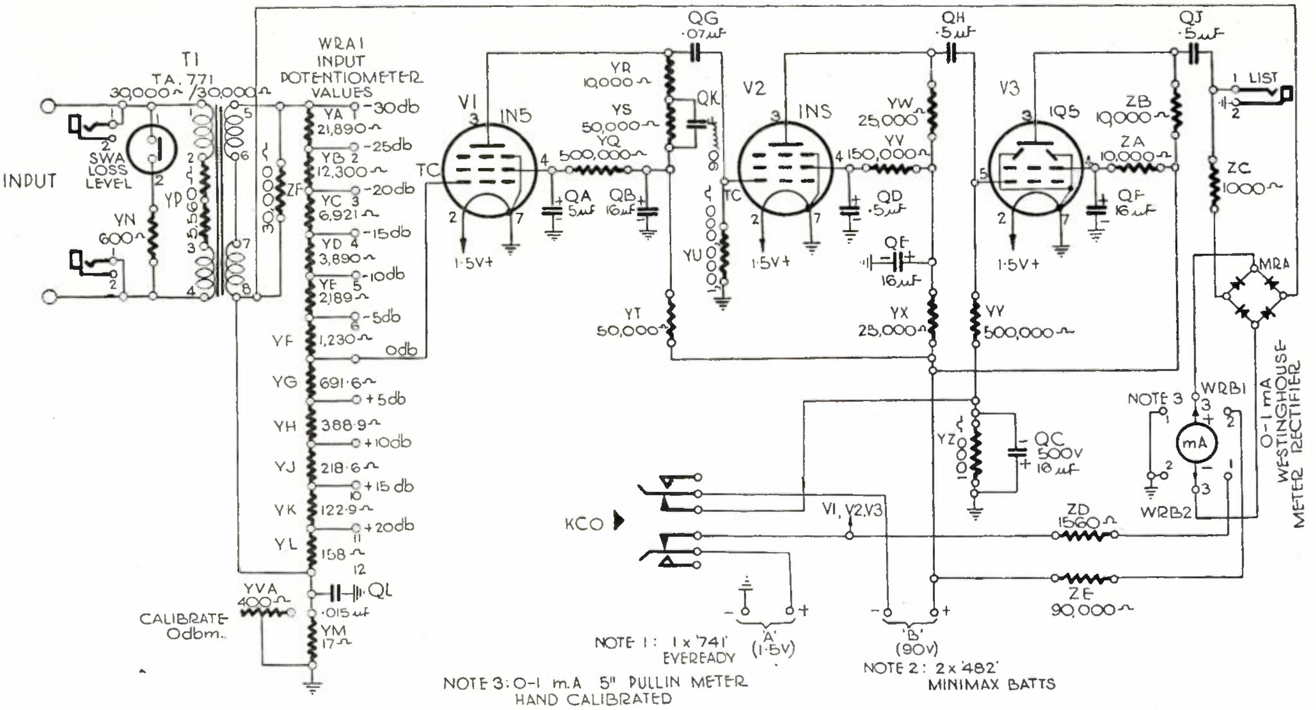
Batteries:
: 1.5 volts, 1X type 741; 90 volts, 2X type 482.

Valves: 2 X 1N5 and 1 X 1Q5.

Current Consumption:
: 0.2 amps. at 1.5 volts, .007 amps at 90 volts.

Batteries, amplifier, meter, etc., are assembled in a 16 gauge sheet aluminium case finished in dark grey crackle enamel. A detachable front cover, leather carrying handle, and rubber feet complete the case assembly.

The amplifier portion of the instrument consists of two 1N5 valves as voltage amplifiers working into a 1Q5



FREQ	30~	35	50	100	200	500	1·0Kc	5	10	20	30	40	50	60	70Kc	
db	+0·1	-0·1	-0·1	-0·1	-0·1	0	0	0	0	-0·1	-0·2	-0·2	-0·2	-0·2	-0·4	

AMPLIFIER GAIN WITH FEEDBACK = 32 db
" " WITHOUT " = 45 db

SIZE 12"x7"x7"
WEIGHT 18 lbs

Fig. 1.—Circuit diagram of transmission measuring set.

power valve. Stages are resistance—capacity coupled. Comparatively large values of coupling capacity and heavy plate and screen de-coupling assist in ensuring stability and a flat gain/frequency response. Bias for the output (1Q5) valve is obtained from the voltage drop across back bias resistor YZ, which is also amply decoupled. After amplification, signals are rectified in the 0-1 mA bridge connected instrument rectifier, and the resulting D.C. is read on the 5 inch scale Paton 0-1 mA meter. Negative current feedback is applied over the 3 amplifier stages and serves the dual purpose of improving frequency response and holding the amplifier gain constant. The feedback controls the gain to a degree that battery voltage variations and small changes in the values of circuit components do not appreciably affect the instrument calibration and short term re-calibrating is unnecessary. Amplifier gain with feedback is approximately 30 db, or 43 db without feedback.

Fig. 2.

Among the facilities included is a plunger type filament switch which is actuated to the "off" position by closing the cover of the instrument, and a means of checking the filament and plate battery voltages. For this purpose the 0-1 mA. meter is converted into a voltmeter. A further facility is that the amplifier portion of the instrument may be used for monitoring purposes by plugging high impedance head phones into the "phones" jack. The input connection may be made either by standard twin plug or by screw terminal binding posts. Either levels or losses may be measured. In the level condition the input impedance is of the order of 30,000 ohms, and is 600 ohms in the loss condition. In each case the impedance is substantially resistive, the angle varying between 2° and 4°. No provision has been made for measuring plate or filament currents, although this feature could be added without difficulties.

Because of small variations in the response characteristic of the input transformer, it was necessary to modify certain circuit details to ensure a flat overall response. In this regard the value of resistors YP, and capacitors QK, QG, QH and QL are critical, and these must be chosen to suit individual instruments.

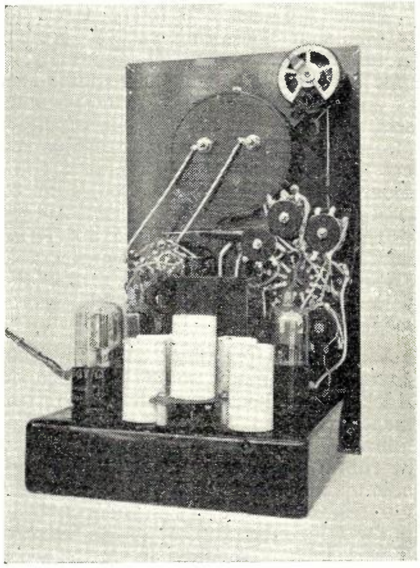


Fig. 3.

It is probable that a better input transformer, such as the ABAC type 909, would allow greater latitude in the values of the components mentioned. Although some care is necessary in final adjustments, these are not particularly tedious or difficult, and may be made without trouble by Departmental staff.

SMALL RACK FOR 2VF SIGNALLING EQUIPMENT

A. J. LINTON

There are a number of small trunk exchanges in the country, where floor space limitations have made it impracticable to install the standard 2VF trunk signalling equipment rack. These exchanges have one or two main trunk circuits which are, at present, operated on a magneto basis.

In order to include such exchanges in the 2VF trunk network, it has been necessary to design an equipment rack that will provide, on a minimum of floor space, for the mounting of two 2VF trunk signalling terminations and the associated common equipment. The new rack, fully equipped, is shown in Fig. 1. It is 6′ 6″ high by one foot wide, and occupies approximately one square foot of floor space. Apart from the miscellaneous relay set for the night, fuse and power fail alarms, the equipment consists of standard 2VF signalling relay sets.

The centre panel provides for a voltmeter, the timing potentiometers, a concentric jack for the speaking circuit of the buttinski and the fuse mounting block. The negative bus-bar of the latter is in two sections for the smooth and the unsmoothed 50 volt D.C. distribution. A small cabinet is fitted to the rack below the relay sets for the storage of circuit drawings, a buttinski, etc. Power for the rack is provided by a 50 volt two ampere capacity constant voltage, wall mounted rectifier.

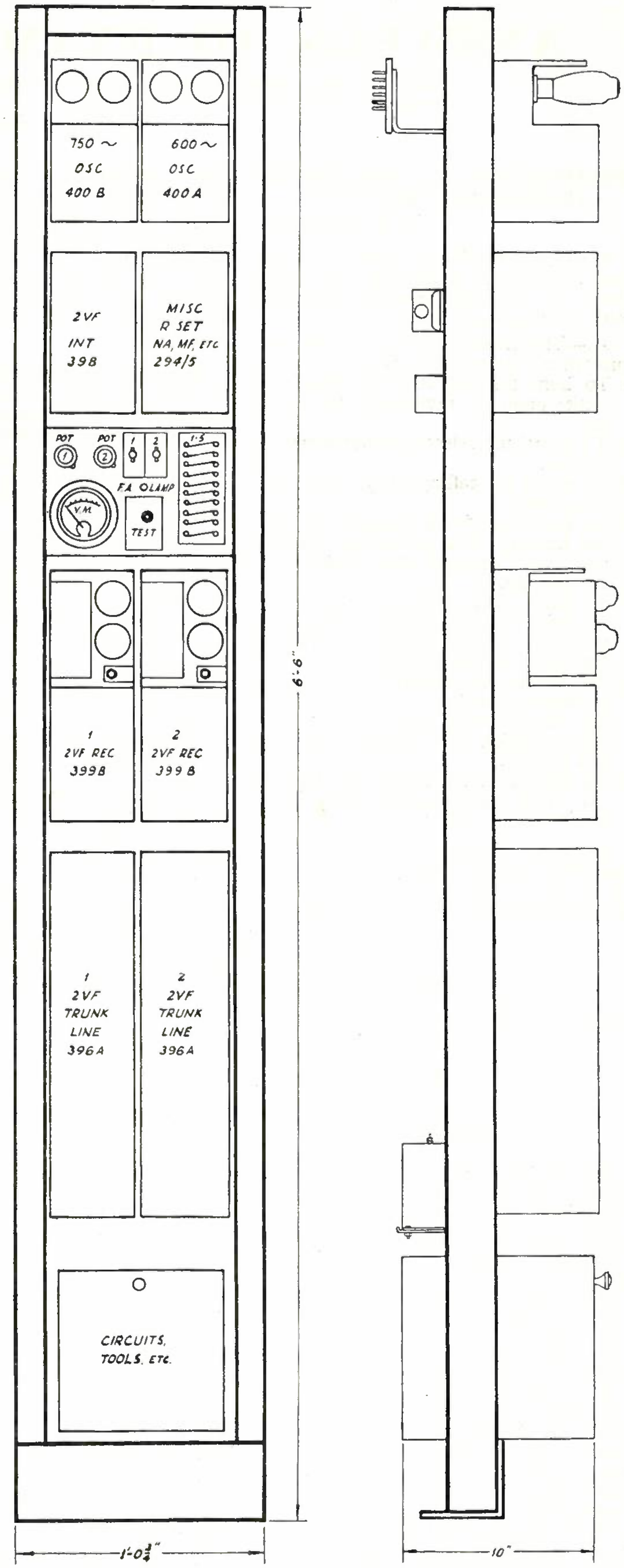


Fig. 1.—Rack layout.

ANSWERS TO EXAMINATION PAPERS

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

EXAMINATION No. 3701—SENIOR TECHNICIAN, TELEPHONE

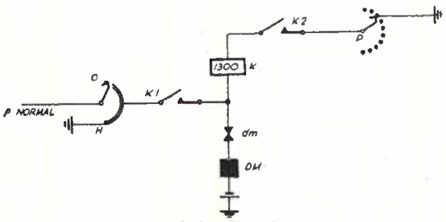
L. W. Wadsworth

Q.4—(a) Describe in detail the general functions of a homing type uniselector of the type normally associated with a subscriber's line.

A.—The functions of a homing type subscriber's uniselector are:—

1. To hunt for and seize the first free outlet upon the removal of the handset.
2. To guard the selected outlet from intrusion.
3. To guard the calling party's line from intrusion.
4. To keep the wipers disconnected during hunting, thus preventing interference with contacts over which they are passing.
5. To extend the calling party's line to the switch seized for the next stage of operation, and to remove all circuits "bridged" across the line.
6. To prepare the circuit of the calling subscriber's register.
7. To release itself and return to the home position when release conditions are applied.
8. To disconnect the calling out apparatus when the subscriber is receiving an incoming call.

Q.4.—(b) Explain, by reference to a simplified circuit diagram, the operation of the above switch during the homing period, including the guarding feature.



Q.4—Fig. 1.

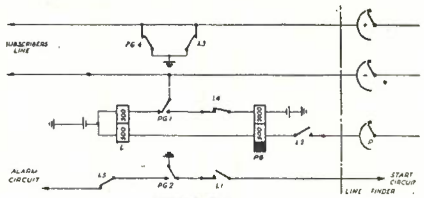
A.—Whilst a call is progressing, the wipers will be standing on a contact other than the home position and the earth on the private from a switch ahead will hold K relay (which was originally operated by L relay over a circuit not shown) operated via K2 operated, 1300 ohm winding of K, interrupters "dm", drive magnet DM, to earthed battery. The DM magnet will not operate in series with 1300 ohms.

The private normal to the final selector bank multiple is earthed by the wiper on the earthed segment of the homing arc H, causing the subscriber's line to test "busy" from final selectors. This wiper also connects the two segments of the homing arc together.

When the call is completed, the earth is removed from the private and K releases. A self-interrupted drive circuit is now completed from homing arc earth, via K1 normal, interrupters (dm), driving magnet (DM) to battery, and the switch drives until the wipers reach the home contact which is not earthed at the homing arc. During homing the guarding earth is still applied to the private normal wire until the homing contact is reached.

Q.5.—(a) What provision is made in a rural automatic exchange to prevent common switching equipment being held busy by faulty subscriber's lines?

A.—In an R.A.X., common switches are released from faulty lines by means of a special feature incorporated in the subscriber's line circuit and the circuit of the common switches (group selectors or final selectors according to size and type of R.A.X.). Fig. 1 shows the elements of a typical line circuit. When the subscriber's line is looped either by the subscriber lifting off his handset, or by a fault, L operates and L1 starts the line finder searching for the calling line. When the line is found and extended through to a group or final selector, an earth is returned on the private which operates PG on its 500 ohm winding and locks L in series with PG. If, however, no dialling is commenced within a predetermined time (usually 30 to 60 secs.) a pulse circuit in the common switch causes the private earth to be removed. L then releases quickly, but as PG is slow to release it is locked, via L4 and its 2000 ohm winding, to the faulty line loop. Thus with L normal and PG held operated, all common switches are released and PG2 operated, and L5 normal, complete the alarm circuit.



Q.5—Fig. 1.

Q.5.—(b) What facilities are provided to indicate to the parent exchange that a fault exists at a rural automatic exchange?

A.—When a fault occurs (such as described in question 5 (a) above) the alarm relay operates and immediately the trunk circuit becomes free a call condition is set up to the parent exchange. When the telephonist answers this call, a particular tone is applied to the line to indicate to the telephonist (a) that a fault exists at the RAX, (b) if the fault is urgent or non-urgent, and (c) the type of fault.

Periodical tests are also made by the telephonist calling a special number and receiving a tone to indicate any abnormal condition.

In some RAX's a special test selector is provided which can only be dialled from the parent exchange, and from which faults on a particular line can be indicated.

Q.6.—(a) List the functions of a 2,000 type discriminating selector repeater installed in a branch exchange which is one of the exchanges in a larger Australian metropolitan network.

A.—The functions of a D.S.R. are as follows:—

1. When seized, to return guarding and holding earth on the private.
2. To operate the junction hunter to hunt for, and seize a free junction to the main exchange.
3. To repeat impulses to the main exchange.
4. If no free junction to the main, to return local dial tone to the caller.
5. To accept dialled impulses and discriminate between calls to the main exchange (or other mains), and local calls (or calls to other branches to which the D.S.R. has direct access).

If the call is to the main or other mains.

6. To perform all the normal functions of a repeater.

If the call is to the local exchange.

7. To act as a 2nd selector and extend the call to a local 3rd selector.
8. To release the junction to the main exchange.
9. If there are no free outlets on the local level, to maintain the connection via the main and allow the call to progress via that route.

If the call is for a branch exchange to which the D.S.R. has direct access.

10. To act as a selector repeater, switching and repeating over the junction to an incoming third selector at the distant branch.
11. To release the junction to the main exchange.
12. If there are no free junctions to the branch exchange, to maintain the connection to the main and allow the call to progress via that route.
13. To release when release conditions are set up.
14. To guard itself during release.

Q.6.—(b) Give a short general description of the operation of the D.S.R. during the setting up of a call to an adjacent branch exchange, i.e., a cross-switched call.

A.—The operation of a D.S.R. is as follows:—

1. When the switch is seized the vertical magnet is operated, stepping the wipers to the first level.
2. The junction hunter searches for a free junction to the parent main exchange, from which dial tone is returned from a 1st selector.

3. If no junction is available the junction hunter searches to the last contact and local dial tone is returned to the caller.
4. Under control of the first impulse train the D.S.R. steps around the first level at the same time as the first selector at the main steps vertically.
5. As the first digit is the first prefix of the local exchange, the D.S.R. mechanism restores to normal.
6. The second impulse train steps the 2nd selector at the main, and the D.S.R., to the level corresponding to the other branch exchange required.
7. The D.S.R. cuts in, searches for, and seizes a free junction to an incoming third selector at the branch exchange.
8. The junction to the main exchange is released and the junction hunter homes.
9. The D.S.R. repeats all further impulses to the branch exchange until the call is complete.
10. If, after 7 above, there were no free direct junctions to the branch exchange, the junction to the main would be held and the call would proceed via the main to the required branch, the D.S.R. acting as a repeater.

Q.7.—(a) The following routine tests are performed regularly in automatic exchanges:—
(i) Off normals;
(ii) Alarms;
(iii) Trunk tests;
(iv) Switch operation;
(v) Junction tests.
Briefly describe how each routine is carried out and state how frequently each test is performed.

A.—(i) Off normals: Switches of all ranks, which are in an operated position are checked to see that a call or conversation is in progress. If the switch is wrongly held up, an investigation is made to locate the cause of the trouble and, if necessary, a fault docket prepared. The "off normals" are done in conjunction with permanent loops in a particular order, which generally ensures that off normals are checked before permanents.

The frequency of off normal tests is three times daily.

(ii) **All alarms** are tested by setting up the actual fault conditions which the alarms are designed to indicate. Urgent alarms are all tested daily, and a proportion of non-urgent alarms are tested daily so that the entire system is checked every week. This proportion is arranged so that all common alarm equipment is tested daily.

(iii) **Trunk tests** are carried out by means of the appropriate outlet test sets, to test the trunks between all ranks of switches. The test set steps the switch to each level in turn, and around the contacts of the level, testing each outlet for opens, crosses or reversals. It stops whenever a fault is located.

On Group Selectors and the local level of D.S.R's a proportion of the switches are tested daily so that all trunks are tested every 10 weeks.

On uniselectors the proportion is arranged so that all trunks are tested every 2 weeks.

(iv) **Switch operation** tests are carried out by means of automatic routiners (where installed) or manual test sets. All functions of each type of switch are tested under conditions more stringent than normal operating conditions. In the case of the automatic routiner all switches are tested in turn automatically and the routiner stops, gives an alarm, and indicates the fault by means of lamps, whenever any unstandard condition is encountered. The manual test sets perform similar tests but under the control of manually operated keys.

The frequency of test for all switches is twice weekly.

(v) **Junction tests** are carried out by automatic routiners or manual test sets on all outgoing junctions. The test is made by dialling a special test number at the distant exchange, from which an interrupted tone and battery reversals are returned, enabling a check of both junction and repeater operation to be made.

Junction tests are carried out over all outgoing junctions every day.

Q.7.—(b) Why are routine examinations made in automatic exchanges and what is the nature of the work done during their performance?

A.—Routine switch examinations are made periodically before routine testing to discover and rectify any mechanical or electrical condition of the apparatus other than the specified standard. This is a form of preventive maintenance as it reduces the number of faults causing interruption to service by detecting and clearing potential faults before they develop sufficiently to prevent the apparatus from functioning.

The switches are removed from service, thoroughly cleaned and re-oiled, and all adjustments checked and readjusted where necessary. Worn parts are replaced and all screws and locking screws checked to ensure that they are not loose. All magnets, relays, and springsets are checked for correct operation and adjustments. The equipment is finally tested on the appropriate routiner before replacing in service.

Q.8.—(a) In a 2,000 type final selector certain functions are performed by the following relays:—
(i) A Relay;
(ii) B Relay;
(iii) F Relay;
(iv) J Relay.
What special features are included in the relays themselves or are provided in the circuit arrangements to enable the relays to perform their functions?

A.—Special features of A, B, F and J relays in 2000 type final selectors are as follows:—

(i) A relay has—
- (a) An Isthmus armature.
- (b) Minimum spring load and large residual air gap.
- (c) Nickel-iron sleeves on the core.
- (d) a 570 ohm winding in addition to the 200/200 ohm balanced operating windings.

(ii) The B relay winding is short circuited by means of A relay contacts in the normal condition, so that it is slow to release when A is normal but quick to operate when A operates.

(iii) The F relay has—
- (a) an armature end slug to make it slow acting.
- (b) 2 windings, a 300 ohm operating winding and a 400 ohm locking winding.
- (c) An "x" or early operating springset which normally short circuits the locking winding.

(iv) The J relay is made slow releasing by means of a heel end copper slug.

Q.8.—(b) Why are the special features needed in each case?

A.—The reasons for the special features mentioned in part (a) are listed below.—

(i)(a) The A relay is an impulsing relay, and to ensure correct operation of the selector magnets, its operate and release lags should be equal. With a normal armature the release lag is greater than the operate lag. However, the shape of the isthmus armature (due to its increased reluctance), causes a decrease in release lag whilst having little effect on the operate lag; thus making the two nearly equal.

(b) The large residual air gap also reduces the total flux, thus assisting release; whilst the light spring load ensures quick operation.

(c) The nickel-iron sleeves make the relay high impedance to speech frequencies, and are necessary because the relay is bridged across the line during conversation.

(d) The 570 ohm winding is used as the primary of an induction coil to induce service tones into the 200 ohm windings and the calling line. The two 200 ohm windings, one in each side of the line, are provided to maintain the balanced condition of the line.

(ii) The B relay is required to be slow releasing so that when A releases its contacts complete the vertical and rotary stepping circuits and provide a guarding earth on the private. These circuits must be maintained during dialling. The slugging effect due to the short circuit applied by the A relay contacts ensures that B holds during the break periods of the dial.

(iii)(a) The F relay is required to operate with D.C. flowing in its 300 ohm winding when a called subscriber answers and loops the line, but not with the A.C. ringing current. The armature end slug partly achieves this effect by making the relay so slow acting that it will not respond to alternating current.

(b) The effect of the armature end slug is assisted by the fact that the second winding (400 ohm) is short circuited when F is normal.

(c) When the F relay operates, it does so via the called subscriber's loop and with this resistance in series, there are not sufficient ampere-turns to fully operate the relay against the spring load of its 8 springsets. This difficulty is overcome by means of the "x" springset because the full spring load of the other seven springsets is not encountered by the armature until the "x" springset is fully operated. The springset removes the short circuit from 400 ohm winding and the relay operates fully and locks on this winding with no other series resistance.

(iv) The slow release time of the J relay is necessary to ensure that the meter pulse applied to the private is sufficiently long to operate the calling subscriber's register. The metering circuit is prepared by the operation of the J relay, and completed by the operation of E which opens the circuit of J at the same time. Thus the meter battery pulse is applied only for the slow release time of the J relay.

Q.9.—(a) What facilities are provided by an A10 intercommunication system?

A.—The A10 intercommunication system provides for 2 exchange lines and 10 extensions (including one external extension). By a slight modification an additional internal extension can be added. The facilities provided are as follows:—

1. Direct calling between all internal extensions. Secrecy is not provided on these calls.
2. Internal extensions may call the external extension direct.
3. The external extension may call the main station and request that an internal extension be notified to call the external extension.
4. Conference facilities which allow any internal extension to speak to all or any number of extensions simultaneously.
5. Direct access to the exchange from any internal extension if desired.
6. Internal extensions may be denied access to the exchange or, alternatively allowed access through the main station.
7. The external extension may call the exchange via the main station.
8. Incoming calls are answered at the main station.
9. Exchange calls may be transferred from one extension to another.
10. An internal extension may hold an exchange line and make a call to any other extension. If two exchange lines are provided, an internal extension may hold one exchange line and make a call on the other.
11. Secrecy on exchange calls with a busy test provided for extensions engaged on exchange calls.
12. Any internal extension with full facilities may be fitted with an extension trembler bell to enable incoming exchange or external extension calls to be answered at that point.

Q.9.—(b) What provision is made in A10 intercommunication systems to minimise loss in transmission during conference calls?

A.—As each telephone is provided with a separate transmitter battery feed via a balanced retard, there is negligible loss in transmission when a number of extensions are connected together on a conference call.

Q.10.—(a) What components, other than those provided in a standard automatic wall telephone, are used in the circuit of a unit fee public telephone for automatic areas and what are the functions of each of these components?

A.—The components, other than those provided in a standard automatic wall telephone, used in the circuit of a unit fee public telephone are:—

1. A polarised relay.
2. A coin-operated springset.

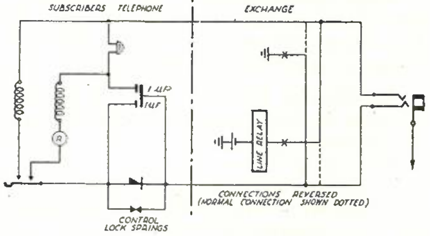
The purpose of the polarised relay is to respond to the reversal of polarity of the battery applied to the line, which occurs when a called subscriber answers. Its contacts short circuit the transmitter so that the caller cannot speak to the called party; and place a low resistance non-inductive shunt across the receiver to prevent it being used as a transmitter. This, however, allows the caller to hear the called party. The dial impulsing springs are also short circuited by the polarised relay to prevent the public telephone being used if the lines are reversed prior to making a call. The main function of the coin springs is to short circuit the polarised relay when the coins are inserted, causing it to release and restore the circuit to normal for speech. The coin springs also short circuit the dial impulsing contacts so that no further calls can be made until the switchhook has been operated to allow the coins to fall into the coin tin.

Q.10.—(b) What circuit alterations is it necessary to make to the telephone and the exchange equipment of subscribers' services in manual exchange areas to provide control lock facilities?

A.—Circuit alterations necessary to provide control lock facilities in manual exchange areas, are as follow:—

Magneto Exchanges: The control lock simply short circuits the generator, preventing outgoing calls but not affecting incoming calls. Inserting the key in the lock removes this short circuit. No alteration is necessary at the exchange.

C.B. Exchanges: At the subscriber's end a rectifier is fitted as shown in Fig. 1.



Q.10—Fig. 1.

It is shunted by a condenser so that it has no effect on speech currents. At the exchange end the connections to the line relay are reversed so that the battery is applied through the line relay in the blocking direction of the rectifier. A call cannot, therefore, be originated unless the rectifier is shorted out by the control lock contacts.

Incoming calls are not affected as the cord circuit battery feed at the exchange is in the conducting direction of the rectifier.

EXAMINATIONS Nos. 3415-6—TECHNICIAN, RADIO AND BROADCASTING.

Section A

Q.1.—(a) Define E.M.F., P.D., Resistivity.

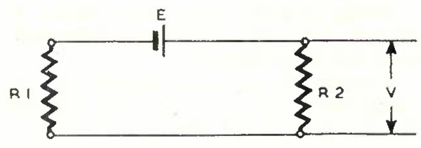
(b) A reading of 10 volts is obtained on a voltmeter of 5,000 ohms resistance when it is connected in series with a battery of negligible resistance and a telephone line which is looped at the distant end. When the 5,000 ohm voltmeter is replaced by another voltmeter of 500 ohms resistance the reading is 4 volts. Calculate the resistance of the line.

A.—(a) E.M.F. (Electro Motive Force) is that force which causes an electric current to flow in an electrical circuit.

If between any two points in an electrical circuit a current is flowing, a P.D. (potential difference) is established between the points.

Resistivity or Specific Resistance is the resistance of a body of unit length and of unit cross sectional area.

(b)



Q.1—Fig. 1.

$V = ER_2/(R_1 + R_2)$ where
R_1 = resistance of line
R_2 = resistance of voltmeter
E = E.M.F. of battery
V = voltmeter reading (P.D. across R_2)

Case 1.
$10 = 5000\ E/\ (5000 + R_1)$
$E = (50000 + 10\ R_1)/5000$

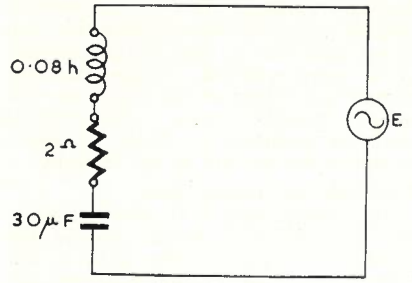
Case 2.
$4 = 500E/(500 + R_1)$
$E = (2000 + 4R_1)/500$
$\therefore 50000 + 10R_1 = 20000 + 40\ R_1$
and $R_1 = 1000$ ohms.

Answer: Resistance of line = 1000 ohms.

Q.2.—A coil having an inductance of 0.08 henries and a resistance of 2 ohms is connected in series with a capacity of 30 microfarads. A potential difference is applied to the circuit and the frequency is varied. It is found that for one value of frequency the current through the circuit reaches a maximum. Calculate the frequency and find the potential difference between the terminals of the condenser.

A.—

Fig. 1 shows the connection of the components set out in the question. E volts are applied to the circuit. At the



Q.2—Fig. 1.

resonant frequency, f, maximum current flows through the circuit.

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

Where f = resonant frequency

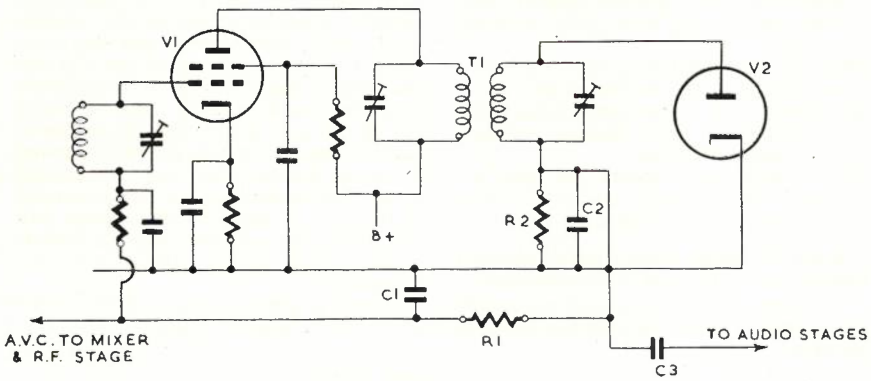
L = inductance (henries)

C = capacity (Farads)

$f = 1/(2\pi\sqrt{0.08 \times 30 \times 10^{-6}})$

= 103 cycles per second (slide rule)

= resonant frequency which is the frequency at which current will be maximum.



Q.4—Fig. 1.

At this frequency the impedance will be non-reactive and will equal the total ohms resistance of the circuit—i.e. 2 ohms ∴ current $I = E/2$.

Potential drop across condenser

$= IXc$

where Xc = capacitive reactance

$= 1/(2\pi fC)$

$IXc = (E/2) \times (1/2\pi fC)$

$= (E \times 10^6)/(2 \times 2\pi \times 103 \times 30)$

= 26 volts approx. = Answer.

Q.3.—(a) State Lenz's Law.

(b) Explain the effect which the "transformation ratio" has on the primary and secondary voltages and currents in a transformer.

(c) State and briefly explain four losses encountered in iron core transformers.

A.—(a) Lenz's Law states that when e.m.f. is induced in a circuit by a changing magnetic flux threading that circuit, then the polarity of that e.m.f. is such that it would cause a current flow whose magnetic action would oppose the flux change.

(b) The ratio of the secondary voltage of a perfect transformer to the primary voltage is the same as the transformation ratio (secondary turns/primary turns), while the ratio of the secondary current to the primary current is the reciprocal of the transformation ratio.

(c) Losses encountered in an iron core transformer include:—

1. **Copper losses.** These losses are due to the I^2R dissipation in the winding.
2. **Eddy current losses.** These are due to power dissipated by induced currents flowing in the core.
3. **Hysteresis loss.** This loss is due to energy being required to take the iron of the core through the magnetic cycle.
4. **Dielectric loss.** This is due to imperfect dielectric material between points of potential difference, e.g., insulating material between windings, varnish on wires, etc.
5. **Insulation losses.** Losses due to imperfect insulating materials between windings, etc.

Section B.

Q.4.—Explain fully the term "A.V.C." as applied to a radio receiver and illustrate your answer with a circuit diagram of the essential portion of a superheterodyne receiver.

A.—The term "A.V.C." is an abbreviation of Automatic Volume Control, and denotes that process whereby the audio output from a receiver is made largely independent of the input signal to the receiver.

A.V.C. is achieved by using a negative voltage derived from the detector to control the bias applied to the radio frequency stages of a receiver. It should be noted that the use of A.V.C. requires variable mu valves in the controlled stages of a receiver.

The main advantages of A.V.C. are:—

(a) Manual adjustment of the volume control is seldom required when tuning between stations of different signal level.

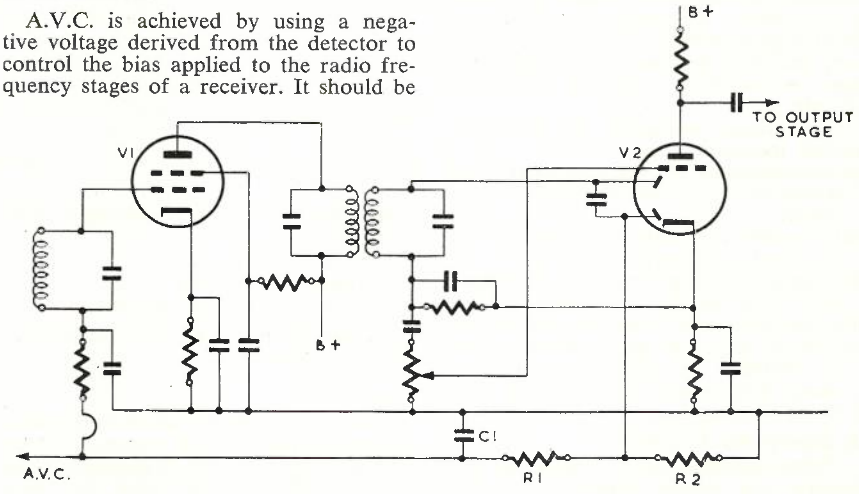
(b) The effects of fading are minimised.

(c) Overloading of R.F. stages is reduced.

Figure 1 shows a simple form of A.V.C.

Operation of the circuit is as follows: Signal is fed to the diode detector V_2 from the tuned transformer T_1. The signal is rectified by V_2 and a detected audio voltage superimposed on a D.C. voltage appears across R_2 (R.F. components are by-passed by condenser C_2). The audio component of this voltage is fed via condenser C_3 to the audio stages of the receiver. (C_3 is necessary to block the D.C. component from the grid of the first audio stage.) The D.C. voltage which is negative with respect to ground is fed via filter R_1 C_1 to the earth end of the grid tuned circuits of the R.F. stages. Thus, as the signal input to the receiver is increased the negative bias on the R.F. stages is increased. The reduced gain of the R.F. stages causes the signal fed to the detector to increase much less rapidly than it would with fixed bias on the R.F. stages. Since the audio output from the receiver for a given volume control setting is proportional to the signal input to the detector, it will be seen that by biasing the R.F. stages from the detector automatic volume control is produced. The time constant of the filter R_1 C_1 controls the speed of A.V.C. action—if too high then the circuit will not follow fading and if too low attenuation of the lower audio frequencies will result due to an audio component being applied to the control grids.

A disadvantage of the above circuit is that inadequate audio output may result due to low signal levels being further reduced by the A.V.C. action. To overcome this disadvantage delayed A.V.C. is used to prevent any reduction of sig-



Q.4—Fig. 2.

nal level until the signal has reached the point where adequate audio output is available. Delayed A.V.C. is the most frequently used form of A.V.C.

The circuit of Fig. 2 indicates a typical method of deriving delayed A.V.C.

In this circuit a double diode triode is used as a detector and audio amplifier. A delayed A.V.C. voltage is also obtained from the tube. The A.V.C. diode is fed from the signal diode through a small condenser. The cathode of V_1 is positive with respect to the A.V.C. anode and thus conduction of the A.V.C. diode is delayed until the signal to the diode rises above the delay voltage provided by the bias resistor of the triode section of V_2, A.V.C. voltage is then produced across R_2 and is fed to the control grids as shown in Fig. 1.

The following comments are relevant to A.V.C.

(i) Distortion will result if the components in the A.V.C. circuit are incorrect.

(ii) A.V.C. may be applied to the audio stages to obtain greater control. It is then necessary for the controlled valves to operate in push pull to reduce second harmonic distortion.

(iii) Amplified A.V.C. is sometimes used to obtain greater control without introducing distortion.

(iv) A.V.C. is often known as A.G.C. —Automatic Gain Control.

Q.5.—Describe three methods of cooling large transmitting valves and any special precautions necessary with each method.

A.—The three methods available for cooling large valves are:—

1. Water cooling.
2. Forced air cooling.
3. Radiation and convection cooling.

1. Water Cooling.

This method requires that a continuous flow of water be maintained in contact with the anode of the tube. Since water has a higher thermal capacity than any other substance it is capable of drawing off very large amounts of heat.

The valve anode is usually fabricated in the form of a hollow cylindrical shell through the annulus of which the water is circulated. Electrically driven centrifugal pumps provide the pressure necessary and after heating in the anodes, the water is cooled in a radiator exposed to the air.

Precautions necessary in a water-cooled installation are—

(a) maintenance of high resistivity of water by using unadulterated distilled water.
(b) Provision of an alarm to indicate fall in water resistivity.
(c) Duplication of pumps to avoid failure of installation due to a pump fault.
(d) Provision of a water flow fail alarm.
(e) Use of inlet and outlet thermometers to indicate, in conjunction with a water flow meter, the amount of heat being dissipated.

2. Forced Air Cooling.

Tubes designed to be cooled in this manner are usually provided with an anode which has one surface exposed to the air. This surface is often increased by the use of radial copper fins. A motor-driven fan maintains a large flow of air through the anode structure. This method is simpler than water cooling, but can dissipate less heat.

Precautions:—

(a) Provision of a sufficient flow of air around the active parts.
(b) Use of an air fail alarm.
(c) Duplication of fans, if necessary.
(d) Provision of cool, clean, dry air for inlet to fan.

3. Radiation and Convection Cooling.

This technique is applicable to lower power tubes where the anode is enclosed with the other tube elements in a large envelope. The anode is permitted to attain a high temperature so that heat is radiated to the envelope and to adjacent equipment. Both envelope and heated components must then be cooled by air circulation and this is usually obtained by convection or a low velocity fan.

Precautions:—

(a) Prevention of over-running the tubes since the tubes are working at high temperatures and have little overload reserve.
(b) Placement of tubes to ensure an even and adequate circulation of air.
(c) Placement of components in the vicinity of tubes to avoid damage resulting from heat radiation.
(d) Provision of a source of cool air directly to the tubes, and not via other heat dissipating components.

Q.6.—(a) Name three types of electron emitters used in radio valve cathodes.

(b) Name the elements of a pentode thermionic tube and explain the function of each.

A.—(a) Three types of electron emitters are:—

1. Pure tungsten.
2. Thoriated tungsten.
3. Oxides of Barium and calcium.

(b) The Elements of a Pentode Tube—The electrodes.

The Cathode.

The cathode is the electron emitting electrode of the tube. A current is passed through it or a current is passed through a loop of wire to raise its temperature. If the wire is of tungsten or thoriated tungsten, electrons are emitted directly, but in most small tubes this loop or heater is used to raise the temperature of a more efficient electron emitter, namely a cylinder of metal coated with certain metallic oxides. The emitted electrons maintain a cloud, or space charge in the vicinity of the cathode.

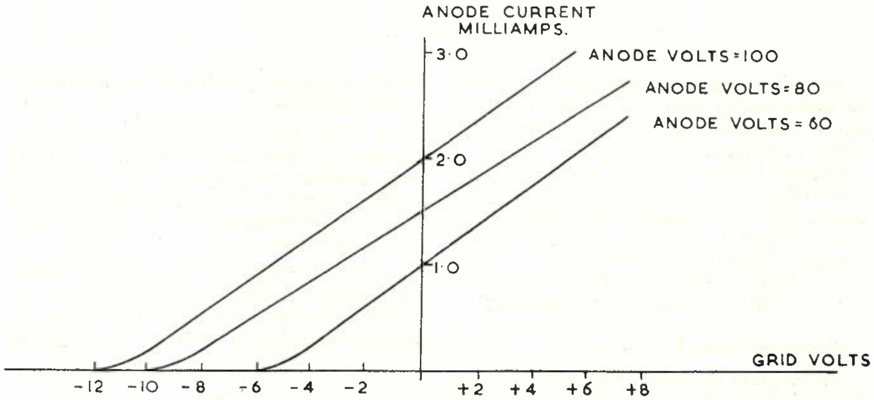
The Grid (or Control Grid)

The control grid is an open spiral of fine wire which is wound around the cathode, but spaced from it by a few millimeters. When a positive potential is applied to the anode with respect to the cathode a current will flow by virtue of the electrons attracted to the anode. The function of the grid is to control this flow, by causing a positive or negative electric field to appear close to the cathode..

If the grid is maintained at a positive potential with respect to the cathode electrons are attracted to it from the space charge, but due to its open structure most of them pass through and are collected by the anode.

However, if the grid is maintained slightly negative, electrons are repelled back to the space charge and the anode current is reduced. Due to the fact that the grid is much closer to the cathode than the anode, a small negative potential at the grid is sufficient to counteract the field caused by a large positive potential at the anode. Thus the grid maintains a sensitive control of the anode current. If the grid is made more negative with respect to the cathode, a point will be reached when anode current will cease altogether.

A typical plot of anode current against grid volts is shown in Fig. 1.

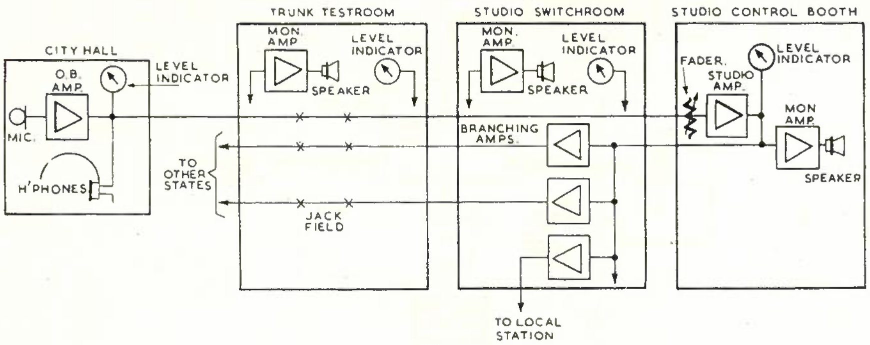


Q.6—Fig. 1.

Section C.

Q.7.—It is desired to broadcast over the National network in several States a musical programme being produced in a city hall. Draw a diagram showing the various inter-connecting links and briefly describe the essential apparatus required to maintain good quality throughout the network.

A.—Fig. 1 shows the arrangement of connections to permit the musical programme produced in a city hall to be distributed for broadcasting in several States.



Q.7—Fig. 1.

The essential items of apparatus required to maintain good quality throughout the network are as follows:

Outside Broadcasting Amplifier Equipment.

Located at the city hall to amplify and mix the outputs of the microphones used; also permits level of programme to be monitored and adjusted.

Branching Amplifiers.

At all points where the programme is to be "split" into a number of separate feeds, amplifiers having a high input impedance are connected in parallel across the main programme source. The branch amplifiers have a small adjustable gain and prevent line or equipment faults on separate programme feeds from affecting other feeds.

Level Indicators and Monitoring Equipment.

As the quality of the programme being distributed may be impaired by noise if its level is permitted to fall below the minimum permissible for the circuit involved, and may be impaired by distortion resulting from the overloading of amplifiers if it is permitted to rise above the maximum level permitted, level measuring equipment and loud speaker monitoring units must be provided at points where the level of the programme is adjusted. The level indicator uses a Volume Unit Meter with amplifier and attenuator to read programme levels from—40 V.U. to + 30V.U. The loud speaker monitoring equipment consists of amplifier with adjustable gain giving a maximum output of approximately 3 watts to drive a high quality loud speaker unit. The loud speaker is usually housed in an enclosure to permit an increase in efficiency together with improved frequency response and reduction in distortion in the operation of the loudspeaker.

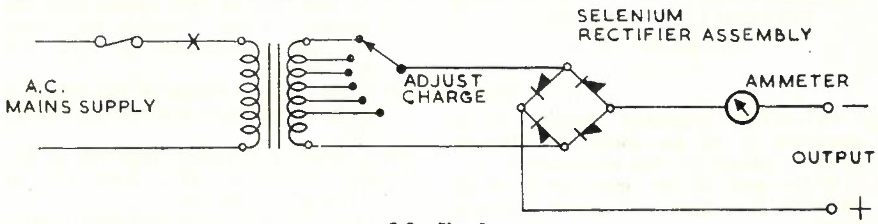
Q.8.—(a) Draw a circuit diagram of a rectifier suitable for charging 6 volt secondary batteries (accumulators) from the A.C. mains. Show the method you would use to vary the charging rate between 1 and 10 amperes and indicate the type of rectifier used.

(b) Show by means of graphs the following:—

(i) The wave shape of the output voltage of the rectifier.

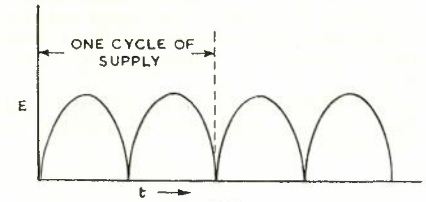
(ii) The voltage delivered by a single cell of a secondary battery when discharged from the fully charged condition to the fully discharged condition over an eight hour period.

A.—Fig. 1 shows the circuit of a rectifier unit used to charge 6 volt secondary batteries. The rectifier uses disc rectifier elements of the selenium or copper oxide type. The charging rate may be varied between 1 and 10 amperes by changing the transformer secondary voltage by means of the tap selector switch.



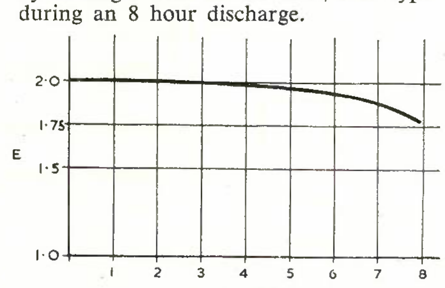
Q.8—Fig. 1.

(b) (i) Fig. 2 shows the output voltage wave form for the rectifier unit shown in Fig. 1.



Q.8—Fig. 2.

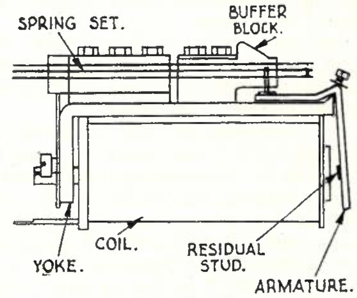
(ii) Fig. 3 shows the voltage delivered by a single cell of the lead/acid type during an 8 hour discharge.



Q.8—Fig. 3.

Q.9.—Describe, with the help of sketches, the construction of a modern telephone relay. Explain the reasons for any special features in the construction.

A.—The main features of a modern telephone relay of the 3000 type are shown in Fig. 1. The coil of enamelled copper wire is wound on a soft iron core which is secured by a nut, to the yoke. The end of the yoke is formed into a knife edge, against which the armature is held by a retaining screw and spring.



Q.9—Fig. 1.

The armature is prevented from touching the core, when operated, by the use of a brass residual stud or screw. If a fixed residual air gap is required a brass stud is riveted to the armature, or, if an adjustable gap is necessary to meet the circuit requirements, a brass screw is threaded through the centre of the armature and locked in position with a locking nut. The contact springs are separated from one another by insulating material and are clamped between plates as complete units, one of which can be secured to the yoke on either side of the buffer block. The buffer block is made of white insulating material and projections on the fixed contact springs rest upon shoulders in this block.

There are several special features in the construction of the standard relay:—

(1) Each spring is slotted from the front end for a short distance along its length and a contact is riveted to each tongue so formed. The twin contacts thus provided reduce the liability to contact faults, and the degree of independent flexibility resulting from the slotting ensures even distribution of pressure between the two contacts of each spring.

(2) The use of the central block for controlling the positioning of the fixed springs facilitates adjustment of the spring sets, by providing an immovable support against which the springs can be tensioned. In addition, the arrangement ensures that adequate contact pressure is obtained, by arranging for the tensioned spring to be just lifted from the block by the moving spring. The light colour of the block provides a good background against which all springs can be viewed.

(3) The front cheek of the coil is usually made of thin copper which acts as a very small armature end slug. This does not materially alter the speed of operation or release of a normal relay, but it reduces the tendency of the springs to bounce when contacts are made or broken.
(4) The poleface is of larger cross section than the core resulting in an improved magnetic circuit and consequent magnetic efficiency.
(5) The provision of the armature retaining spring and screw enables the relay to be mounted on its side while still retaining the correct knife edge contact between yoke and armature.
(6) The coil and core and the spring sets are detachable as separate units from the yoke, and it is thus an easy matter to replace these items.
(7) The knife edge on the yoke, and the corresponding recess in the armature are ground to correct shape, and provide a most efficient magnetic joint, having the minimum of resistance to armature movement.

EXAMINATION No. 3701—SENIOR TECHNICIAN, TELEPHONE.

TELEPHONY II

Section 1

H. G. Hodge

Q.1.—The measured output of an amplifier is 30 db above 1 milliwatt. What is meant by this expression?

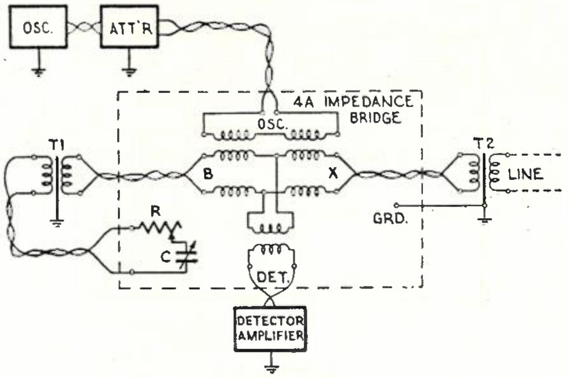
If the gain of the amplifier is 20 db calculate the value of the input power in watts.

A.—The "db" or decibel is a unit used in measuring the ratio of amounts of power, voltage, or current, in different parts of electrical circuits. When the common logarithm of the ratio of any two quantities of power is unity, the difference in level is said to be one bel. The practical unit, the decibel, is one-tenth of a bel. For two electrical powers then P1 and P2, the difference in level in "db" can be calculated from the formula $10 \times \log_{10} P1/P2$ or $10 \times \log_{10}$ Power ratio. (For voltage and current the formula is $20 \times \log_{10} E_1/E_2$ or $20 \times \log_{10} I_1/I_2$.)

If the output of an amplifier is 30 db above one milliwatt, it follows that the ratio of one milliwatt to the output power has the logarithm 3, which indicates 10^3 or a ratio of 1000. As the output was quoted as above one milliwatt, this output is 1000 times greater than one milliwatt, or 1000 milliwatts. (= 1 watt.)

If the output power
= 30 db above 1 milliwatt
and the gain = 20 db
Then the input power
= 10 db above 1 milliwatt.
Let P_2 = input power in milliwatts
Then $10 \times \log_{10} P_2 = 10$
$\therefore \log_{10} P_2 = 1$
$\therefore P_2 = \text{antilog } 1.$
= 10 milliwatts or .01 watts.

Q.2.—List the equipment you would require to measure the characteristic impedance of an open wire line in the range I kc/s to 30 kc/s and show by means of a schematic diagram how the equipment would be connected. What arrangements would be necessary at the distant end of the circuit.



Q.2—Fig. 1.

A.—For the measurement of the characteristic impedance of an open wire line in the range I kc/s to 30 kc/s the following equipment is required:
(i) An oscillator whose frequency is capable of being varied continuously or at intervals of 100 cycles over the required range. Suitable oscillators for the purpose are the 17B, 10B or 8A types.
(ii) An impedance bridge of the balanced hybrid coil type such as the 4A or 5A.
(iii) A detector amplifier, type 1A or 3A.
(iv) An attenuator, STC type 1A, or Muirhead type 4B.
(v) Two 600/600 ohm matched carrier transformers.

Measurements are taken on the circuit under test with the distant end (a) open and (b) short circuited. (Note. Both conditions to be proved by DC loop test.)

Values of R and C at which balance is obtained, are recorded and from them the characteristic impedance is calculated.

It is important that the screens of all items of test equipment be earthed as shown in Fig. 1.

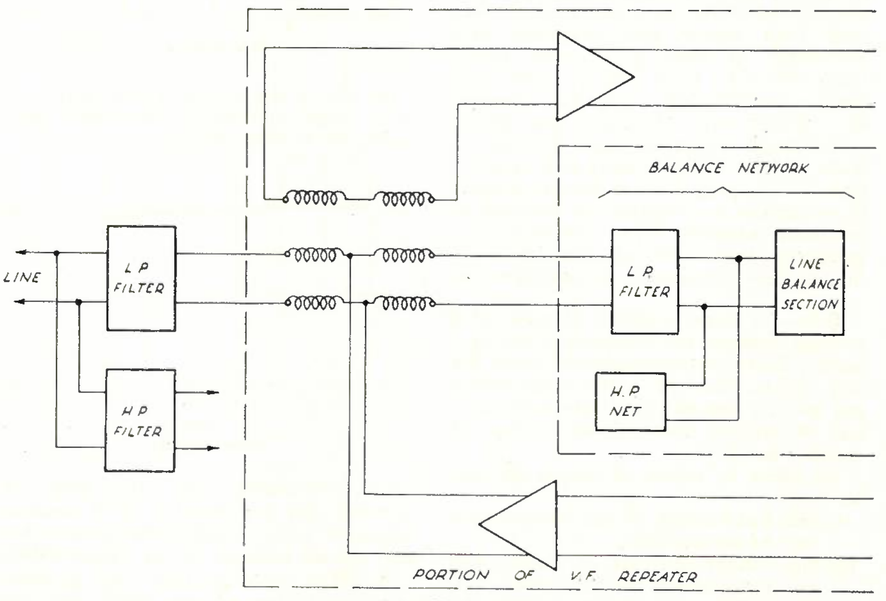
Q.3.—Show by means of a simple diagram, where a high pass network is associated with a voice frequency repeater and explain briefly why it is used.

Why is it necessary to maintain a singing margin in voice frequency repeaters?

A.—Where a V.F. repeater is installed in a line which is also equipped with low and high pass filters, it becomes necessary, in order to retain the balance condition of the repeater hybrid coil, that the balance network includes components to balance the filters as well as the line.

The only satisfactory balance, over the repeater frequency range, for the low pass section of the filter is a similar low pass section, which is normally used. The high pass section of the filter, however, presents only a high impedance shunt across the circuit at the frequencies passing through the repeater, and this can be simulated by a very simple inductance and capacity combination known as a high pass network, which is much less costly than a high pass filter section, and which also provides the correct termination condition for the low pass section of the filter balance.

In two wire repeaters the total gain which can be obtained is limited by the degree of balance which can be main-



Q.3—Fig 1.

tained between each line and its balance network.

While it is usually possible to obtain networks which will simulate the lines which they have to balance, at the time the measurements for such networks are made, it is not possible to maintain this balance due to changing weather conditions, varying line termination conditions, etc. To prevent the repeaters from singing under all circumstances, the gains of the repeaters have to be kept lower than the figure obtained under the best balance conditions, by an amount which will keep the repeater stable with a certain degree of unbalance existing across the hybrid coil. This is the singing margin, and in practice a gain reduction of 3 db in each direction of the repeater is usually found satisfactory.

Section II

Q.1.—Describe the signalling facilities of any single channel system with which you are familiar. Illustrate your answer with simple schematic circuits.

A.—The signalling facilities of the SOA/SOB single channel carrier systems are as follows:—

The signalling equipment consists of two panels—

(a) A signalling receiver panel which amplifies and detects the incoming ringing signals.
(b) A relay panel which mounts all the relays associated with the ringing equipment.

Ringing current, or battery, from the switchboard energises relays which perform the following operations:—

(a) Prevent the passage of 17 c/s current to the modulator.
(b) Unbalance the modulator circuit allowing the normally suppressed carrier to be transmitted.
(c) Alter the constants of the tuned circuit in the modulator oscillator, thus lowering the frequency by 1000 c/s.
(d) Connect vibrating contacts across the modulator output thus interrupting the transmitted carrier 17 times per sec.
(e) Start the 17 c/s ringer if necessary.

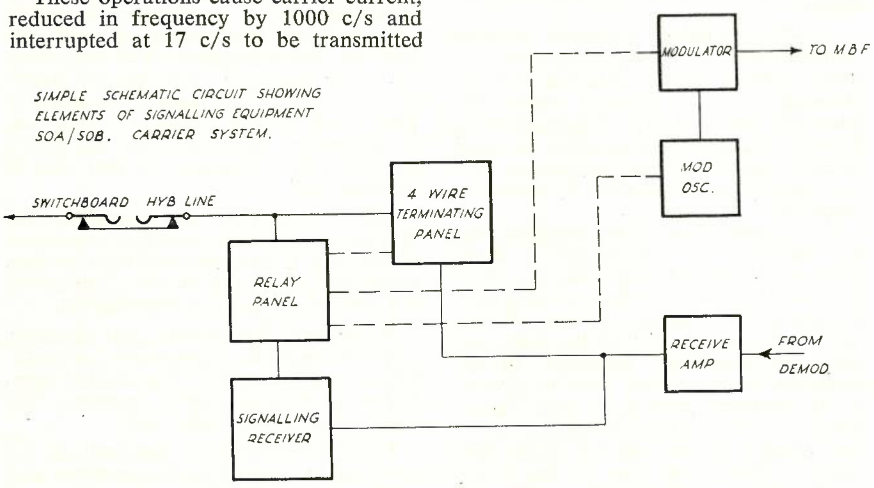
These operations cause carrier current, reduced in frequency by 1000 c/s and interrupted at 17 c/s to be transmitted to the distant terminal. In effect this corresponds exactly to the application at the switchboard of a 1000 c/s tone interrupted at 17 c/s, and the signals are consequently demodulated as such at the receiving terminal.

At the signalling receiver the demodulated signals are amplified and detected. A 1000 c/s tuned circuit accepts the 1000/17 c/s signal and passes it through a rectifier to operate relays which include a normally operated, slow release relay. After an interval this relay releases and operates other relays which isolate the incoming 1000 c/s signals from the switchboard while connecting 17 c/s ringing current to that point.

The following conditions must be met to allow a 17 c/s signal to be sent to the switchboard:—

(a) The full chain of relays to operate on rectified 1000 c/s current only.
(b) The signals must be maintained for at least 200 millisecs.
(c) The chain of relays must be prevented from operating if certain frequencies present in speech are received at an appreciable level.

Condition "C" is met by means of three circuits in the signalling receiver, which are sharply tuned to 1000 c/s, 600 c/s, and 1250 c/s respectively. The rectified output from the 1000 c/s circuit is applied to a relay "A", while the combined rectified outputs of the 600 c/s and 1250 c/s circuits are applied to a relay"A", while the combined rectified outputs of the 600 c/s and 1250 c/s circuits are applied to relay "B". If this combined output is of sufficient level, relay "B" operates and prevents relay "A" from operating the later relays in the chain, thus preventing false signalling from taking place.



NB — — — — — INDICATES CONNECTION TO RELAY CONTACTS.

Q.1.—Fig. 1.

Q.2.—Two three channel systems terminate in an office X, as shown in the sketch.

The circuits from each system terminate on the local trunk switchboard and each is provided with pad switching facilities. Draw a simple diagram of the office wiring and Jacking facilities of one channel from each system. If these channels are to be patched temporarily at X to form a through circuit between M and N illustrate the patches required and state what precautions would be necessary.

A.—For a temporary through circuit insert patches from Hyb Line of one channel to Hyb Line of the other channel, and from Hyb Net of the one channel to Hyb Net of the other.

It is necessary that these patches be made in a manner which gives correct poling of the hybrids, in order to obtain normal transmission through them, and the usual practice is to insert the plugs of the Hyb Net to Hyb Net patch in such a direction that a transposition of the A and B sides takes place, the Hyb Line to Hyb Line patch making a straight through connection.

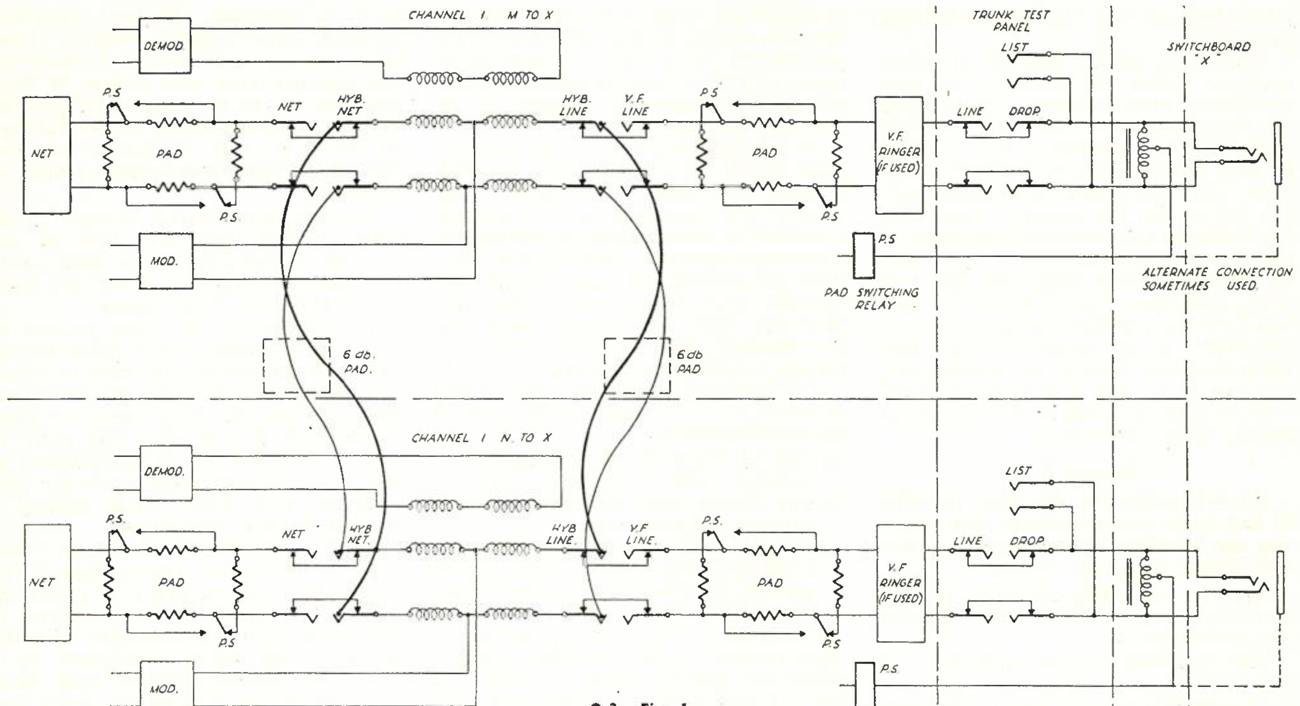
This arrangement (known as "tail-eating") eliminates the normal 3 db hybrid loss, and in order to retain the correct input level to the Modulator in each direction, it is necessary to either insert a 6 db pad in each patch, or to reduce the demod output in each direction, for the duration of the patch condition.

Another method sometimes used to obtain a through circuit is a "four wire" connection. In this case the demod output of one channel is patched through a pad to the Mod input of the other channel, with a similar patch in the opposite direction. It is important that the pads used, reduce the output from the demod to the correct level to apply to the Mod. input (e.g., for a four wire patch between two C.5 system channels, a pad of 17 db would be required in each direction.)

Q.3.—What are line equalisers? Describe the procedure necessary to adjust the line equalisers on a 3 channel carrier telephone system when it is being installed, or alternatively, when it is transferred from one line to another having different characteristics.

A.—Line equalisers are networks consisting of inductances, condensers and resistances which are so proportioned and arranged that their attenuation frequency characteristics are complementary to the line characteristics that produce the attenuation distortion. These equalisers are usually associated with the repeaters or amplifiers which are included in the circuit at various points, in order to provide a uniform level of power at the receiving end, over the frequency range employed.

The three channel S.O.S. system uses a combination of fixed and variable equalisers. The fixed equalisers are designed to compensate for the attenuation distortion over the lower or upper group of carrier sidebands, introduced by any filters such as directional filters, physical programme line filters, telegraph separating filters, etc., of the system, together with 100 miles of average copper line. In conjunction with the fixed equaliser, variable line equalisers compensate for the attenuation distortion introduced by



Q.2—Fig. 1.

the line section immediately preceding the terminal or repeater. These equalisers are adjustable in steps of 0.1 db per kilocycle.

When equalising the three channel S.O.S. system the general procedure is as follows:—

The bearer line is checked to ascertain that it is in good order

At Transmitting Terminal—

Send 800 c/s tone at correct line-up level into Hybrid Line of each channel in turn, and check that each channel sends correct level (e.g. + 12 dbm + 0.5 db) from the "Trans Amp out" jacks.

At First Repeater

All the variable equalisers are patched out of circuit.

The transmitting terminal again transmits 800 c/s tone at line-up level into each channel in turn, and the repeater takes a measurement at the output of the amplifier in the appropriate direction. The amplifier gain is adjusted to give an output approximating the required send level, from the first channel received, and readings are then taken of the other two channels without altering the amplifier gain setting.

The output reading for each channel is plotted against the 800 c/s sideband frequency of the channel, on graph paper, and the best straight line possible drawn through the three points obtained, for the particular direction of frequency under measurement.

The slope of this straight line is measured in terms of db per Kc, and the corresponding amount of variable line equalisation connected into circuit.

The three channel readings are then taken again at the amplifier output and should be the same within ± 1 db. If not, further slight adjustments of the variable line equalisers should be made, and the amplifier gain then adjusted to give the correct output level.

The same procedure is observed for succeeding repeaters if they exist.

At the Receiving Terminal, the measurements are made at the Receive Amp Out, and the same procedure followed as for the repeaters, with the Receive Amp adjusted to an appropriate level.

Q.4.—You are required to investigate a report of unintelligible cross talk between channels of a multichannel carrier telephone system using dry batteries for bias voltage supply.

List the possible causes of the trouble indicated and briefly outline the steps you would take to locate the fault condition.

A.—Unintelligible crosstalk between channels of a multichannel carrier telephone system usually indicates that the crosstalk is taking place at carrier frequencies, and is due to intermodulation between channels, taking place in some common section of the equipment, such as transmitting, Repeater or Receiving Amplifiers.

In the case where these amplifiers use dry batteries for bias supply, a likely cause of intermodulation is incorrect bias voltage. This could be due to wrong connection of the batteries, or loss of voltage due to ageing, etc., of the cells, and causes a non-linear condition in the amplifier, as the valves tend to operate on an incorrect portion of their characteristic curve. Instead of operating on the straight portion of the curve they tend to operate on one of the bends, causing detection to take place with consequent intermodulation between channels passing through the amplifier.

Another cause of intermodulation is non-linearity in an amplifier due to overloading. This may be due to an incorrect setting of the amplifier gain control, or a failure of regulating equipment which allows too high a signal level to reach the input of the amplifier.

A non-linear condition can also be set up in an amplifier due to deterioration in performance of a valve, or valves in the amplifier.

In endeavouring to locate such a crosstalk fault, if a pilot frequency and indicators are in use on the system, a first step would be to inspect the pilot indicators and regulator settings at repeaters and terminals in the direction in which the crosstalk is taking place. If all settings are normal the pilot indicators should be observed while signals are applied to the affected channels. As both the pilot frequency and the channel frequencies pass through the amplifiers a variation will usually be noted in pilot level during channel modulation, at indicators subsequent to the faulty amplifier. By this means the fault can be sectionalised.

Substitution of a spare amplifier for the suspected faulty amplifier provides a check, and if the crosstalk fault is then eliminated the faulty amplifier should be left out of service for investigation.

If no pilot is available, and amplifier stops are normal, a progressive substitution of spare amplifiers for normal amplifiers at terminals and repeaters will usually locate the faulty unit.

If a spare amplifier is not available for substitution, a check of the amplifier tube plate currents should be made, and if normal, a linearity test performed which should reveal any fault condition.

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