INSTALLING THE PERTH-CARNARVON COAXIAL CABLE

*J. A. HUSTON, B.A., B.E., M.I.E. Aust**

INTRODUCTION.

Authority to commence this 602-mile extension of the Australian broadband communications network was given in September, 1966. The target dates set for the completion of cable installation were to Geraldton by the end of May, 1968, and to Carnarvon by the end of December, 1968. To meet these dates the rate of cable installation had to exceed any previous achievements and it was therefore very satisfying to reach both towns ahead of schedule.

The cable as planned became the first fully transistorised 12-MHz cable system capable of transmitting both television and telephone traffic simultaneously over a pair of coaxial tubes, besides introducing the concept of a totally buried system. Its use in this capacity, to transmit live, the first landing on the moon by man, early in 1969 was consequently a fitting finale to the project as a whole.

In this paper an attempt is made to describe what was done, with the emphasis on new developments rather than repeating what has been adequately described elsewhere. (See further reading list.)

THE CABLE PATH.

Route Selection.

The route is shown in Fig. 1 and it will be seen that between major repeaters there were minor repeaters at 5000-yard spacing, housed in buried 6 ft x 6 ft. circular concrete manholes.

Between Perth and Geraldton the route selected depended to some extent on nominated towns where relief was required or where new exchanges were to be provided. Wherever possible the railway reserve was utilised to obviate damage to property, and to take advantage of the naturally good grades and lightning protection offered. Access to the route was always considered paramount because of the problems that would otherwise be encountered in placing 1000-yard, 4¼ ton drums of cable on peg, and also for maintenance purposes.

The route selection was performed by an engineer assisted by an estimating foreman and two linemen. The latter carried out test borings and soil resistivity measurements as directed. During this operation, conduit requirements, together with special provision at major rivers, were decided upon. Only four rivers, viz., Moore, Chapman, Murchison and Wooramel, were placed in this category.

Survey.

Two survey parties then pegged the route in accordance with normal practice, from which 8 chains to the inch base plans were prepared. Using these plans, drum length advices were produced within the limits specified by the overall system design. A standard allowance for snaking, rippling, and loss of alignment was applied to each drum length. This was initially set at 20 feet, subsequently reduced to 12 ft., and now to 9 ft. per 1000 yds. The actual joint and repeater positions were then pegged and marked on the drawings. The plans also set out the type of soil that would be encountered, besides recording other surface information such as gates, clearing and levelling required.

The speed and accuracy with which these surveys were carried out and plans produced are a credit to the drafting office. The average rate for a survey field party was 10 miles per week.

A close liaison was maintained with the drafting office and from the experience gained on the project certain changes have resulted.

Reference marks which were placed at 5000 feet are now located at 3000 ft. intervals. These marks then became the joint and repeater positions in the majority of cases. The initial strip plan virtually becomes the drum length advice except for minor altera-

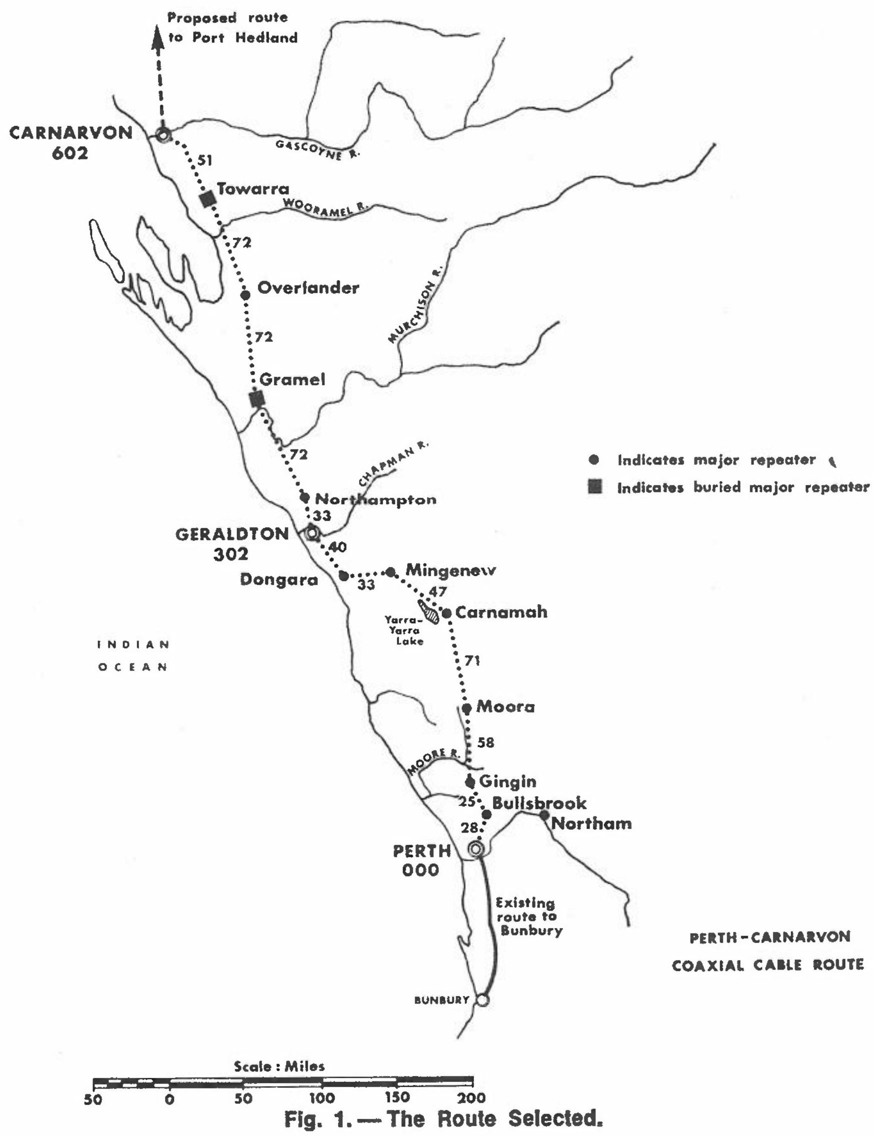
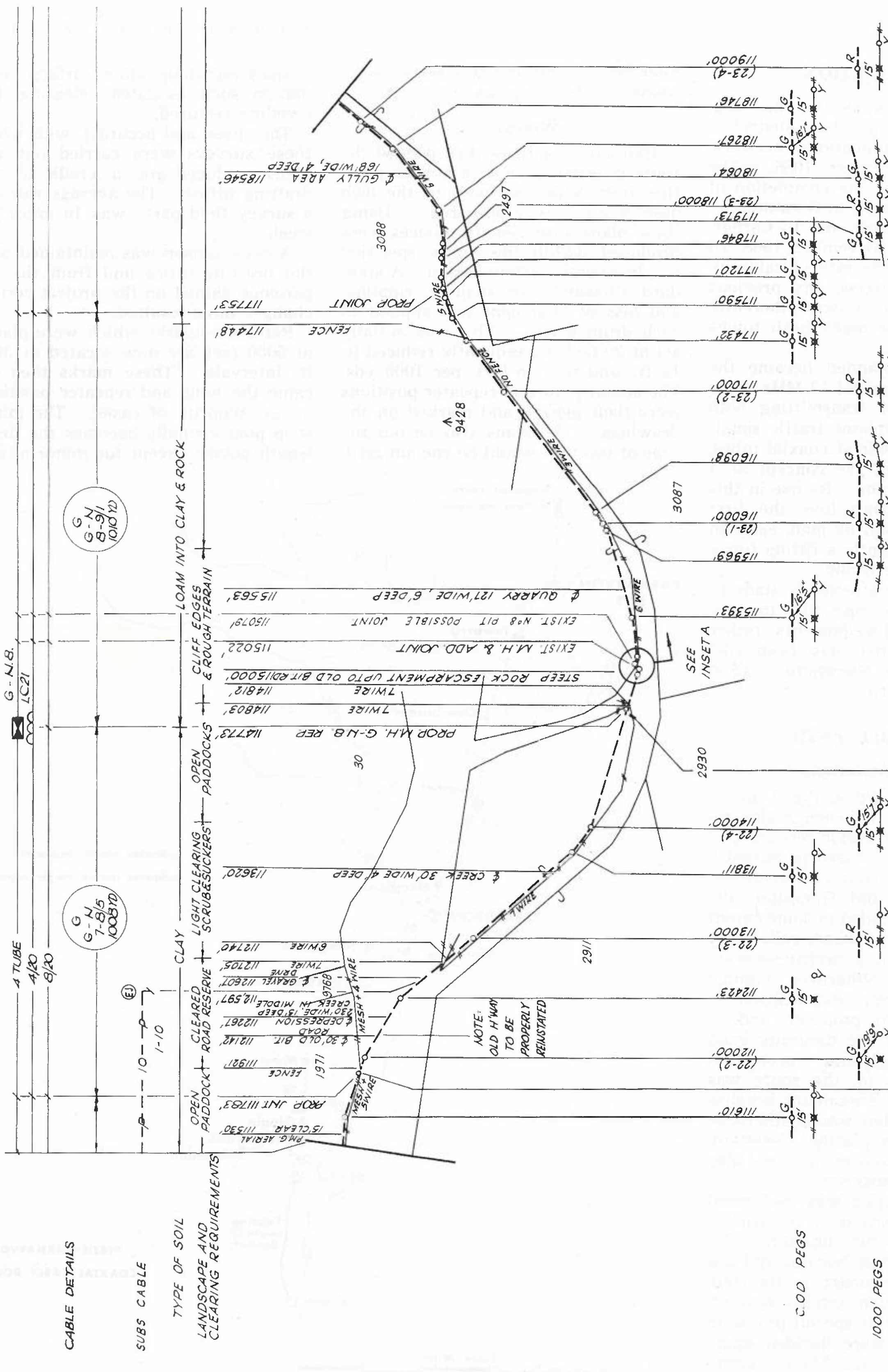


Fig. 1. — The Route Selected.

* Mr. Huston is Engineer Class 3, Coaxial Cable Division, W.A.


CABLE DETAILS
SUBS CABLE
TYPE OF SOIL
LANDSCAPE AND CLEARING REQUIREMENTS
C.O.D. PEGS
1000' PEGS
JOINT & M/H PEGS
4 TUBE
4/20
8/20
OPEN PADDOCK
CLEARED ROAD RESERVE
CLAY
LIGHT CLEARING SCRUB&SUCKERS
OPEN PADDOCKS
CLIFF EDGES & ROUGH TERRAIN
LOAM INTO CLAY & ROCK
G-N.B.
LC21
SEE INSET A
NOTE: OLD H'WAY TO BE PROPERLY REINSTATED
STEEP ROCK ESCARPMENT UPTO OLD BIT RD 115000'
EXIST. M.H. & ADD. JOINT
EXIST. No 8 PIT POSSIBLE JOINT
PROP. M.H. G-N.B. REP
NOTE C.O.D.

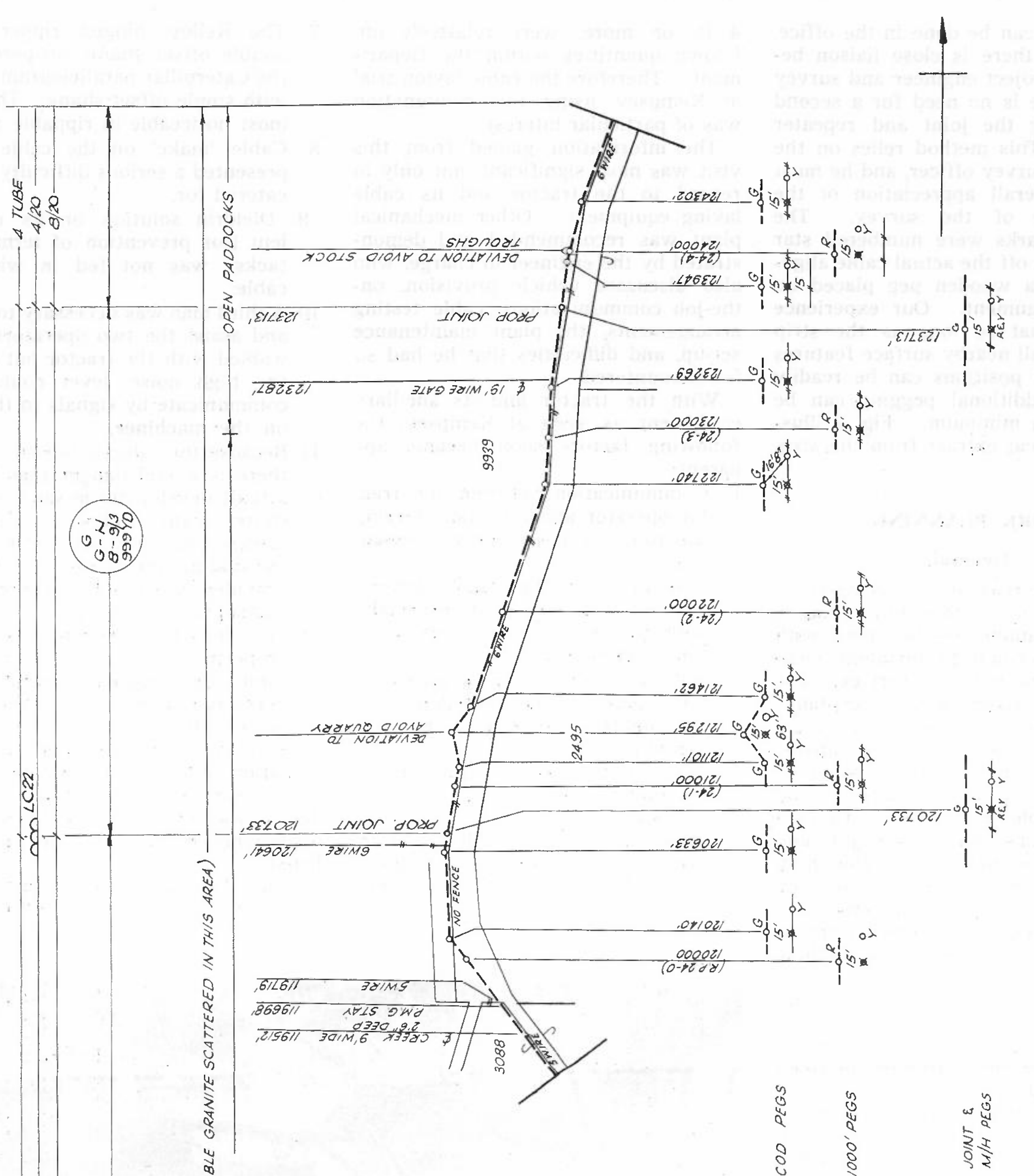


Fig. 2. — A Typical Example of the Strip Plans Used.

tions which can be done in the office.

Providing there is close liaison between the project engineer and survey officer, there is no need for a second pass to peg the joint and repeater positions. This method relies on the skill of the survey officer, and he must have an overall appreciation of the end purpose of the survey. The reference marks were numbered star pickets 20 ft. off the actual cable alignment, with a wooden peg placed on the true alignment. Our experience has been that so long as the strip plans tie in all nearby surface features so that joint positions can be readily identified, additional pegging can be reduced to a minimum. Fig. 2 illustrates a typical extract from the strip plans.

WORK PLANNING.

General.

One of the reasons for opting for a cable solution on this route was a calculated gamble on the speed with which cable could be installed, commissioned and put into service. The gamble was based on the acceptance of an unproven mole plowing technique, which was considered capable of installing more than 10 miles of polythene-jacketed non-layer lead sheathed cable in a week. The big worry, of course, was the fragility and bedding of the unarmoured cable in an unseen environment that would often contain rock. Subsequent events vindicated this decision. Once committed to the proposed new method, installation techniques had to be finalised as quickly as possible so that suitable plant could be ordered and supplied in time. Visits were made to a trial installation of 10 miles of steel-sheathed coaxial cable on the Geelong/Warrnambool route and later to a more extensive trial, conducted with polythene-jacketed lead - sheathed cable on the Kempsey/Coffs Harbour route. On the basis of this information, plus local knowledge and advice from headquarters, initial orders for mechanical plant, vehicles, and camp accommodation were placed by December 1966. These were later slightly modified after further field trials in the West during March 1967. The modifications were mainly in regard to vehicles and mechanical aids to maintain a 4 ft. depth of cover through heavy rock. At about the same time bulk orders for material were placed and a first approximation work schedule drawn up.

Plant Selected.

The D9G Caterpillar tractor and Kelley ripper cable layer, which make cable plowing possible at depths of 4 ft. or more, were relatively unknown quantities within the Department. Therefore the cable laying trial at Kempsey using this combination was of particular interest.

The information gained from this visit was most significant, not only in regard to the tractor and its cable laying equipment. Other mechanical plant was recommended and demonstrated by the engineer in charge, who also discussed vehicle provision, on-the-job communications, cable testing arrangements, the plant maintenance set-up, and difficulties that he had so far encountered.

With the tractor and its ancillary equipment as seen at Kempsey, the following factors soon became apparent:

1. Communication between the tractor operator and the man steering the Kelley cable layer was essential.
2. Visibility from the tractor driver's position was very poor, especially with a drum of cable carried on the dozer blade.
3. With a drum of cable carried on the blade the tractor tended to be unbalanced, especially in soft ground.
4. In the set-up used it took as long or longer to change a drum as it did to install a drum.
5. Only one drum of cable could be carried and plowed in at a time.
6. The Kelley cable layer worked very efficiently.
7. The Kelley hinged ripper with double offset shank out-performed the Caterpillar parallelogram ripper with single offset shank. This was most noticeable in rippable rock.
8. Cable 'make' on the cable drum presented a serious difficulty unless catered for.
9. Dieldrin solution or its equivalent (for prevention of termite attacks) was not fed in with the cable.
10. A third man was necessary to direct and assist the two operators. He walked with the tractor but due to the high noise level could only communicate by signals to the men on the machines.
11. Because the cable is buried unseen, there is a real danger that due to a fault developing, in say the layer chute, many miles of damaged cable could be innocently installed.
12. Excavating the buried cable ends provided a situation where cable damage could occur.
13. Provided the ground had been properly ripped, then adequate cable depth could be maintained.
14. Personnel safety would have to be looked into.

Following this visit and a trial installation of a 15-mile section of our cable near Gingin in March 1967 a design was evolved which eliminated or minimised most of the problems listed.

Items 1 and 10 were resolved by providing an intercom on the tractor

Fig. 3. — The Cat D9G, with Kelley Cable Layer, operating in the Moora Region.

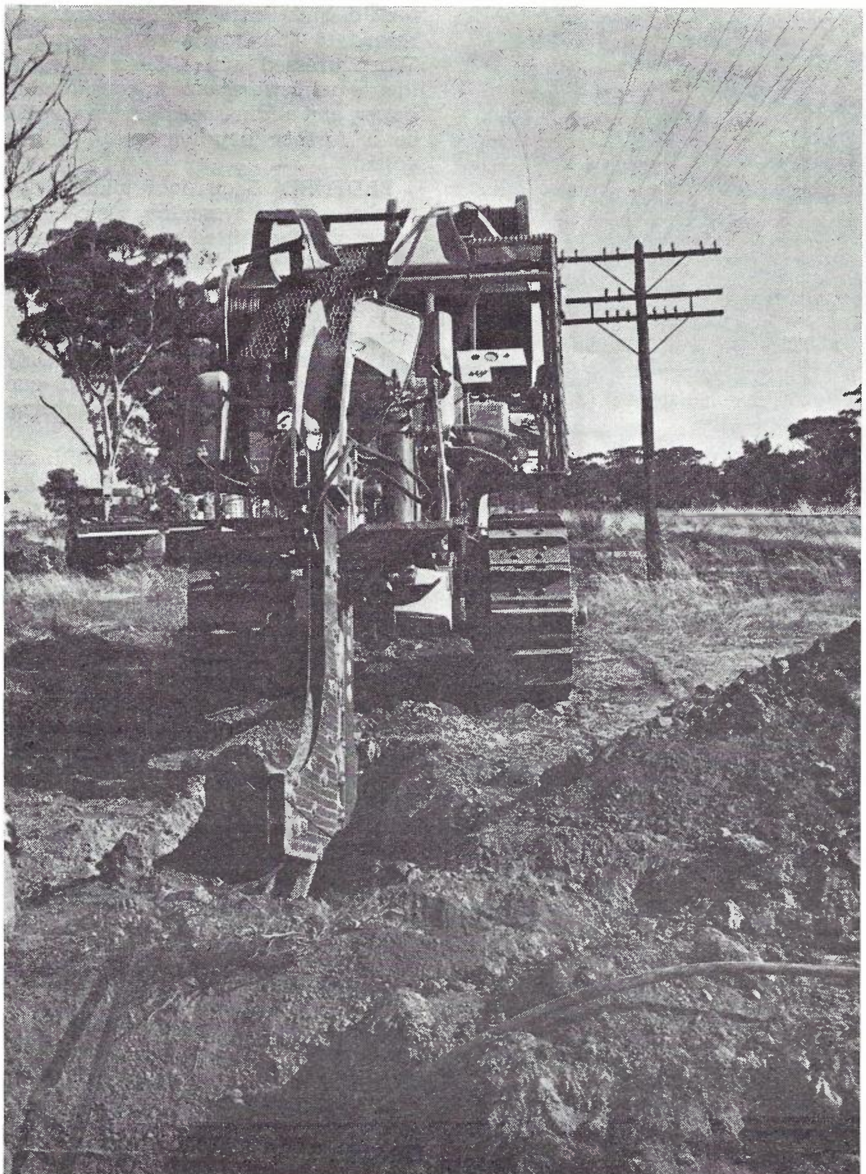


Fig. 4. — A Rear View of the Cable Layer Illustrating Shute and Cable Box Detail.

with the third man mounted on the operator's platform. The intercom system employed noise cancelling microphones with the receiver enclosed in earmuffs. A complete standby circuit with amplifier and attention given to vibration problems, was incorporated in the design.

Items 2, 3, 4, 5 were significantly improved by designing a special set of cable drum handling forks in lieu of the dozer blade. Drum changes could be effected in less than ten minutes and the co-ax plus another drum could be carried simultaneously on separate spindles riding on bearings. Overrun on both drums was controlled by disc brakes on the spindles.

Item 8 is dependent to a large degree on the way the drum is constructed and the smoothness of the laying operation. The make was catered for by holding the inner end under continuous tension by means of spear gun rubbers. Other methods were tried, but this proved the most effective.

Item 9 was taken care of by mounting a 60-gallon tank on the tractor on the opposite side to the hydraulic tank. The dieldrin solution was mixed in this tank using special pumps and pourers designed around a "no touch" technique. This tank was replenished at every second drum change. A gravity feed from the tank to the cable laying chute was employed with the air cylinder injection point controlled by the layer operator. The latter also had a simple visigauge to indicate that dieldrin was being applied.

Items 11 and 12 were covered in the tray, chute and fairlead design and by having an advance test group moving with the tractor about two drum lengths behind.

Item 14 was tackled by engineering safety into every operation, and emphasising safety at all times. Films, lectures, stickers, and a generous attitude on personal safety wear helped considerably in this regard.

A set of local drawings was produced, and the tractor in its eventual form is shown in Figs. 3, 4, 5.

Besides this unit the following major items of plant were purchased:

JOY 500RR Air Track Drill with Ingersoll Rand 600c.f.m. trailer mounted compressor (Fig. 6)—a good reliable combination, although the compressor power unit tends to overheat on hot, still days. The very high noise level demands ear protection and there is a dust hazard on still days. The dust problem could be alleviated by conversion to damp drilling. This is still under investigation. (Two units.)

HYMAC 580 crawler mounted 5/8-yd. hoe plus clamshell attachment (Fig. 7). This low ground pressure high capacity hoe proved invaluable in service. Besides digging and installing the 6 ft. circular repeater manholes, where it doubled as a crane, it was used on river crossings, across swamps, and for rock removal rigged as a grab. The only drawback was the need to permanently associate it with a 17-ton low loader; in this case with a Dodge prime mover, because of its low travelling speed. (One unit.)

JOHN DEERE 95 tractor equipped with JD 400 $\frac{3}{8}$ yd., back hoe—a high capacity robust unit which would have been vastly improved with high flotation front wheels. A fair degree of maintenance was required, which was made more difficult by this model being the first of its kind in this State at the time. (Four units.)

CATERPILLAR D9G crawler tractor with 9S tilt blade. Fig. 8 shows two of these machines operating in tandem on ripping. It was some time before both ripping machines were equipped with Kelley gear and this was a major factor in the workface not being well north of Geraldton when an abnormally wet winter set in. The machines have tremendous power available; the problem is to deliver the power. As supplied, they were fitted with standard 24 inch tracks. These were rapidly cut down on the rock sections or where a handicap in soft standing. At present the tractors are being converted to 27 inch extreme service tracks. (Three units, including the cable-laying tractor).

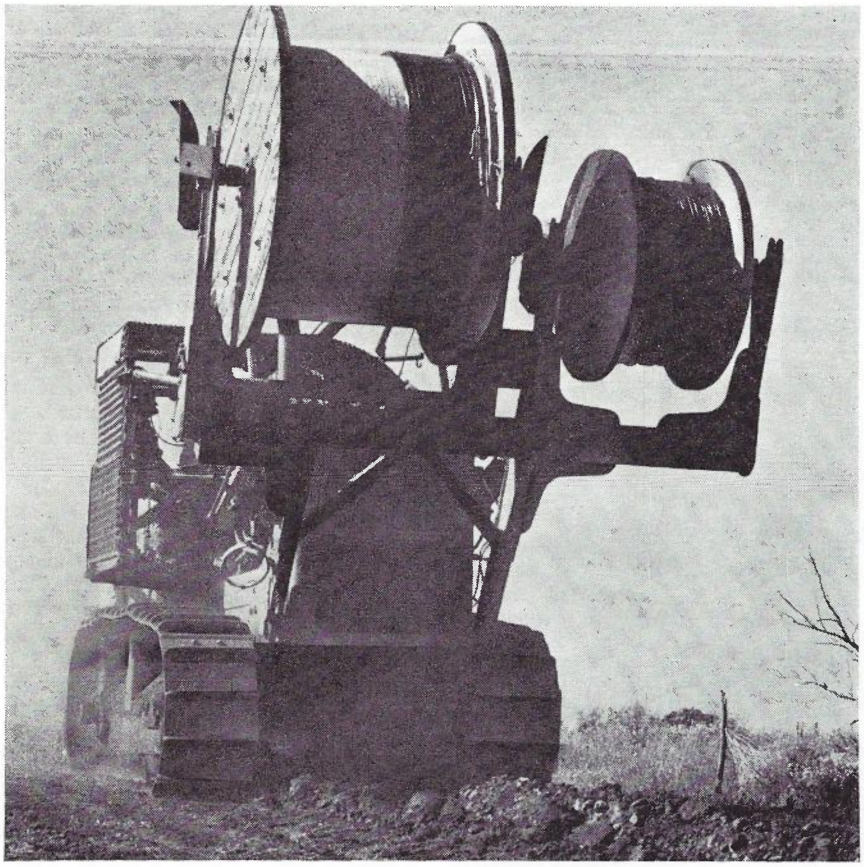


Fig. 5. — A Front View of the Cable Layer Illustrating the Drum Carriage Arrangement.

tory, despite limitations in sand and in regard to stability in rough country. When dressed with 7-50 x 16 tyres their sand performance is considerably better, and a four-speed gearbox would be a further improvement. (Thirty units.)

BEDFORD 5-ton four-wheel drive trucks. These were the basic heavy truck, whether fitted as mobile workshops, test vans, Hiab equipped or straight flat tops. They have done well, only demonstrating weakness in the transfer case chassis attachment, and fuel tank holding brackets. Only five trucks were Hiab equipped, and this has since been increased to nine. (24 units.)

KENWORTH prime mover with 50-ton capacity quad axle float plus dolly. These trucks were fitted with sleeper cabs and air-conditioning, with a view to long distance heavy haulage. They have performed superbly, especially after conversion to Michelin tyres. (Two units, see Fig. 11.)

LEYLAND prime mover with 25-ton capacity triple axle float. Intended for cable transportation and the movement of any mechanical aids other than the D9s. However, this unit proved to be slower and less reliable than the Kenworths. In retrospect it would have been more flexible and economical in the long run to have had a third Kenworth prime mover with quad axle float and no dolly, rather than the Leyland.

CATERPILLAR D7E crawler tractor with 7A Straight blade. These proved to be very useful and reliable machines. Their only drawback was again the original fitting of standard tracks instead of extreme service; also their flexibility would have been vastly improved had they been supplied with 7S tilt blades. (Two units.)

CHAMBERLAIN/CRANVEL 5 - 8 ton crane. This is a fairly well-known combination in our department. In this case the load-bearing wheels were fitted as duals to improve flotation. The unit did the job it was intended for, but with some difficulty. The unit originally requested was a crane with 360 deg. slew, all wheel drive, power shift boom, and capable of a 10-ton lift. It would have been ideal for the purpose. The Austen Weston is a crane of this type. Both machines are illustrated in Figs. 9 and 10. (Two units.)

TOYOTA 1-ton four-wheel drive trucks. These were selected as the basic light truck for the project because of their power and good maintenance record in the State. Their overall performance has been satisfac-

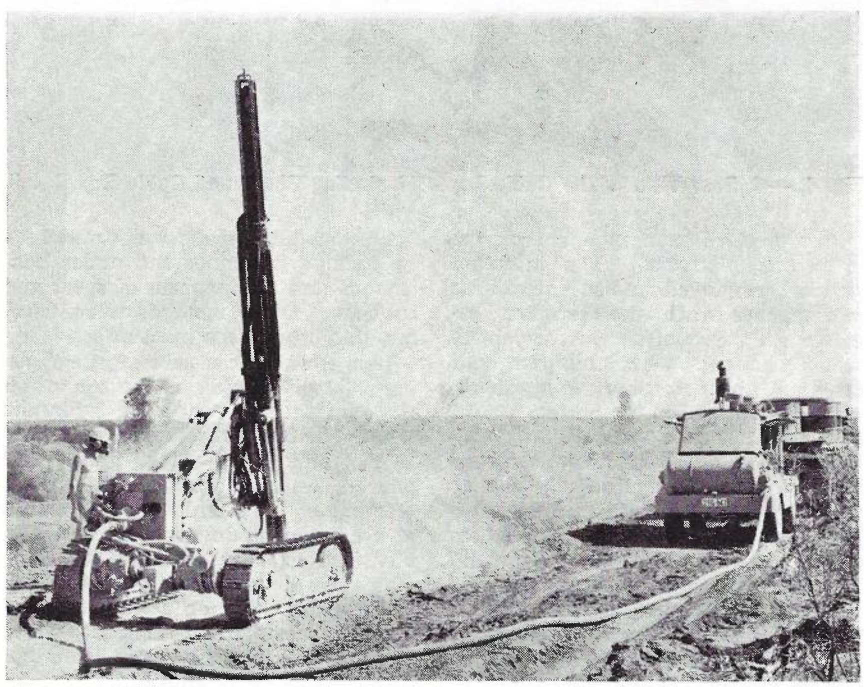


Fig. 6. — Joy 500 RR Air Track Waggon Drill and Ingersoll Rand 600 c.f.m. Compressor.

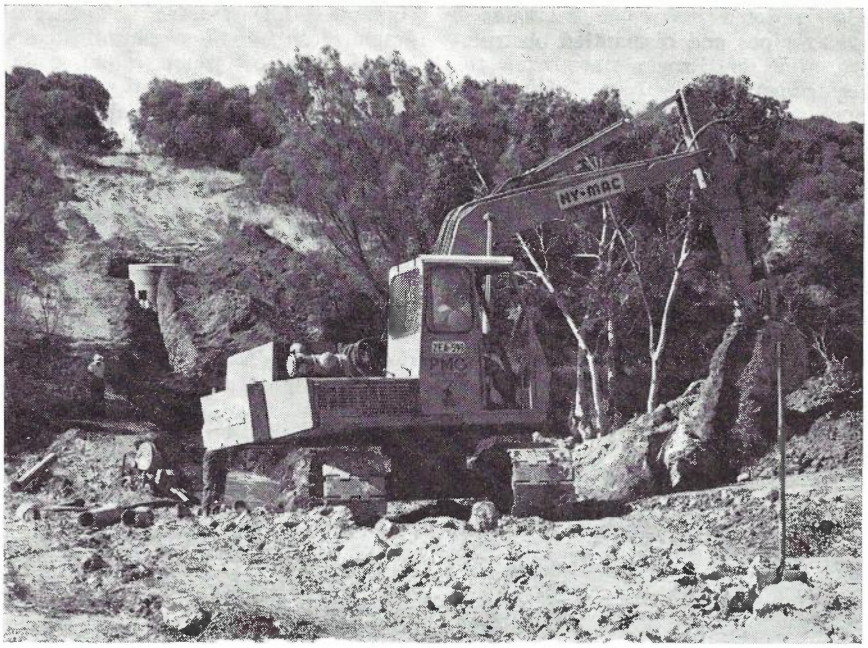


Fig. 7. — The Hymac 5/8 yd. Excavator.

One camp based on 32 ft. x 8 ft. caravans capable of housing 50 men. This includes diner kitchen, office, ablutions, storage, amenities and sleepers. (14 vans plus two 35 K.V.A. trailer mounted power generators.) (See Fig. 12.)

Three camps based on 20 ft. x 8 ft. caravans capable of housing a total of 60 men. Similar facilities to those listed above were provided (30 vans plus one 35KVA one 12.5KVA, and one 6KVA power generators, either trailer or truck mounted.)

One two-way radio telephone system, including 25 mobiles and 4 talk through repeaters with associated 1½KVA power generators. Good on-the-job communication is essential to a project of this nature, and although the system purchased could be improved upon, it served the purpose intended. The nominal range with all repeaters in service was 120 miles.

PRELIMINARY ACTIVITIES.

General.

In January, 1967, using plant on loan from the State fleet or hired from contractors, the preparatory phase of the project got under way. The activities undertaken consisted of installing gates, conduits and ducted river crossings, track preparation, test ripping and blasting rock that could not be ripped.

The men recruited were all voluteers from within the State organisation. They were selected with a view to their eventual roles for cable installation, and every opportunity was utilised to train them accordingly. A maximum staff of 46 men were in the field at the conclusion of this stage, with a skeletal divisional structure consisting of two engineers, a line inspector, two foremen and one clerk supporting them.

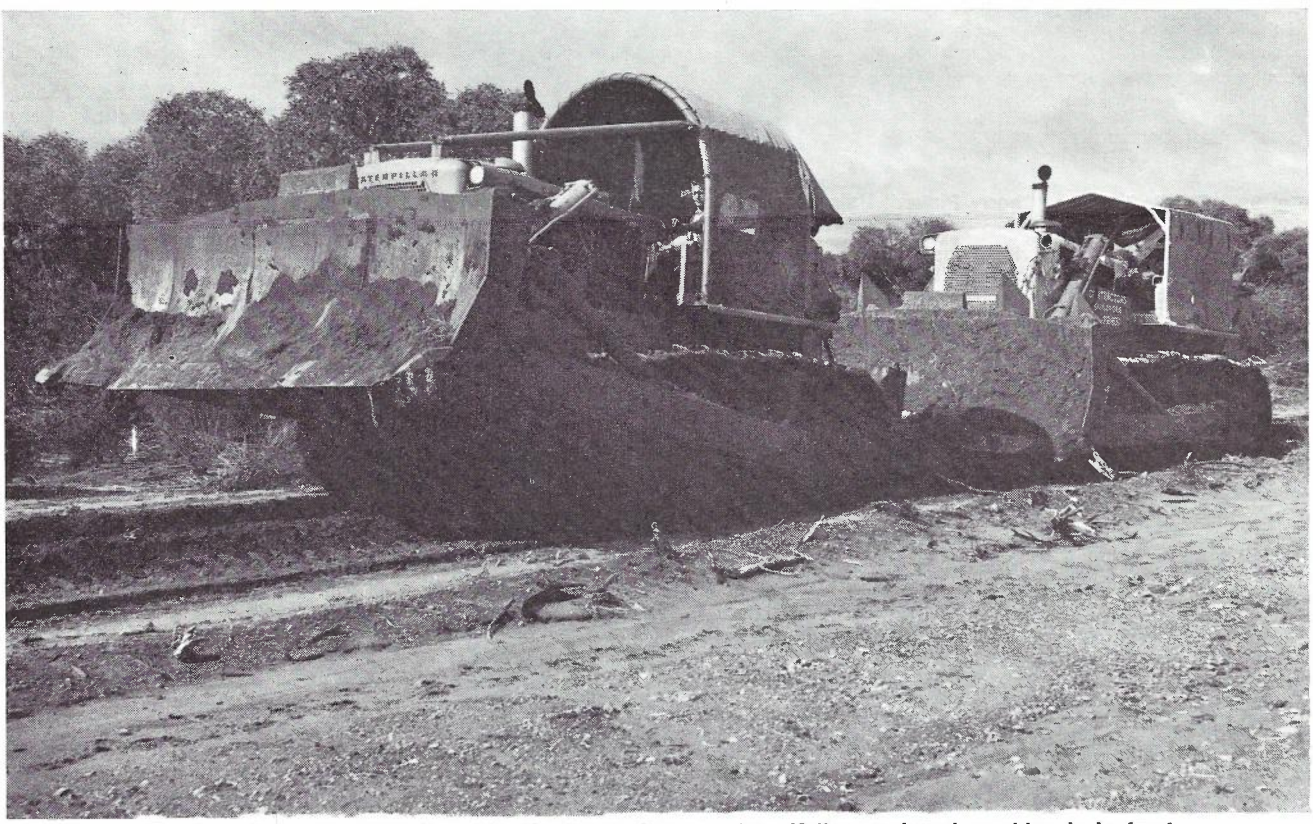


Fig. 8. — Caterpillar D9G Tractors Ripping in Tandem. The Kelley equipped machine is in front.

Gate Erection and Ductwork.

There was nothing particularly novel about these tasks except for the economies achieved by the Hymac on the river crossings compared with tendered prices, and the adaptation of the tractor mounted piledriver used on the East/West route, for gatepost installation. The posts, either pipe or railway iron, thus installed proved to be very stable and strutting was only necessary on permanent M braced 16 ft. gates.

Track Preparation.

A grader and D7E crawler tractor were used for this purpose. The party also inserted removable sections in water pipes and dismantled obstructing wind and angle stays from the departmental pole route where this occurred. In place of angle stays a 2 in. pipe strut was inserted.

Their main function, however, was to provide a clear level path for ripping and cable laying. In deviations they also provided an access track alongside the actual cable path, i.e., a clear level strip 30 ft. wide in lieu of the usual 20 ft.

Ripping.

Test ripping commenced in February 1967 with the arrival of the first Kelley equipped D9G tractor. The programme ran into immediate difficulty because only one shank, point, collar and fixing pin came with the unit. These parts are only available ex the United States with a lead time of about twelve weeks. The average usage rate for these items was later established as 17 off 308 short blue points, 5 collars, and 10 flex pins per hundred miles of ripping. It was also found that the original design Kelley double offset ripper shank, fitted with wear pads, lasted for 100 to 125 miles of ripping before fatigue failure occurred through the wear pad locating pin holes. At this stage, whether the shank had failed or not, it was beyond repair. As a result all future orders have been for the shank with wrap around style protector, but their life has not been evaluated yet.

With what was available, and after the cable laying trials near Gingin, selected rock areas at Coorow, Dongara, Murchison, and Overlander were test ripped. Records were kept of performance through various soil conditions of wear, progress rates and failures, corresponding to the configuration used. The opportunity was also taken to evaluate ripping through blasted rock in the Murchison River area. We found that very little was known about deep ripping for cable laying, even by well-known contractors.

The recorded results were carefully analysed and it was possible to set down guide lines on how to go about the ripping function. These results also indicated that the blasting operation would now be critical because the limestone in the Dongara and Overlander areas proved to be unrippable. This nearly doubled the blasting originally allowed for.

Pertinent points from the ripping instruction are listed below:—

1. To lay cable at 4 ft. the minimum ripping depth must be 4ft. 6 in. In moderate going every inch of ripping depth beyond 5 ft. costs 50 per cent more than the preceding inch.
2. The ripped slot must be at least 3 in. wide all the way down. Consequently the final pass must be carried out with a ripper point that is in good condition. This ensures passage for the cable laying box.
3. Except in sand, loam or loose clay the ripping machines should be worked in tandem.
4. After 9 tandem or 20 single passes the ground is either unrippable, or the loose surface causing loss of traction must be bladed off before further ripping.
5. After blading off use one machine for a maximum of 7 passes, and if

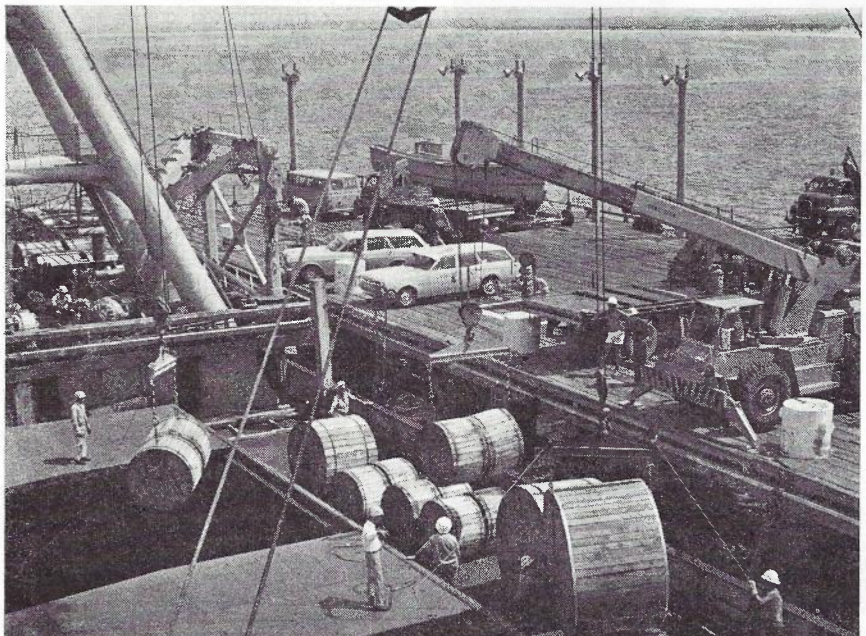


Fig. 9. — The U.S. Navy "Cherry Picker" Unloading Cable at Exmouth. Illustrating the Preferred Type of Crane.

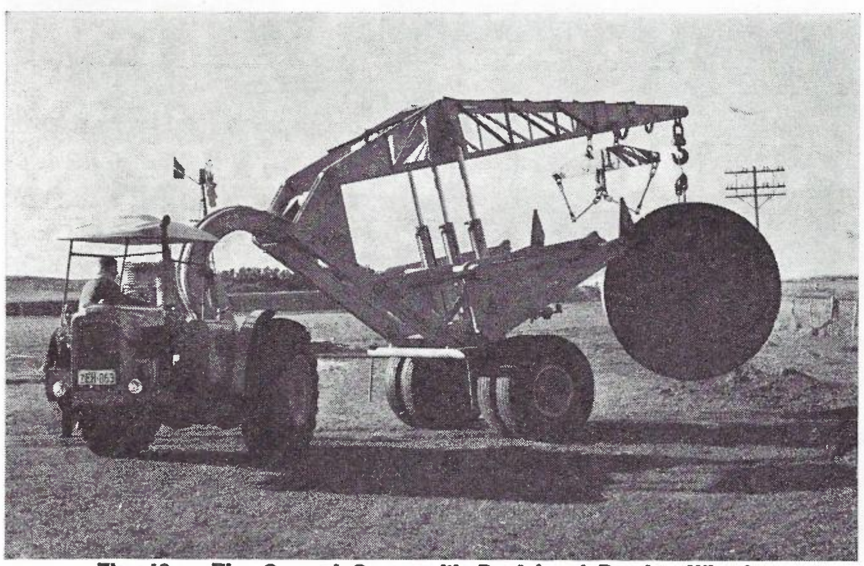


Fig. 10. — The Cranvel Crane with Dual Load Bearing Wheels.

Fig. 11. — A Kenworth 50 ton Low Loader. On the rear is a tracked cable drum trailer capable of handling the 5 ton, 7ft. x 5ft., coaxial cable drums.

still unsuccessful, clean up the surface and leave it for blasting. If successful, fill in, and proof rip with a minimum of three passes.

6. In ground that has been blasted, level off and proof rip with a minimum of 5 passes. This ensures sufficient 'fine' generation to safely bed the cable.
7. All large rocks brought to the surface (over 15 in. diameter) in the rip line or track path must be removed.
8. In a 10-hour day, with two Kelley equipped D9G tractors, the following approximate production figures should be achieved. For Cat equipped machines the figures should be reduced by 20 per cent.
   Pure sand—16 miles.
   Loam—8 miles.

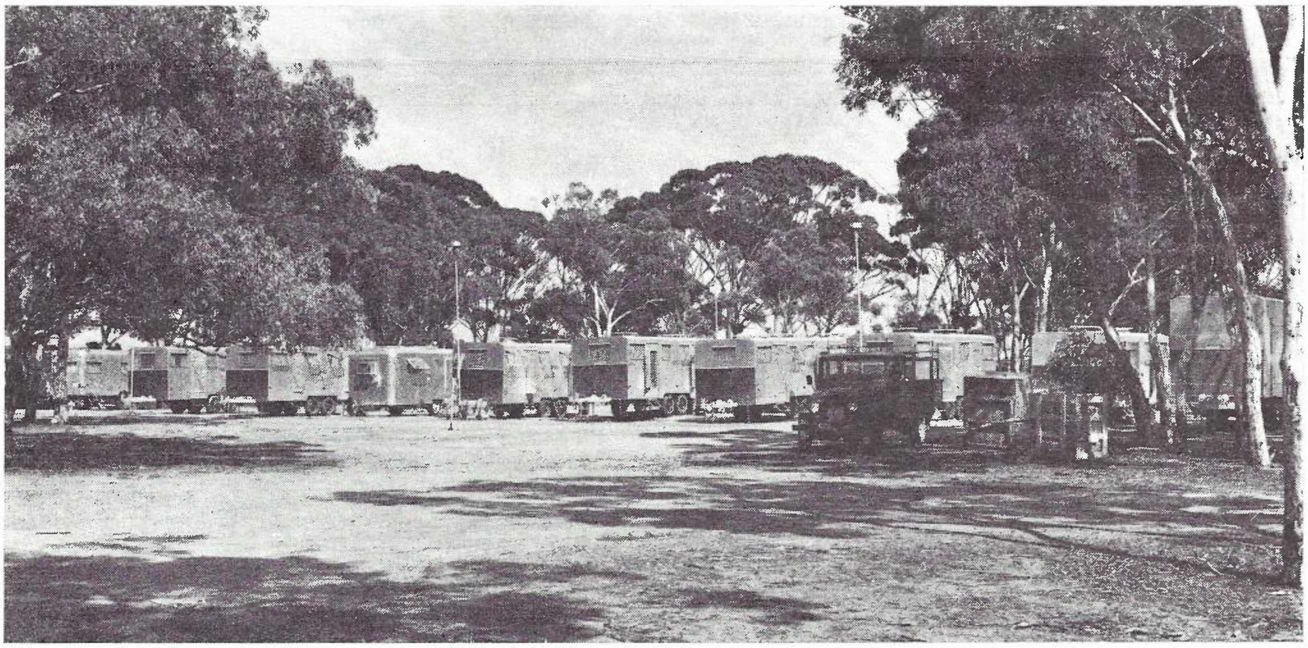
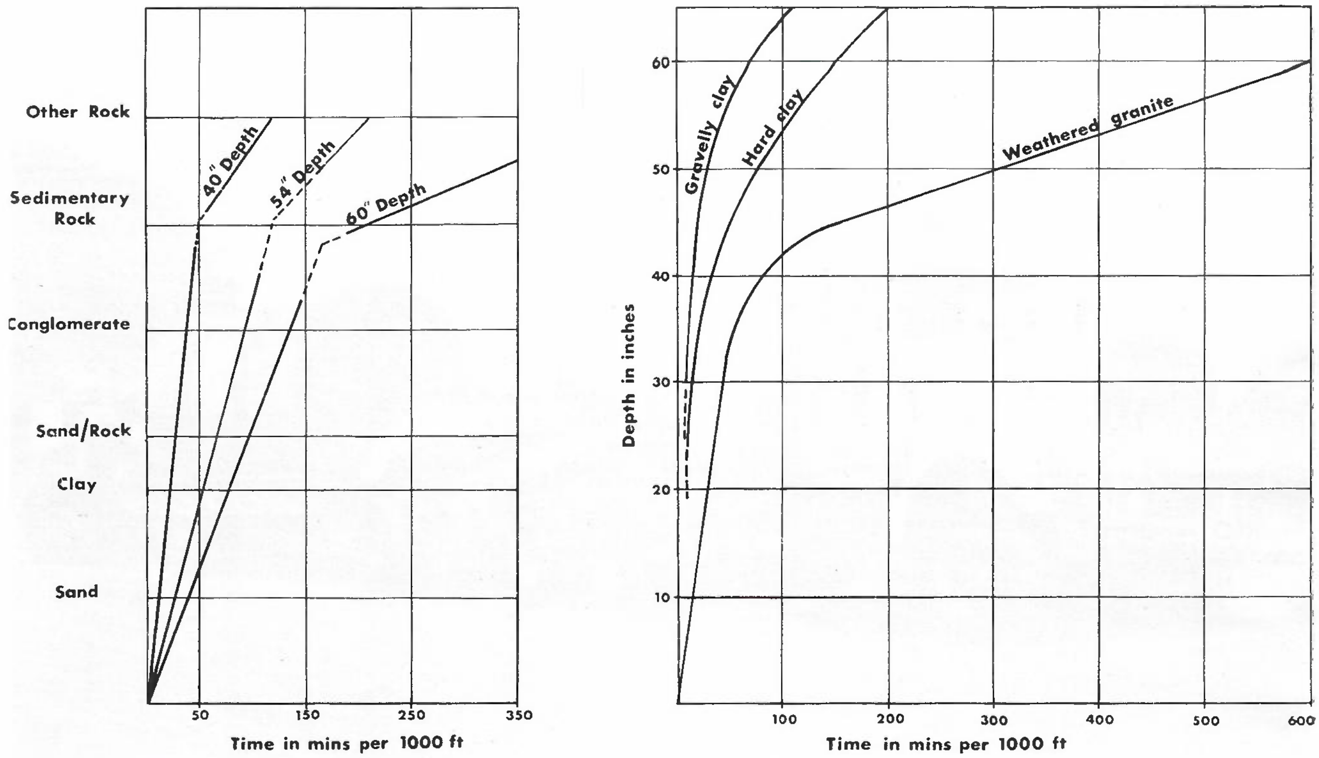


Fig. 12. — A view of the Jointing and Testing Camp then Situated Near Moora.



Single D 9 G, Kelley Ripper

Tandem D9Gs, Kelley Ripper.

Fig. 13. — Two of the Charts Used in Scheduling Ripping Operations.

Loose gravelly clay—4 miles.
Tight packed hard clay—3 miles.
Sand into conglomerate at 36 in. — 2 miles.
Ironstone or conglomerate at 12 in.—1½ miles.
Limestone or weathered rock—1 mile (assuming it is rippable).
Pre-blasted granite or limestone—1 mile.

Rock at a depth of 3 ft. with a loose surface is one of the most difficult soil conditions to contend with. Fig. 13 shows two of the charts produced in the ripping analysis. From the data compiled the ripping effort required for Perth/Geraldton called for two D9G tractors, and if Kelley equipped would take 5 months. In fact it took 6 months because the second set of Kelley gear did not arrive till midway through the fifth month.

The characteristics of the Kelley and Cat rippers are compared in Fig. 14. An Esco shank was also observed and found to be 10 per cent. worse again than the Cat.

Ripping and its associated techniques have proved to be most critical on a cable-laying project, and much could still be done to improve the economics in this area.

Blasting.

The original estimate for blasting was 40 miles, but this was increased to 75 miles when it was found that the limestone and caliche occurring in the Dongara and Overlander areas could not be ripped. One Joy drilling rig could only complete about one mile per week, so it became necessary to double our resources in this direction. The other areas where unrippable rock occurred was mainly in the Northampton/Murchison mineral

KELLEY RIPPER	CAT. 9B RIPPER
Fixed beam hinged tool bar with forged steel shank. Depth adjustment mainly by altering shank length.	Fixed beam parallelogram action, with forged steel shank. Depth adjustment by using the parallelogram and by altering shank length.
With 60" penetration, shank can be completely withdrawn.	Cannot be cleared.
Hydraulic pin puller very fast, operating 10-15 seconds.	Slow 30-40 seconds.
Hanging up characteristic is good.	Poor.
Penetration in rippable rock is good.	Fair.
Angle of attack is 25° and with double offset profile good speed, cutting and breakout is achieved.	Angle of attack is 37° with single offset profile giving only fair cutting, speed, and breakout characteristics.
Performance in soil containing floaters is only fair.	Good.
Average point life 24 hours, but cost approximately double Cat.	8 hours.
Service and parts poor.	Good.
Shank not repairable if fatigued.	Repairable.

DG9 RIPPER COMPARISON

Fig. 14. — A Comparison of the Main Advantages and Disadvantages Between the Kelley and Caterpillar Rippers.

belt and on the fringes of the Darling Escarpment nearer to Perth.

Again methods that would be appropriate to ripping rather than trenching had to be evaluated. Basically our equipment was suited to in line firing, and it was a question of determining optimum hole spacing, hole diameter, hole depth and type of explosive. Other factors such as hole angle, delay firing, and electrical firing were also explored. The end result was a basic 12 ft. spacing in the less homogeneous rocks and 8 ft. spacing in the very dense rocks. A 3 inch bit was used and the holes set at an angle of 12 deg. - 15 deg. and down to a depth of 7 ft. The most effective, safe and economical explosive was found to be prilled ammonium nitrate primed with diesoline. Depending on spacing either 9 lb. or 6 lb. of explosive was the recommended quantity, and an instruction for the guidance of field staff was produced. There has been very little variation from this instruction except for the limestone areas, where successful blasting depended to a large extent on liaison between the drillers and shot firers, and therefore on the experience of both. Initially many of these firings had to be repeated two and three times before the right recipe was found.

Electrical firing was not adopted, mainly for the sake of simplicity and safety.

From figures taken out during the evaluation period, the chart shown in Fig. 15 was produced. It illustrates the expense involved with blasting, since ripping must still be carried out. In fact, the hole spacings settled on were maximums in order to get the job done in time. It would have taken less subsequent ripping time, but more drill and shoot time if spacings of 10 ft. and 6 ft. could have been nominated. The only other trick employed on the rare occasions where blasting was required but could not be performed (e.g., across a road) was to drill 3 in. holes, 5 ft. deep, 9 - 12 in. apart, and then rip through.

CABLE INSTALLATION.

General

At full strength the Division consisted of 105 men. The supervisory and clerical group numbered 15 men, comprising 3 engineers, 3 clerks, 1 supervising technician, 4 line inspectors, 1 plant, inspector, and 3 foremen. Amongst the field staff there were 2 senior technicians, 1 trainee technician, 5 mechanics, 10 party leaders and 12 jointers. By this stage instructions had been written covering the following topics and the key men were fully briefed.

1. General information sheet.
2. Ripping for cable laying.
3. Blasting prior to ripping.
4. Cable laying.
5. Reinstatement and advance testing.
6. Circular manhole and repeater installation.
7. Cable jointing.

By late October 1967, as soon as ground conditions permitted a full-scale dress rehearsal was carried out in a sand plain north of Gingin. Finally on November 22, 1967, the installation of the 602 miles of coaxial, plus 270 miles of subscribers' cable, began at a point some 70 miles north of Perth. A start here was necessary due to wet ground conditions further south.

The cable in all the long conduit sections was hauled in by the staff of the Primary Works Division to fit in with the cable laying schedules. Their co-operation was also appreciated in completing the duct runs at Geraldton and Carnarvon.

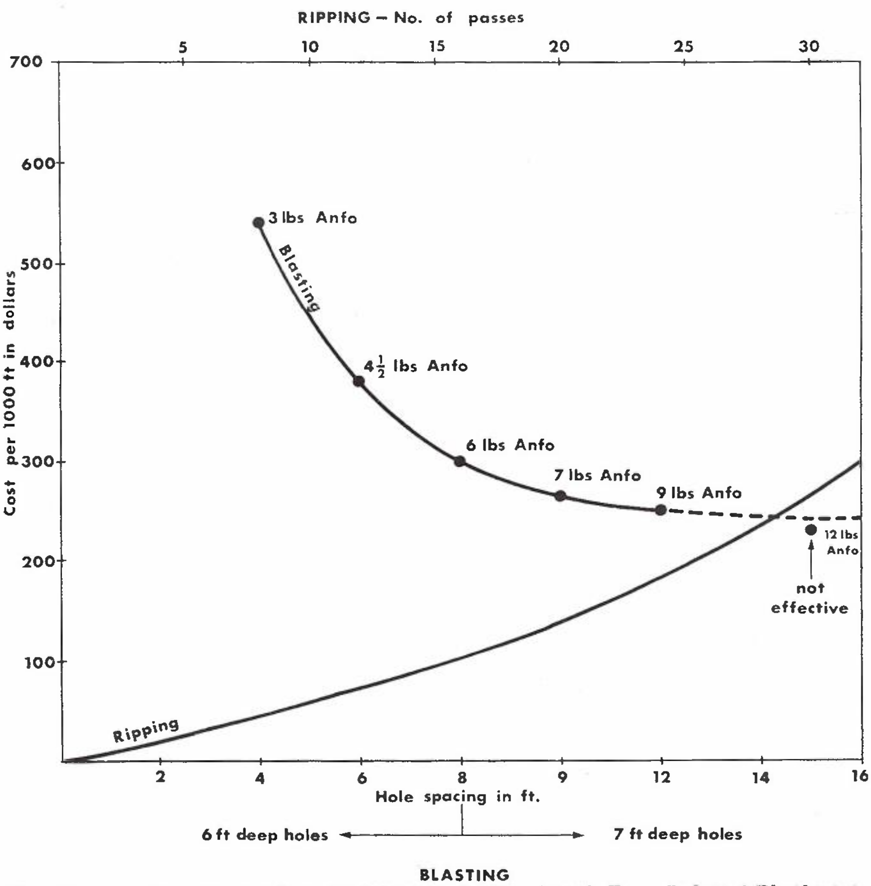


Fig. 15. — A Cost Comparison Chart Depicting the Break Even Point of Ripping vs. Blasting.

Cable Laying.

This group comprised 38 men, excluding engineers and inspectors. They were divided into parties taking care of circular manhole and repeater installation, cable laying, route reinstatement, and camp duties.

The success and speed achieved by the new method depended on the design work that went into the tractor and its ancilliary fittings. It is a considerable advance on the plowing techniques that have been used in the Department for many years.

One aspect not overcome till about 150 miles of cable had been installed was the practice of lashing the tail end of one drum to the start end of the next and plowing continuously. The backhoes, which then excavated the ends and joint position had great trouble in avoiding a hit on the cable. Besides this, due to the way in which the ends are made up in the factory, one cable tended to crush and damage the other. Hence we changed to a fresh start with each drum of cable in a backhoe excavated slot alongside the end that had been run out of the ground. Thus if the backhoe does strike the old end the joint position can be moved back slightly to avoid the dented cable, and crushing of lashed ends, of course, does not occur.

Besides checking the cable, the advance test group also coupled the cable ends together by means of Beverage tu-

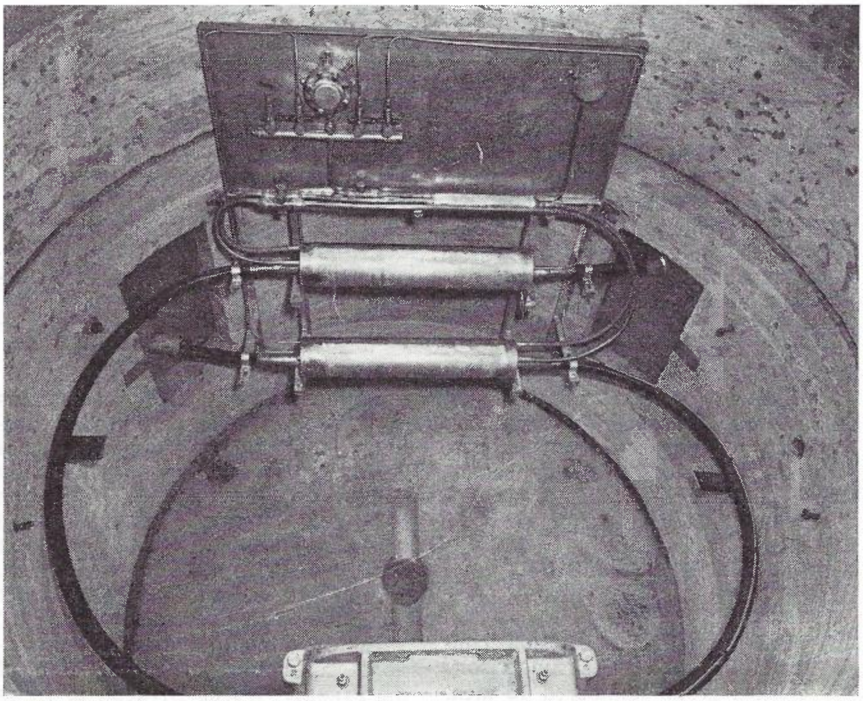


Fig. 16. — Looking down into a Minor Repeater Circular Manhole.

bing to feed air through from cylinders located at 11-mile intervals. Dieldrin was applied at the tractor, at the rate of 20 gallons of 1.1 per cent. concentration per 1000 yards. Consequently these men and others handling the cable had to observe a high degree of cleanliness.

Circular manholes and repeaters were placed in position ahead of the cable layers, and the route, apart from joint positions, was reinstated behind them. The reinstaters also erected cable markers at a nominal rate of 4 per drum length.

Cable installation averaged 16 miles per week, with the best performance on one day being 12 miles.

Jointing and Testing.

Jointing, testing and hole reinstatement employed a total of 30 manipulative staff. Their progress rates were tailored to coincide, and be about the same as cable laying. In the beginning this camp was about 100 miles behind the layers, but at Carnarvon the ripping, laying and jointing activities concluded in the same week a fortnight ahead of schedule.

The standard rolled sleeve method of tube jointing was used throughout and each jointer's target was two joints completed, flash tested, and wrapped with denso tape in a day. Fig. 16 shows a complete minor repeater manhole, jointing of cables, and a section of the repeater container. With practice this proved no problem and only the two minor-repeater joints took slightly longer. Several jointers consistently completed three joints in a day (Figs. 17 and 18.)

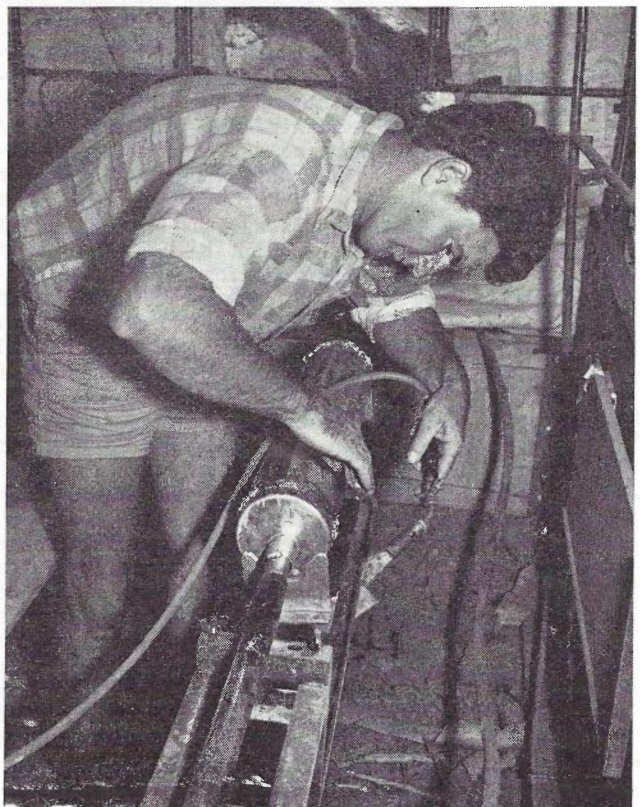


Fig. 17. — Jointer Completing a Straight Joint in an Open Hole Protected by Tent and Frame. The special jointing jig and seating arrangement can also be seen.

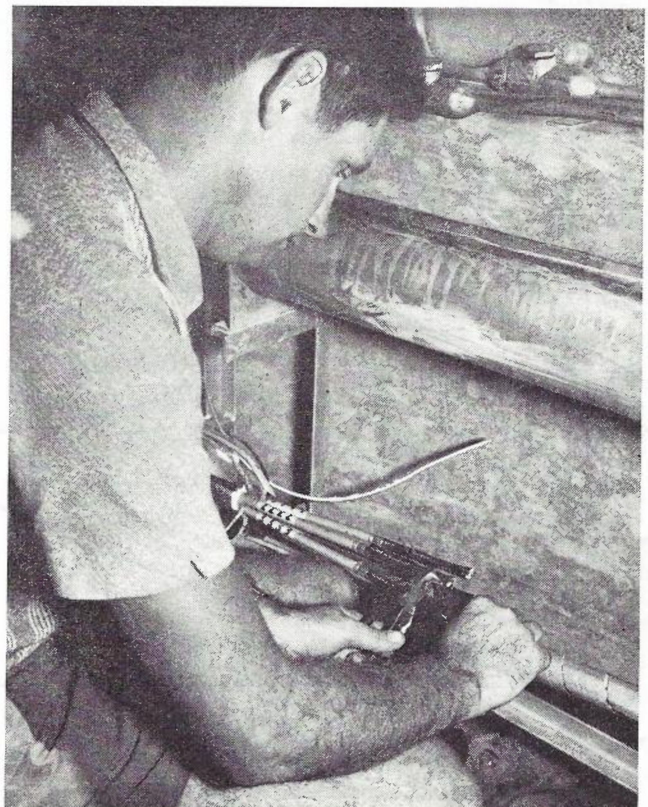


Fig. 18. — Jointer Working in a Minor Repeater Circular Manhole.

After testing and acceptance, the joint positions were filled in, paving slabs being left about 6 in. above the joint canister as a warning for future excavators. A pipe cable marker was also erected at each joint position. Thus only the concrete lids of minor-repeater manholes every 2.8 miles, and the yellow markers in between will indicate the presence of buried cable joints.

The jointing canister used was an improvement on previous designs and has now become standard for this class of work. Instead of a lead slip sleeve a preformed tinned bronze sheet was used to wrap around the end caps. It is held against the internal pressure by self-tapping screws so that the plumbing merely seals the canister.

The testing crews used the Kieler Howaldswerke pulse echo test set (P.E.T.S.) to accept or reject the tubes in each minor repeater section and a Siemens complex level tracer with X - Y locus plotter to test and admittance balance each Z12N minor repeater section on the interstitial pairs. On the core pairs chosen for supervision it was essential to have a cut-off frequency not lower than 3.04 kHz. This was not possible with standard loading and their high 0.95 microfarad/mile, mutual capacity. (Fig. 19.)

Special rearrangements of pair allocations were therefore made, and in future similar cables 88 millihenry loading at 3000 ft. spacing has been specified. Fault location was generally carried out with the P.E.T.S. and verified by means of the S.T.C. high voltage bridge. Wherever possible a ratio calculation was employed since this was found to be more accurate than an absolute measurement based on the cable characteristics. Fault locations to within a few inches were usually made.

The subject of testing both pairs and tubes in coaxial cables is fully treated in engineering instructions, and reference is made to these in the list of further reading.

A problem arose from the thermal behaviour of the circular manholes. This is described in an associated journal article.

Gas Pressure System.

Three men installing the continuous flow gas pressure system were the last project people through the route. They had the invidious task of working with a newly-conceived system capable of operation when totally immersed. It had many shortcomings, and is still under development so will not be further described here. Suffice to say that a basic contactor alarm principle is used, with compressor fed gas injection points at every major repeater station. (Fig. 20).

Costs.

The overall external plant cable installation cost per mile for the project was $8350, excluding administration charges. Of this the cable cost per mile amounted to $5830, and miscellaneous material to $780 per mile. The figure of merit, or installation cost per mile, then becomes $1740. Conduit work amounted to $120790 vote, for 20.5 duct miles, i.e., a cost of $5890 per duct mile.

In Retrospect.

This article would not be complete without mentioning some of the more important lessons learnt.

1. The time spent on trials, analysis, training, planning, scheduling, safety, public relations and just critical thinking, was amply rewarded.
2. The weather is a major factor, and job scheduling must give full consideration to precipitation/evaporation data. In the doubtful months the study must get down to weeks and even days in allotting time slots to various activities.
3. Test boring to evaluate soil conditions is a waste of time and money. An engineer with some

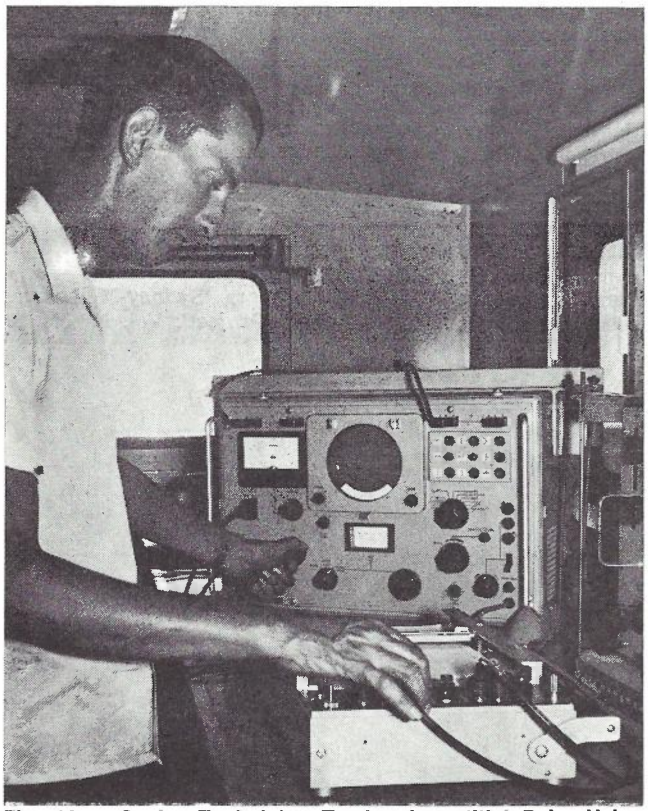


Fig. 19. — Senior Technician Testing Interstitial Pairs Using the X-Y Locus Plotter.

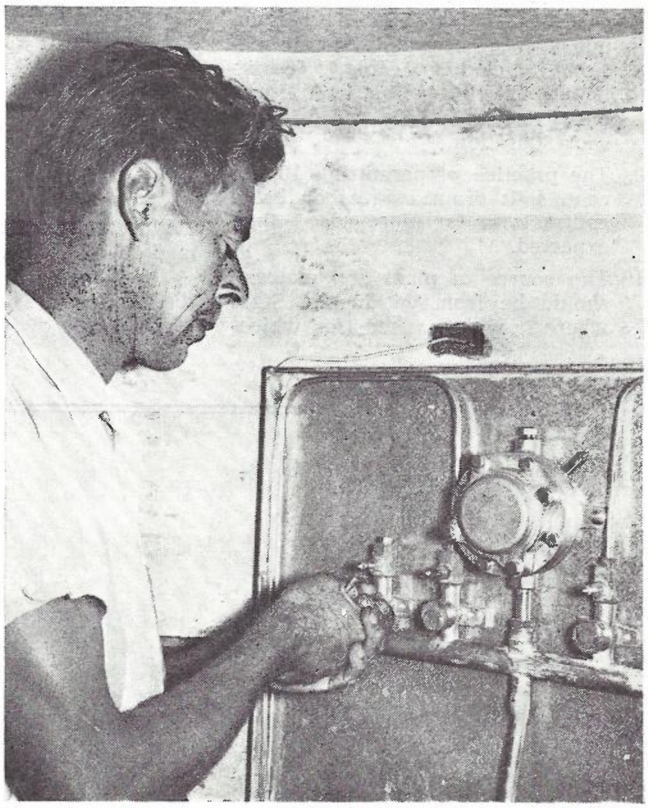


Fig. 20. — The Low Pressure Manifold and Contactor Arrangement on the Joint Frame in a Minor Repeater Manhole.

knowledge of geology, coupled with a lot of experience on ripping, can predict soil conditions from surface indications with 90 per cent. accuracy. In the 10 per cent. area of doubt there is no substitute for ripping the whole track with a D9G tractor.

4. Engineers must have a very close familiarity with the route, but the often stated necessity to walk the route should be forgotten.
5. It is always better and cheaper to rip first and shoot afterwards than the other way round.
6. The preparatory functions of track preparation and gate erection can readily be absorbed into the ripping function without increasing staff numbers.
7. Ripping will take at least twice as long as cable laying, even with two ripping machines. It is therefore essential on a large project to have at least two ripping machines, and to programme the cable laying machine, as an additional ripper, for as long as possible before beginning to lay cable.
8. A substantial stockpile of materials is essential before commencing cable laying. A minimum of 50 per cent. of the year's job requirement should be on hand with the balance coming forward. In our case we at some time or other ran out of every item of Interstate material, including cable. Fortunately the latter occurred only once, and then only for a very short duration.
9. The practice of permitting 10 per cent. split drum lengths on cable contracts is far more costly than expected.
10. The source of plant and material should be from within the State where it will be used (for whichever items this is possible). The advantage of local control of material supply in a project of this size and nature permits overall economies greater than those resulting from a collective schedule.
11. Small size plastic cable is not a proposition for installation in long drum lengths. Stick to 1000-yard lengths, and then regard 6/20 as the minimum acceptable size for this application.
12. In allocating times for any activity work on the basis of 50-minute hours, and besides this allow 10 per cent. down time on all mechanical plant.
13. Do not stint on engineers, supervisors or mechanics. In the long run basic engineering, supervision, plant maintenance and morale will determine the success or failure of a project.
14. Relief vehicles are essential if the mechanics are to ever cope with the maintenance problem.
15. The difficulties involved with matching cable ends and fault location have been very much exaggerated in the past.
16. There is a very substantial penalty involved in experimenting with a project while it is in progress.

CONCLUSION.

It would not be fair to conclude without paying tribute to the rank and file of the project. Staff morale was always excellent, with a healthy competitive spirit between the various groups. This was highlighted when the cable reached Carnarvon, and all camps, set up within yards of each other, celebrated the occasion. The engineers and field supervisors also made a major contribution.

The people in support, principally the Perth workshops and automotive division, and the transport and supply, branches, should also not be forgotten. Without their assistance and the outposted blacksmith situated in the project depot, the targets could not have been achieved.

The senior line inspector on the project, near its completion, confidently asserted to Mr. C. J. Griffiths, then F.A.D.G. Works, that given another chance the high performance figures already achieved could be bettered by at least 15 per cent. He and the division were given the chance on the extension of the cable from Carnarvon to Port Hedland and are keeping that promise.

FURTHER READING.

'Acceptance Testing of Coaxial Cable'; A.P.O. External Plant Information Bulletin No. 40.

'Gas Pressure Systems'; A.P.O. External Plant Information Bulletins Nos. 31 and 35.

'Acceptance Testing—Carrier Cables'; A.P.O. Engineering Instruction, Lines, Cables, T2401.

'Acceptance Testing—Tubes'; A.P.O. Engineering Instruction, Lines, Cables, T2431.

'Coaxial Cables, Systems, Design and Plant Layout'; A.P.O. Engineering Instruction, Lines, Cables, SY3902.

And the following articles from The Telecommunication Journal of Australia:—

F. T. Harding and T. N. Pimm 'Lightning Protection for Buried Cables'; Vol. 16, No. 1, page 56.

F. J. Harding, 'Cross Country Cable Construction—Installation Programming Based on Predictable Climatic Conditions'; Vol. 14, No. 1, page 36.

D. MacQueen, 'Some Aspects of the Design and Use of Cable Ploughs'; Part I, Vol. 13, No. 6, page 459; Part II, Vol. 14, No. 1, page 52.

Various authors, 'Sydney-Melbourne Coaxial Cable Project'; Vol. 13, No. 3.