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# THE ROYAL ENGINEERS JOURNAL

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MARCH, 1972



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# The Emplacement of Military Bridges by Helicopter

LIEUT-COLONEL B. W. BRUNS, US ENGINEERS
COLONEL R. T. WELD, MA, CEng

ALTHOUGH the river obstacles to be crossed have always remained the same, the requirement for military bridges has changed over the years with the development of new vehicles and equipments.

Up to about 1911, military transport was all horse-drawn and the heaviest load was a 2-ton axle. During World War I the introduction of mechanical transport, heavy guns and particularly tanks, increased the load requirements dramatically to some 35 tons. World War II further increased the load requirement to 55 tons or more. The effect of this has been that, whereas before 1914 most military bridges were improvised, the heavy loads today force the engineers to be almost entirely dependent on equipment bridges.

The introduction of mechanical transport has given the engineers a bonus in that it is possible to carry much heavier and larger portions of bridges and to move them much faster.

The speed of movement of MT has increased the whole tempo of operations and construction times, which were acceptable in 1870 (CL 20 floating bridges 2–3 days), are not acceptable in 1970. The need for rapid construction is also accentuated by the introduction of more powerful weapons with which to attack the bridge and the improvements in communications which reduce the response time for the enemy to attack the bridge once it is located.

While there has been an evolution of increasing loads and increasing required-construction speeds, technology has also provided new materials, new techniques, better transport which make it feasible to meet the requirements. The latest capability, air transport; however, is somewhat double edged—it produces a demand for air-portability with consequent necessity to restrict weight to an absolute minimum. So the designer is now faced with the requirement for equipment which is very rapidly built, capable of carrying the heaviest tanks, yet is light in weight for airportability.

While future loads seem more likely to decrease than to increase, improved surveillance methods and more powerful weapons will in turn dictate requirements for speeded up construction and dismantling times. To achieve very rapid construction calls for assembly of large pieces of bridge which is not a welcome addition to a highly mobile, fully tracked battle group. Today we use a tank-mounted bridge to accomplish the very rapid construction requirement. The result is an expensive specialist equipment which moves relatively slowly, particularly on long moves.

A MOBILE SKY HOOK—AN ENGINEER'S DREAM. The engineer has always coveted an equipment which can rapidly move bridging, engineer equipment or materials forward into battle or from work site to work site without relying on movement across terrain. Historically, engineer transport has been big, slow and was essentially devoid of a cross-country capability. The closest thing that exists today to fulfilling the engineer's dream is the helicopter. During the Korean War, the helicopter made its mark as a life-saving aerial ambulance. In the early 1960's a form of combat relying on air mobility was tested and was later proven in the Vietnam low intensity war. Today, the use of helicopters is accepted and considered proven, both in the civilian world and for the military. However, the use of helicopters is limited by certain inherent limitations, i.e., the largest helicopters in the western world today have a lift capacity of only 12 tons, they create a hurricane in the work area and their ability to move loads at night in a combat environment is limited. We can expect helicopters with a greater lift capacity to become available. The Russians have developed a series of helicopters which have a lift capacity far exceeding those available in the western world. Reportedly their largest helicopter has lifted a 68,410 lb payload to an altitude of 9,678 ft. All weather operation has always been an aviator's dream, and certainly a near all weather, including night, capability, must be developed for the helicopter to realize its full potential on the battlefield.

The questions which come to mind are: How does the helicopter fit in the future battlefield and more specifically how can it benefit the engineer in his bridging mission? Is a bridge under a helicopter more vulnerable than a bridging train in convoy en route to a site? Can a helicopter with a bridge underslung be distinguished on radar from other helicopters in the area, or will multi-targets (helicopters) in the battle area disguise the one carrying the bridge, and will detection/positive identification be limited to visual means?

Current medium lift helicopters have considerable potential for lifting current bridging and the future heavy lift helicopters (HLH) will be able to lift all of the assault and support bridging likely to be used on gaps ranging to 100–160 ft (see Fig 1). Where then is this capability likely to be employed? Certainly the US experience in Vietnam indicates that in a low intensity, limited, counter-insurgency type of war it will be used extensively. In fact, in a counter-insurgency type of war, helicopter emplacement of bridging may be the only viable alternative in a great number of situations. In the medium to high intensity war, it is felt that whenever the time available to accomplish bridging is critical, whenever cross-country mobility is seriously affected or whenever requirements exceed logistic programming, helicopter emplacement of bridges will be considered AND used by the tactical commander. Surely these situations are likely to occur during any phase of battle, i.e. reconnaissance, attack, exploitation and withdrawal.

| GAP | BRIDGE – AUW | | HELICOPTER | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | EUROPE | | USA | | FUTURE | | |
| | CL 16 | | 47A | 54A | 47C | 54B | MLH | 53E | HLH |
| 36′ | 44′ | 10,100 | 30 | 120 | ✓ | ✓ | ✓ | ✓ | ✓ |
| 44′ | 52′ | 12,250 | NIL | 90 | ✓ | ✓ | ✓ | ✓ | ✓ |
| N/A | 72′ RAFT | 19,700 | NIL | 5? | ✓ | ✓ | ✓ | ✓ | ✓ |
| | MGB CL 60 | | | | | | | | |
| 47′ | 55′ SS UND | 9,550 | 35 | 150 | ✓ | ✓ | ✓ | ✓ | ✓ |
| 72′ | 80′ SS UND | 13,500 | NIL | 80 | ✓ | ✓ | ✓ | ✓ | ✓ |
| 22 | 30′ SS DKD | 10,200 | 30 | 120 | ✓ | ✓ | ✓ | ✓ | ✓ |
| 32′ | 40′ SS DKD | 12,900 | NIL | 90 | ✓ | ✓ | ✓ | ✓ | ✓ |
| 42′ | 50′ SS DKD | 15,600 | NIL | 60 | ✓ | ✓ | ✓ | ✓ | ✓ |
| 42′ | 50′ DS UND | 16,000 | NIL | 55 | ✓ | ✓ | ✓ | ✓ | ✓ |
| 92′ | 100′ DS UND | 32,000 | NIL | NIL | x | x | x | ✓ | ✓ |
| | TANK BRS | | | | | | | | |
| | 45′ CENT. | 17,300 | NIL | 30 | ✓ | ✓ | ✓ | ✓ | ✓ |
| | 80′ CHIEFT. | 29,800 | NIL | NIL | x | x | x | ✓ | ✓ |
| | MAB | | | | | | | | |
| | END BAY | 22,000? | NIL | NIL | ✓ | ✓ | ✓ | ✓ | ✓ |
| | INT BAY | 16,500? | NIL | 50 | ✓ | ✓ | ✓ | ✓ | ✓ |

Fig 1.

The UK in 1959 conducted trials of helicopter emplaced bridges using a full scale lightweight fixed assault bridge mock-up. Documentation of the techniques and procedures used, is, however, lacking. Accordingly, it was recommended at the Second Meeting, Quadripartite Working Group on Bridging and Gap Crossing, that US and UK should undertake cooperative trials to develop improved techniques for helicopter carriage and emplacement of bridges. Following this, a committee was set up to develop a proposed program, with the first meeting held in March 1970. A trials program suggesting the following objectives was proposed:

A. Develop techniques for emplacement of bridges and rafts by helicopter.
B. Define limitations of loads, sizes, configurations and emplacement sites.
C. Determine special equipment requirements.
D. Determine training requirements for air crew and ground personnel.
E. Determine operational procedures for national and bi-national operations.
F. Determine tactical features to be considered in emplacing bridges and rafts by helicopter.
G. Determine feasibility of extending fixed bridging into the assault phase and river crossing operations.
H. Note features to be considered in the design for future bridging equipment.

The program was to be divided into three phases:

A. Phase 1: Technical trials in UK with UK helicopters and wind tunnel models to establish principles in 1970–71.
B. Phase 2: Confirmatory trials using full scale bridges and US helicopters in 1971.
C. Phase 3: Introduction of helicopter emplacement into tactical setting into exercises in Germany in 1972 by USAREUR and BAOR.

Trials began in the United Kingdom in the summer of 1970 with an instrumented Sea King Helicopter (see Plate 1). The initial results confirmed two generally known

Plate 1. Sea King Helicopter.

The Emplacement Of Military Bridges By Helicopter phenomena associated with the carriage of large sized loads by helicopter, ie, the loads tend to stabilize broadside to the direction of flight and that there was rapid increase of hook loads at 40–50 knots. Additionally, it was found that at a hover significant loads may be added to the aircraft over and above the basic weight of he bridge. In an effort to overcome the large load build-up during cruise, two fins were fitted to one end of the bridge. It was found the bridge then flies with the span parallel to the air flow (direction of flight) and at a given forward speed the added aerodynamic loads were greatly reduced. Figure 2 summarizes preliminary data available from UK flight trials and wind tunnel tests. The dramatic effect of fins is

HELICOPTER BRIDGE EMPLACEMENT

PRELIMINARY DATA

FIG. 2

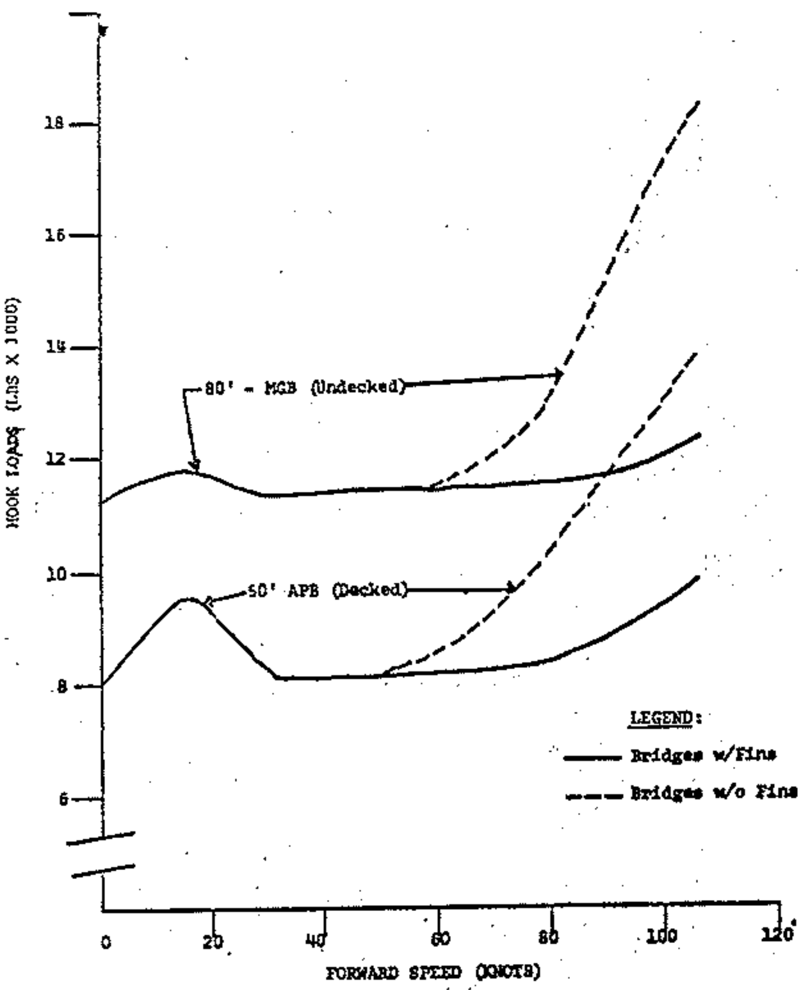


FIG.3. BRIDGE CARRYING CAPABILITIES OF HELICOPTERS.

(PREDICTED NOT CONFIRMED)

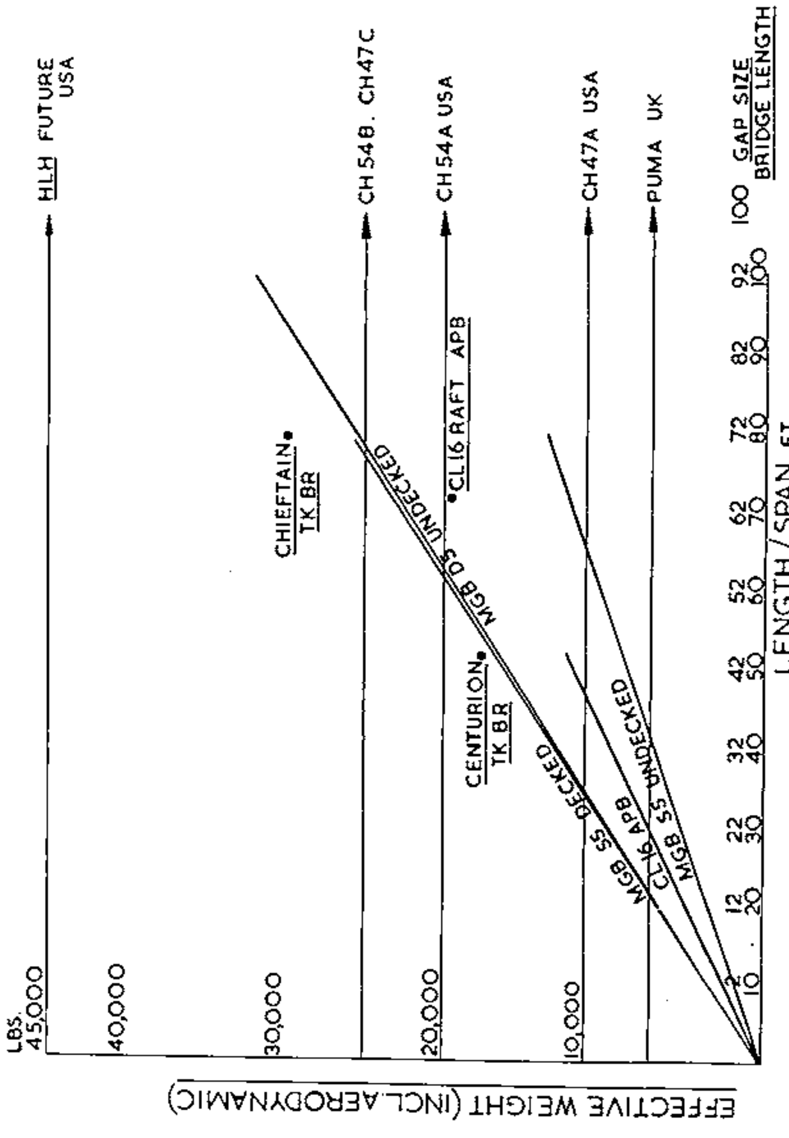


**Plate 2.** CH 54A Carrying 52 ft Cl 16 (APB) Bridge complete.

**Plate 3.** CH 54A Carrying Cl 16 (APB) Raft complete.

The Emplacement of Military Bridges by Helicopter 2 & 3

Plate 4. CH 47A Carrying 55 ft SS MGB Undecked.

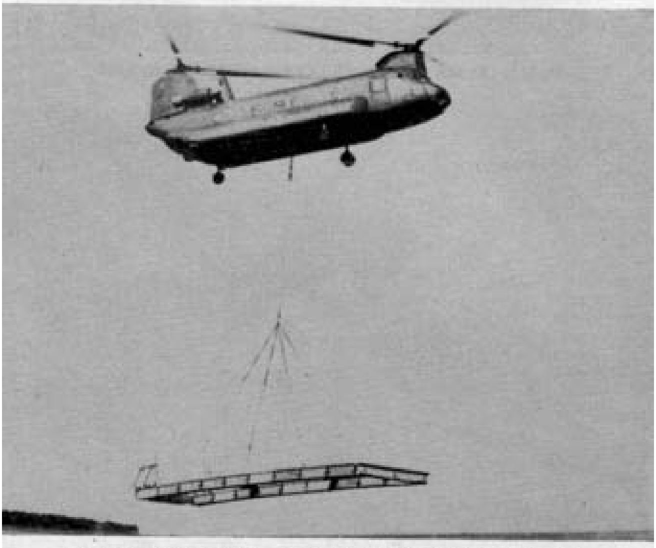


Plate 5. CH 47A Carrying 55 ft of Single Storey MGB (undecked).

The Emplacement of Military Bridges by Helicopter 4 & 5

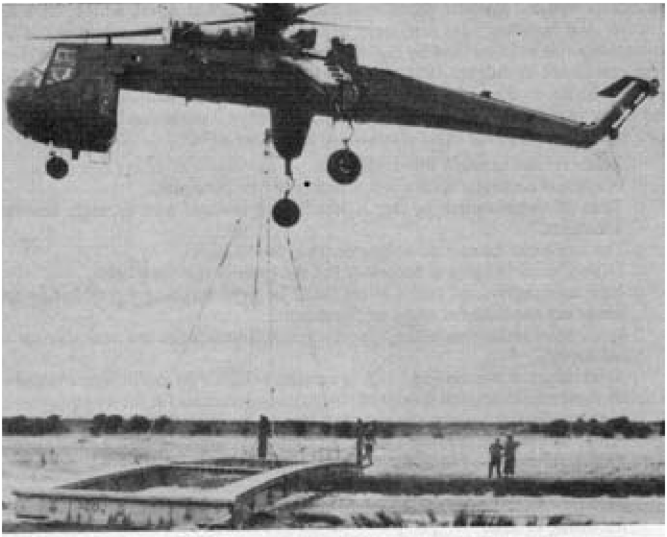


**Plate 6.** CH 54A Emplacing 80 ft SS MGB undecked.

**Plate 7.** CH 54A Carrying 55 ft MGB DS undecked.

The Emplacement of Military Bridges by Helicopter 6 & 7

indicated. Without fins the rapid load increase occurs at 40–50 knots; with fins, however, the build-up does not occur until about 90 knots. All points of the load curves have not been verified by flight. Phase 2 of the trials began in May 1971 and were completed in August 1971 with the US providing a CH-47 and CH-54 helicopter with crew. The UK conducted the trials using the British Medium Girder and Class 16 airportable bridges. Although the Phase 2 trials results have not been completely analysed, the main conclusions are likely to be:

- Loads fly better when fitted with fins.
- Positional accuracy within 3–4 ft can easily be obtained.
- Time of emplacement by day is less than 3 minutes and by night less than 4 minutes.
- The loads can be carried at speeds from 50–70 knots.
- Little special training is necessary for the ground handling crew.
- Low level light aids and a short burst of light (landing light) during final hover are required for night emplacement.
- Hook load indicators and angle of approach indicators are desirable for the helicopter.
- The bridges shown on Fig 3 can be carried TODAY by the helicopters shown.

What do these results suggest should be design considerations for future equipments?

- Lightweight for a given strength will clearly improve flying possibilities.
- As far as possible corners and edges should be rounded rather than sharp.
- Provision must be made for sling positions capable of taking loads well in excess of the dead load of the bridge.
- Fins should be provided as part of the equipment or at least provision made for fitting of fins.
- For heavier bridges, consideration should be given to the possibility of launching each girder separately.

Multi-hook/attachments might improve stability of large loads and should permit faster carriage. Whatever the size of helicopter available or however light bridges may become there will inevitably be limiting cases when the effective drag plus dead weight of the load approaches the available lift or instability limits forward speed. Therefore, it is desirable that bridges should be so designed that they can be launched undecked and be subsequently easily and quickly decked down.

## CONCLUSIONS

Over the last decade, helicopters have been produced with ever increasing payloads while bridges have been getting lighter. We are at the present time at a point where existing helicopters can lift useful lengths of existing bridges. The trials indicate it is technically feasible to emplace bridges by helicopters. Why not then let the engineer use this "tool". The "instant bridge" made possible by helicopter emplacement gives the commander an asset to overcome a calamity to an existing bridge or to exploit a situation by the use of "oportunity bridging" to permit rapid movement. We need now tactical data to enable an appreciation to be made of when and how best helicopter emplacement can be employed in battles. The equipment is available now, the Plea therefore is to introduce this technique into war games, field training exercises, command post exercises and manoeuvers with troops.

Since this paper was written the British Medium Lift Helicopter has been cancelled. Army exercises involving substantial lifts will therefore have to depend on larger helicopters borrowed from US or elsewhere.

* * * * *

# Control Blasting Techniques used in Road Construction

MAJOR J. N. LEIVERS, RE, BSc(Eng), CEng, MICE

## INTRODUCTION

Until about the mid 1950s blasting as used in road construction showed very little finesse. The main charge required to shatter enough rock to form the cutting was placed and fired. The only control of excessive overbreak was the use of delay detonators to throw the rock away from the cut line. This resulted in an unsightly and ragged face usually with unnecessary overbreak. In furnishing a bid, for a job involving blasting, contractors had to allow for two extra items, disposal of inevitable overbreak and trimming up of the ragged and often unsafe surface left by the blast.

It was during the late 1950s that both contractors and explosive manufacturers devised various controlled blasting techniques, to minimize overbreak. This was achieved by the reduction, and better distribution of explosive charges to stop stressing and fracturing of the rock beyond the required excavation face.

The first method used was that of line drilling, which consisted of a single row of unloaded, closely spaced holes, drilled the full depth of the excavation along the desired line of cut. This provided a plane of weakness to which the primary blast could break. This technique has since been modified and developed into other methods such as trim-blasting, cushion blasting, and in recent years, pre-splitting or pre-shearing, a method now used in practically every road construction job in the USA.

Pre-splitting was first used in the United States of America about 1960. The US Corps of Engineers started to use the method in 1961 and found it so successful, that by 1964 the requirement to use pre-splitting techniques was written into the specifications of most construction jobs requiring rock blasting.

## AIM

The aim of this paper is to cover the main blasting techniques used when constructing a road through rock cuttings. Many papers and articles have been written on blasting in general, therefore this report will concentrate on those techniques used to control and minimize overbreak. The types of control blasting covered are as follows:—

a. Line drilling.
b. Pre-splitting.
c. Scale on trim blasting.

To ensure continuity some basic data about primary blasting has also been included.

## PRIMARY BLASTING

As already stated this paper is concerned mainly with controlled blasting to limit overbreak. However, as the primary blast will often be referred to in the report, a few practical pointers about how the bulk of the rock is broken up by the main charge are given below.

*Type of explosive*

(*a*) Most plastic explosives can be used, but that normally preferred is a 60 per cent standard gelatin dynamite. This is usually made in 8 × 1¼ in diameter sticks (approximately ½ lb). Any British Army plastic explosive can be used satisfactorily.

(*b*) To use PE to fill a number of deep large diameter holes becomes very expensive; therefore most contractors will use a mixture of ammonium nitrate (fertilizer) and diesel, this they can either buy ready mixed or mix their own, in the ratio of

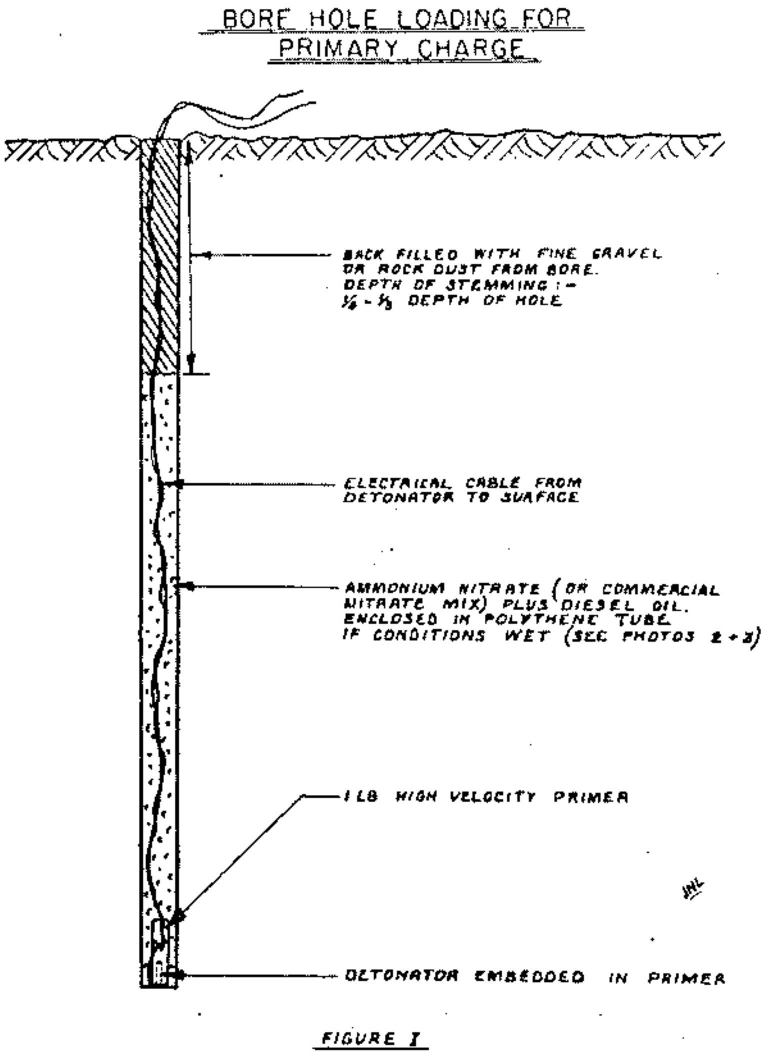



Fig 1. Bore hole loading for primary charge.

approximately one US gallon of diesel to 160 lb of nitrate. This mixture cannot be fired using a detonator alone, but requires approximately one pound of high velocity primer (75 per cent gelatin dynamite). Diesel soaked nitrate is supposed to be water resistant for up to seven hours, in practice this is seldom true and extra precautions must be taken when working in wet conditions. See paragraph 2.

*Amount of explosive.* There are many theoretical calculations, which can be done to determine the exact weight of explosive required per cubic yard to break up a specific rock to a given size. The quantities given below are only a rough guide from which a first trial blast can be made.

| *Type of rock* | *Wt exp/cu yd rock* |
|---|---|
| Good hard rock | 1·0–2·0 lb/cu yd |
| Medium shale | 0·5–1·2 lb/cu yd |
| Weathered shale | 0·25–0·75 lb/cu yd |

These figures should break the rock sufficiently for it to be removed by dozer assisted motorized scrapers or face shovels. The spacing of the holes is usually determined by the most economical hole diameter, that can be drilled with rigs available (usually 3 to 6 in diameter). Once the hole size is fixed, then the spacing is calculated from the wt/cu yd required.

*Loading of holes.* This is covered by Photographs 1 to 3 and Figure I. For small holes, up to 3 in diameter, one primer at the base of a hole with up to 15 ft filled with ammonium nitrate is sufficient to detonate the charge. For deeper holes a primer charge should be positioned every 15 ft of loaded hole. These primers can either be fired electrically or by detonating cord. The depth of explosive per primer can be increased for larger diameter holes.

*Delay blasting.* The shot is fired using different delay intervals on the detonators. These are arranged in such a way as to throw the mass away from the cut face and thus reduce stresses beyond the proposed cut. A typical road cutting delay pattern is shown in Figure IV, No 1 firing after the pre-split line and No 8 firing last, thus throwing the rock towards the centre line of the road and into the already excavated area.

## LINE DRILLING

This was the first method of control blasting used, the other methods covered by this report have been developed from line drilling.

*Theory.* The principal is much the same as that behind the perforated edge of a postage stamp, which ensures that the paper tears in the correct place without damaging the adjacent stamp. Line drilling is a single row of closely spaced holes drilled along the outer edge of the required excavated area. This line provides a plane of weakness up to which the primary blast can break. It also helps to reflect the shock waves created and thus reduce the stresses transmitted to the rock face beyond. This in turn reduces the amount of shattering and eliminates most of the overbreak associated with normal blasting using primary holes only.

*Use of line drilling.* Figure II shows a typical drilling layout in a road cutting, using line drilling along the final line of cut to control overbreak.

*Guidelines.* The following are guidelines which if followed should produce a good neat excavation line.

a. Diameter of line drill holes—2 to 3 in.
b. Spacing of line drill holes—two to four times the diameter of the holes.
c. The holes can be drilled vertically or at an angle, but to obtain good results they must be on the same plane. If the operator does not have the drilling rigs or the skill available to ensure the correct hole alignment, then line drilling should not be attempted.
d. The line of primary holes next to the line drill should be closer together than the other primary holes and only loaded to 50 per cent of the main primary charges. The explosive in these holes should be evenly distributed throughout

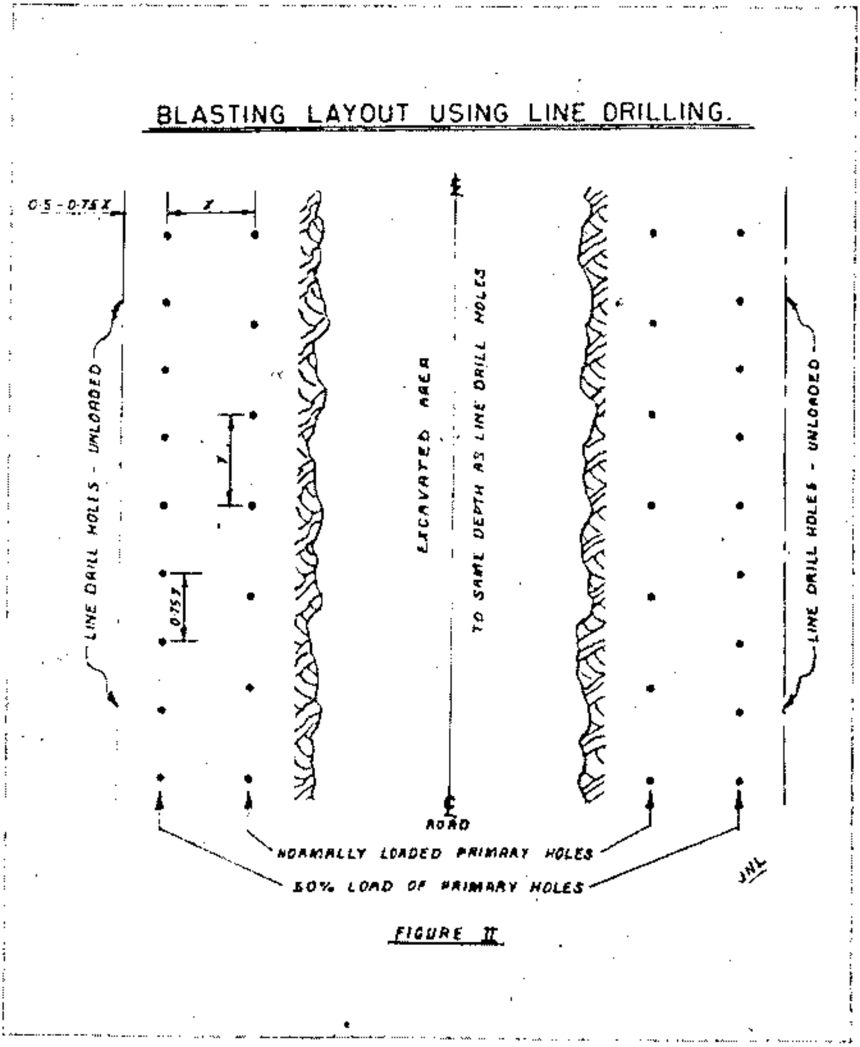



Fig 2. Blasting layout using line drilling.

the depth of the hole. If the line drill holes are angled, then this first line of primary holes should also be angled to the same degree.

e. Figure II shows how, for best results, the primary excavation is removed by normal blasting to within one to three rows of the proposed side of the cutting. The charge is then fired by using delay detonators to fire the lines consecutively from the road centre line, thus "slabbing" away from the finished face and reducing the back pressure which could cause overbreak.

*Advantage.* One advantage of line drilling over the other techniques covered in this report is, that it can be used in areas where the use of even light explosives along the control line may cause damage beyond the cut, ie, when excavating near building foundations. Line drilling can also be used to great advantage in conjunction with other control blasting methods.

*Disadvantages and limitations*

a. Line drilling will only guarantee good results in hard unweathered rock which has a minimum of bedding planes, faults and seams. These irregularities form natural planes of weakness along which the rock tends to split in preference to the artificial plane created by the holes.
b. Line drilling is slow and costly due to the large number of holes to be drilled and the alignment accuracy required.
c. Hole alignment accuracy cannot be maintained when deep drilling is required. The maximum depth to which line drilling can be used effectively is about 30 ft.

## PRE-SPLITTING

The technique of pre-splitting has only been perfected over the last ten years. The principal was first developed by lightly loading some of the holes in line drilling operations. It was found that this helped to promote cracking along the desired plane. Hole spacing was then increased and therefore drilling costs reduced.

*Theory*

A single line of holes are drilled 1 to 4 ft apart, all lightly loaded and fired simultaneously ahead of the primary charges. The charge is designed to be just enough to ensure fracture between the holes but not into the face of the rock (see Figure III).

This fractured zone between the pre-split holes acts as a reflecting plane to the shock waves of the main primary charge, preventing them penetrating the finished wall and causing fracture and overbreak.

*Procedure*

As the name implies the pre-splitting of the rock is done before the primary charge is fired. Figure IV shows a typical layout using delay detonators combined with pre-splitting for a road cutting operation. The pre-split lines are fired instantaneously via the detonating cord trunk lines with the points of initiation as shown. The delay intervals of the primary charges may vary from 5 milliseconds up to 35 milliseconds depending on type of formation and hole spacing. For most road work, where the hole spacing is less than 10 ft and hole diameters 3 to 6 in, the interval is usually 5 milliseconds.

Pre-splitting well ahead of the primary blasting is often practiced especially when working in a confined area. This enables the pre-split drilling rigs, which are usually smaller than the primary hole rigs, to be clear of the site by the time primary drilling starts.

The main advantage of pre-splitting only one-half the length of one shot ahead of the primary, as illustrated in Figure IV, is that if the nature of the rock changes producing inferior pre-splitting results, it is immediately evident. The spacing and/or loading of the next shot can therefore be adjusted accordingly. Prior splitting well ahead of the excavation should therefore only be used when the nature of the rock is known to remain constant.

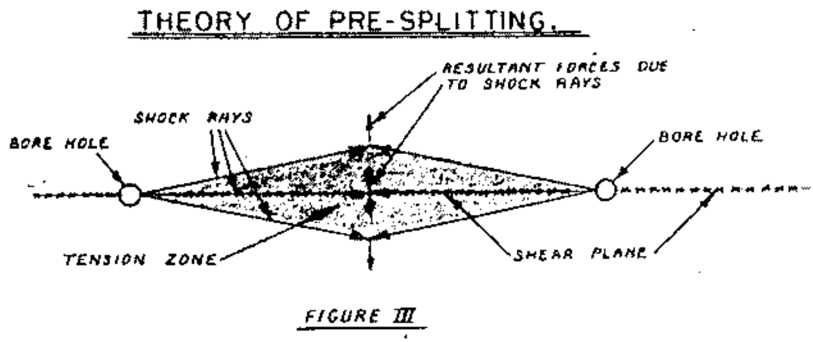



Fig 3. Theory of Pre-Splitting.

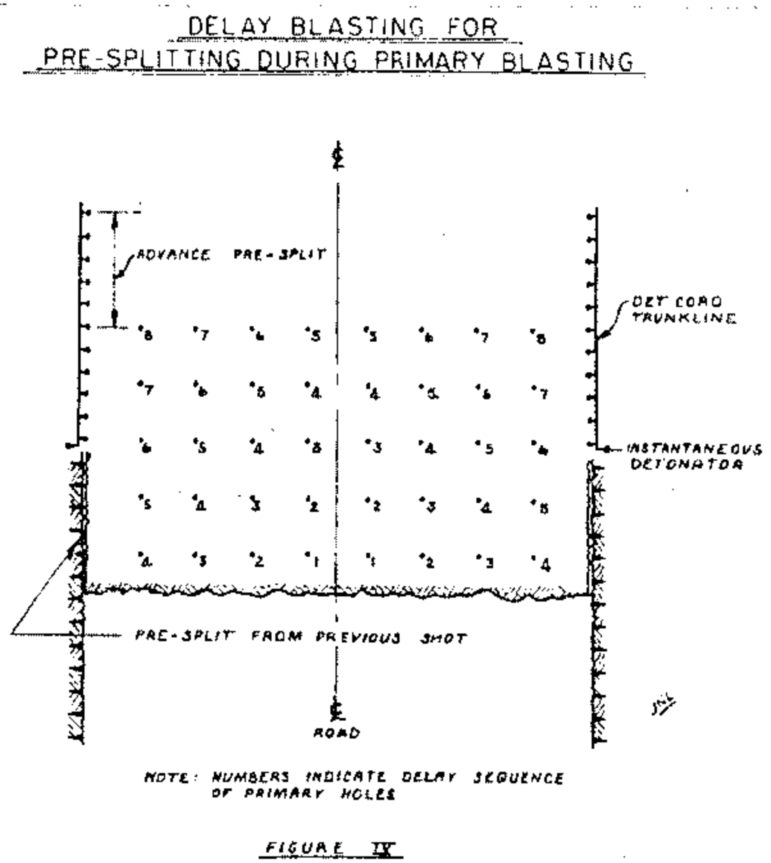



Fig 4. Delay blasting for Pre-Splitting during primary blasting.

*Loading, diameter and spacing of holes*

Figure V shows a typical loading for a 3 in diameter hole at 2 ft spacing. It is suggested that this loading and spacing should be used for a first trial shot if no other information is available.

Table I gives a rough guide for loading and spacing. Generally, poor rock, such as weathered shale, requires small diameter holes lightly loaded with close spacing, while good solid homogeneous rock can be pre-split by using heavier loading and wider spacing. The pre-splitting shown in Photograph No 5 was achieved with 3½ in diameter holes, 0·17 lb/ft exp at 4-ft hole spacing.

All formations cannot be pre-split or even line drilled, for if the formation cannot support itself, then overbreak will result regardless of the blasting techniques used.

TABLE I

Proposed loads and spacings for pre-splitting

| Hole dia<br>in | Explosive charge*†<br>lb/ft | Spacing*<br>ft |
|---|---|---|
| 1½–1¾ | 0·08–0·25 | 1–1½ |
| 2–2½ | 0·08–0·25 | 1½–2 |
| 3–3½ | 0·13–0·50 | 1½–4 |
| 4 | 0·25–0·75 | 2–5 |

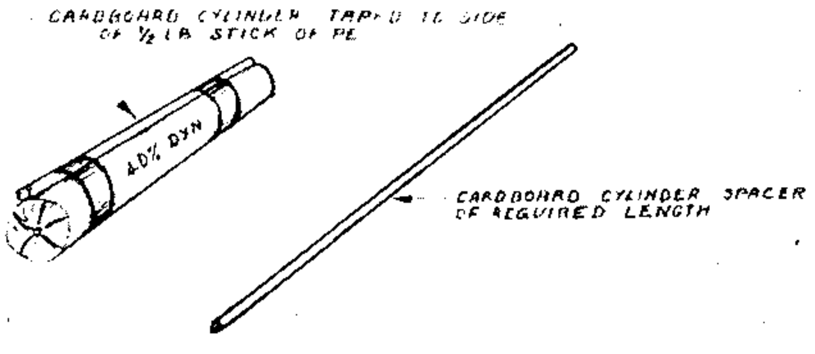
* Depends upon formation being shot. Figures given are an average range.

† Ideally, dynamite cartridge should be no larger than half the diameter of the hole.

*Type of explosive and loading techniques*

The example in Figure V shows how sticks of plastic explosive, ie, 30 or 40 per cent weight strength or grade of gelatin dynamite (1¼ in diameter × 8 in sticks), can be cut and attached to the detonating cord down line, in such a way as to obtain the required lb/ft average distribution. In the case of Figure V this is 0·25 lb/ft. There are several methods of attaching the explosive to the detonating cord, three of which are as follows:—

a. The 4 or 8 in sticks are taped on to the cord at the required spacing using adhesive tape—slow but effective.
b. Elastic bands, two per stick, are used to attach the explosive to the down line. This is quicker than adhesive tape but the elastic bands tend to slip.
c. By the use of cardboard cylindrical spacers. Most American explosive manufacturers make dynamite sticks of the required grade, with tubes already taped to the side, to enable them to be threaded on to the detonating cord. See sketch below.




SKETCH No 1

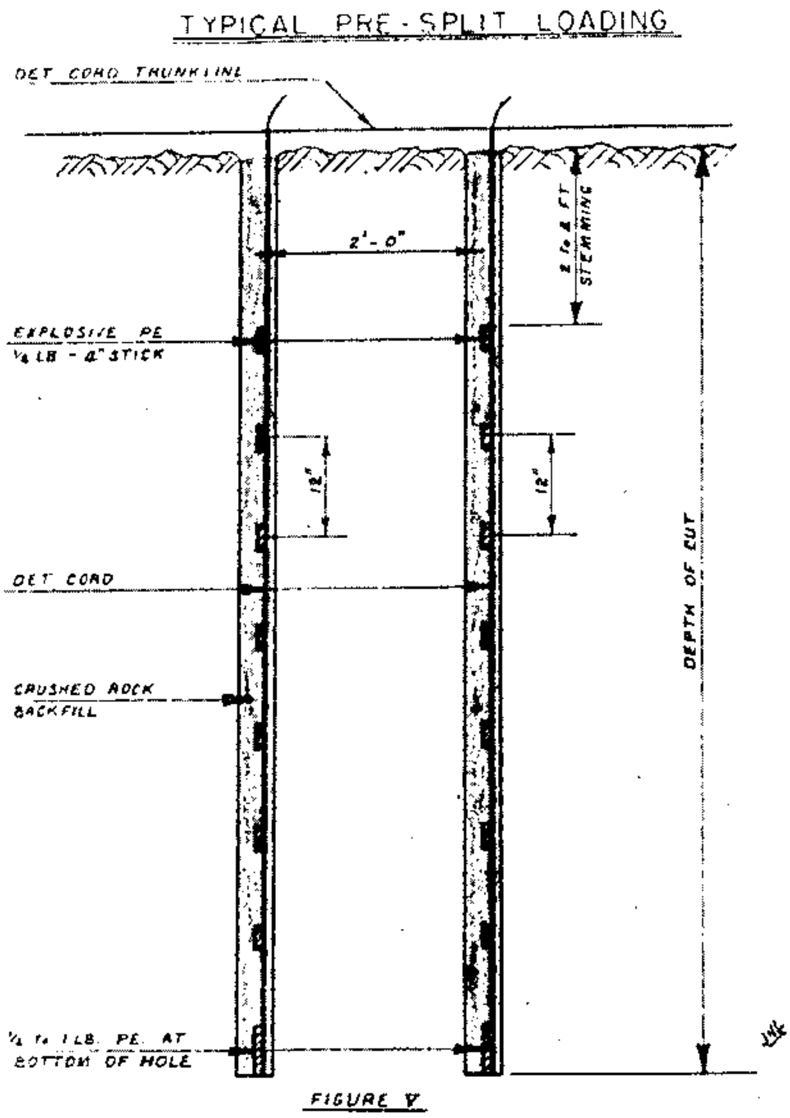



FIGURE V

Notes: 1. PE taped to Det Cord.
2. Charge increased at base of hole to ensure shearing at bottom of cut. Only required in hard rock.
3. For variations in spacing and loading. See Table I.

Fig 5. Typical Pre-Split loading.

The above methods of loading pre-split holes give good results, but if the explosive distribution could be even throughout the depth of the hole (except for the stemming at the top of the hole), then results would be more uniform. With this in mind the leading manufacturers in the USA have produced solid columns of small diameter (7/8 to 1 in) low density powder. Photo No 4 shows one of these called "Kleen Kut" made by Atlas Chemical Industries. This comes in 36-in cartridges with bayonet type couplers attached to each length. The photo also shows how the detonating cord is attached for lowering into the borehole. Other commercial makes are "Hercosplit" by Hercules Powder Company and "Trimtex" by Dupont. To provide the extra charge required at the base of the cut, especially in hard rock, a ½-lb stick of 75 per cent grade primer gelatin dynamite is often placed at the bottom of each hole.

*Results obtained*

Photo No 5 shows good results of pre-splitting in hard limestone. These were 3½ in diameter holes at 4 ft spacing. It can be seen here how the mark of the drill hole is clearly visible and the rock has been neatly sheared between the holes giving a smooth finish. All photographs in this report show surfaces which required no further work after pre-splitting, to conform to the Corps of Engineers specifications which require:—

a. Maximum depth of drill holes 30–35 ft.
b. Hole spacing 2 to 4 ft.
c. That the pre-split face should not deviate more than 6 in from the front of the line of drill holes, or 1 ft from the back.

Photo No 6 shows how the primary shot leaves a face when no control techniques are used. In the background a good pre-split face in the same rock can be seen for comparison.

If results obtained are not satisfactory the following is a guide as to where the fault lies and the remedy:—

a. A concave surface between drill holes.—Indicates overloading.—Reduce lb/ft of charge.
b. Burning of rock where the explosive has been in contact.—Indicates overloading.—Reduce lb/ft of charge.
c. Back half of pre-split hole removed by blast.—Indicates overloading.—Reduce lb/ft of charge.
d. Results are poor towards the bottom of the cut.—May indicate poor alignment of drilling holes.—If not possible to improve alignment, then reduce depth of each cut.
e. If rock is very soft and first shot produces overbreak and shattering reduce load and spacing of holes and/or introduce unloaded guide holes between pre-split holes.
f. Rock not sheared along pre-split line and leaving protruding rock without causing undue shattering beyond the neat excavation line.—Indicates underloading and/or hole spacing too great, usually the latter.

*Benching*

There is a limit on the depth to which a one shot pre-split can be effective. This depends on the following factors:—

a. *Experience of drillers*, ie, can they keep alignment when deep drilling? Anything greater than a 6-in deviation from the desired line usually gives bad results.

b. *Type of drilling rigs*. Rigs are not covered in this report but Photograph No 9 shows a typical small bore rig with its air compressor being used to drill pre-splitting holes (3½ in diameter). Photograph No 8 shows a larger self-pro-

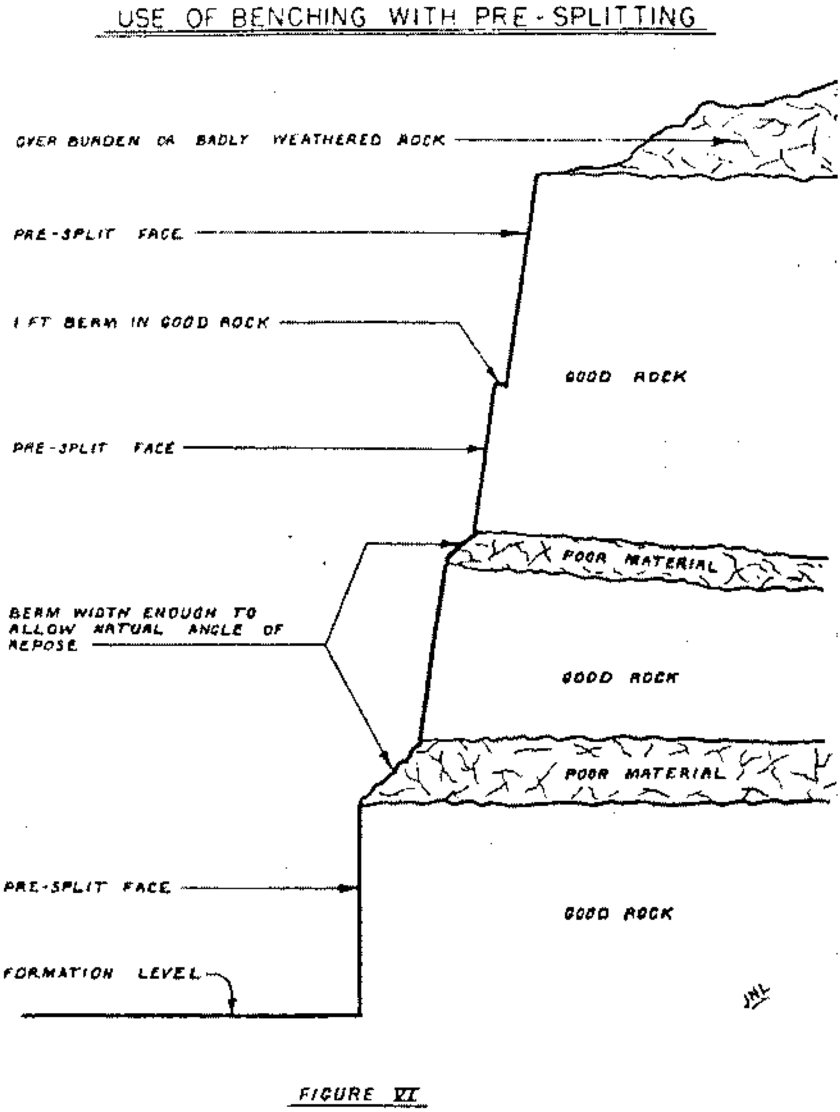



Fig 6. Use of benching with Pre-Splitting.

pelled crawler type rig which does not require the back up of a separate air compressor. In the photograph the rig is being used to drill 4½ in diameter primary holes.

c. *Geological rock formation*

(i) In practice, all the rock in any given cut is seldom of the required strength to give good pre-splitting results. There is normally some overburden on the surface, and possibly a depth of badly shattered or weathered rock, that will not pre-split. This must be cut back to a safe angle away from the pre-split face. See Figure VI.

(ii) There are often bedding planes beneath the surface of poorer material such as soft shale, coal, sand or clay. These will not pre-split, and if the cut is continued through them on the same plane, they will eventually erode and undermine the good rock above, causing it to break away.

When for any of the above reasons a face cannot be split with one drilling operation, the cut must be achieved by combining a number of shallower cuts. Between each cut a berm must be left. When the depth is limited purely by drilling ability the berm left can be as small as 1 ft in width, which is as close to the standing face that it is possible to drill without difficulty.

When poor rock or soil is encountered, then the pre-splitting holes should only be drilled to the top of the weak layer. The width of berm should then be such as to allow the weaker material to lie at its natural angle of repose, thus reducing the chances of further weathering beyond the finished face.

*Use of line drilling and pre-splitting together*

When a non-linear cut is required, pre-splitting as described in the previous paragraphs does not always give good results. In order to achieve a sheared face between the loaded holes it is often necessary to line drill between them. The unloaded holes act as a guideline and ensure that the split follows the desired route. Figure VII shows how line drilling is used in conjunction with pre-splitting to form 90° change of direction. If the rock is soft, such as poor shale, then pre-splitting can often only be achieved by introducing one or more guide holes between the loaded holes. This can be very effective but increases cost of drilling and causes loss of time.

## TRIM OR SCALE BLASTING

This uses the pre-splitting technique to not only split the rock along the desired plane, but also to remove some burden or buffer zone. See Figure VIII. Trim or scale blasting is sometimes used, when it is found that pre-splitting at the same time as firing the primary, as in Figure IV causes shattering beyond the line of cut. To stop this the primaries are fired and the area excavated, leaving a burden of 3 to 6 ft. When the pre-split shot is finally fired, the rock is not only split along the desired line, but the buffer zone is also pushed out into the excavated area. Note: enough buffer must be left to ensure that rock beyond the desired final cut is not affected by the primary shot.

When old rock faces become weathered and dangerous it is necessary to cut back into firm unweathered rock. Trim or scale blasting is a very effective way of doing this. If there is a possible danger from flying rock due to say the close proximity of buildings, then a steel wire rope net can be draped over the face before blasting. See Figure VII. This method of controlling the blast has been used very effectively by the US Army Corps of Engineers.

## RECORDING OF ALL BLASTING

Complete records should be kept of every blast. It is always much easier to improve and modify the blasting as a job progresses, if complete and detailed records

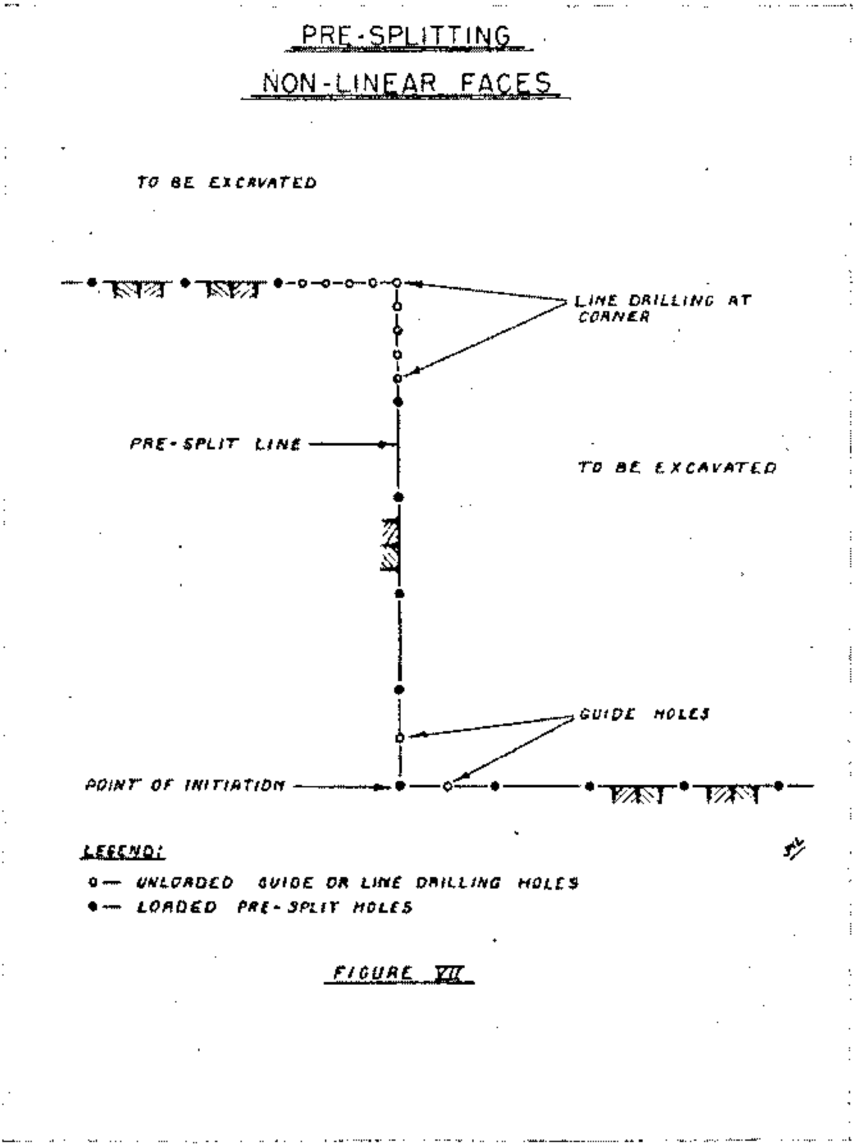



Fig 7. Pre-Splitting Non-Linear faces.

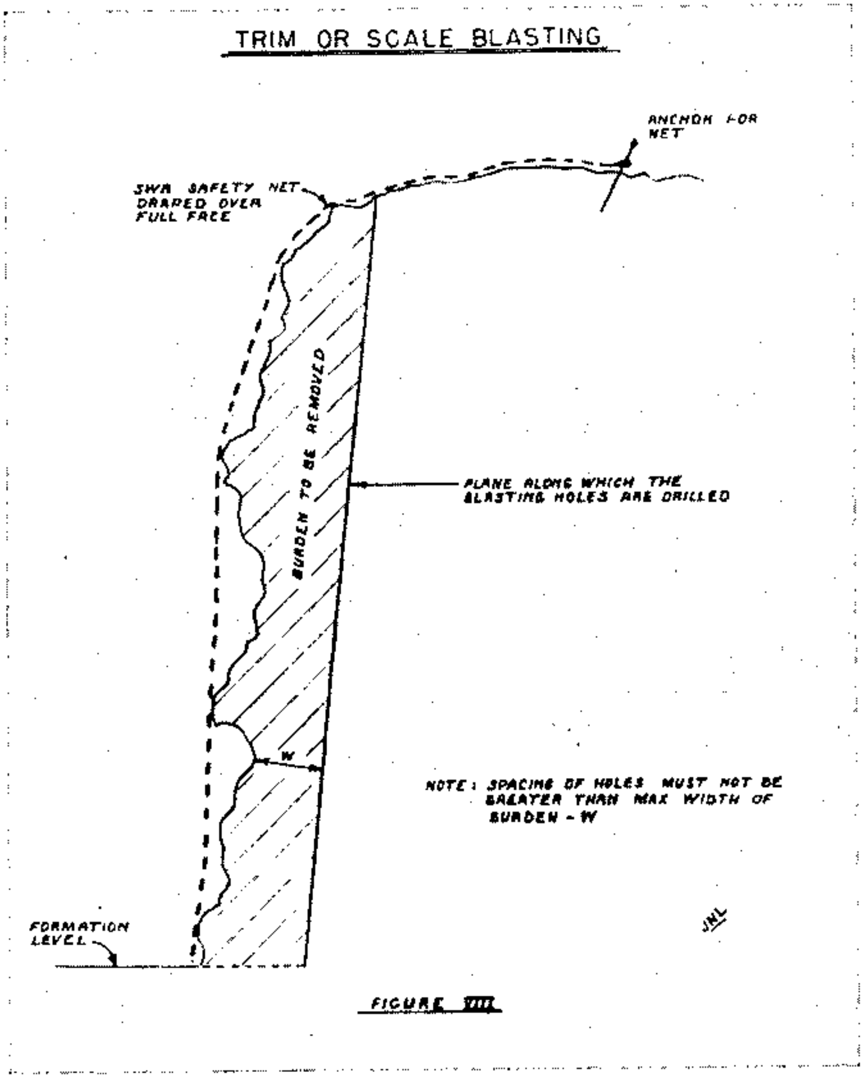



Fig 8. Trim or scale blasting.

are available. Some form of standard record sheet can be used. This should include the following data:—

a. Date and exact time of shot.
b. Weather and wind conditions.
c. Location of shot including elevations.
d. Holes: number, diameter, depth, spacing and depth of water if any.
e. Purpose of blast: eg, side hill cut to grade, through hill cut to first berm, etc.
f. Explosive: weight and description of each type, number and type of detonators, amount of detonating cord used, amount of explosive per hole.
g. Pattern including delays (diagram).
h. Type of initiation.
i. Source of power for electrical firing.
j. Description of material blasted.
k. Performance and final result of blast including any suggestions for modification or improvement.
l. Any injury or damage to property should be recorded either on the record sheet or attached to it.

**Plate 1.** Mixture of Ammonium Nitrate and Diesel being poured into a dry primary hole. Stick being used to measure depth of fill.

**Plate 2.** Ammonium Nitrate in protective polythene tube being loaded into wet primary hole.

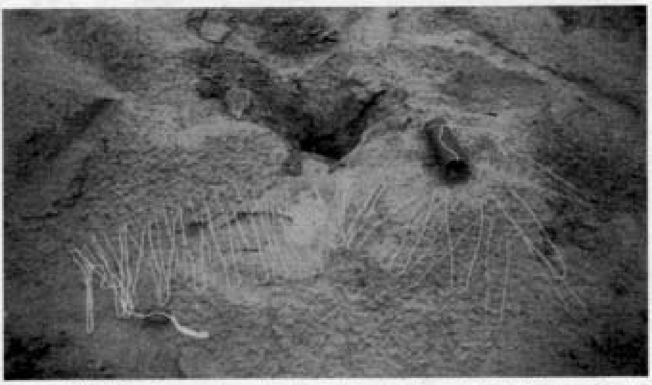


**Plate 3.** 1-lb high velocity primer with electric detonator inserted ready for lowering into primary hole. See Fig 1.

Control Blasting Techniques Used In Road Construction
2 & 3

**Plate 4.** 1-in diameter column of low density powder in 36-in cartridges with bayonet couplers. Two lengths shown with det cord attached. "Kleen Kut" by Atlas.

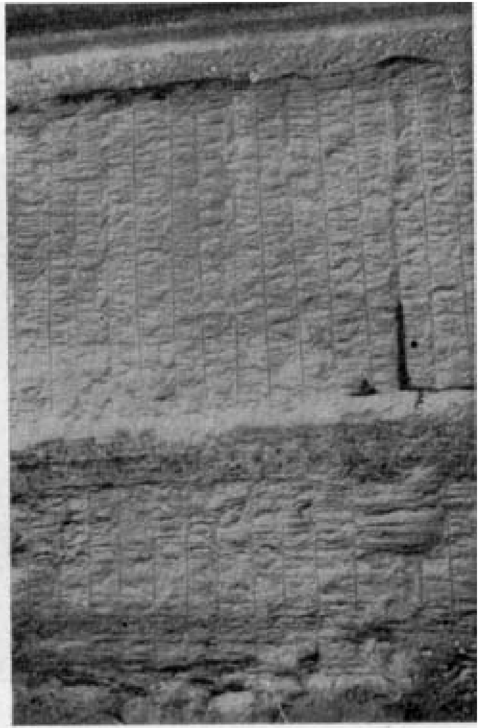


**Plate 5.** Example of good Pre-Splitting in hard limestone. Hole diameter $3\frac{1}{2}$ in, hole spacing 4ft.

Control Blasting Techniques Used In Road Construction 4 & 5

**Plate 6.** Foreground: Shows face left after primary blast with no control blasting techniques used.
Background: Top of photo shows face left by Pre-Splitting in the same rock.

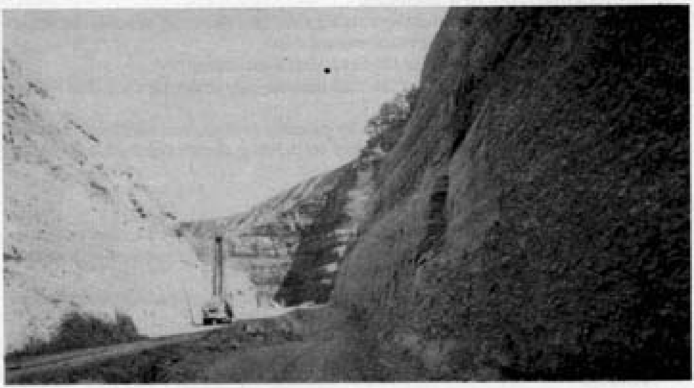
**Plate 7.** Scraper being used after blasting using Pre-Splitting. Note how it can work close to the rock face.

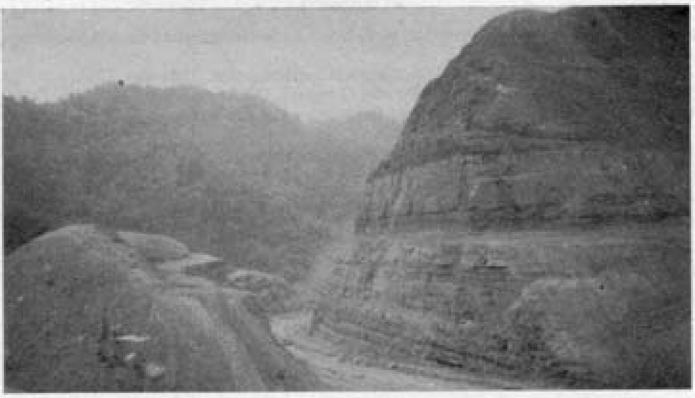
Control Blasting Techniques Used In Road Construction
6 & 7

**Plate 8.** Self-propelled crawler drilling rig seen here drilling 4½-in diameter primary holes. Pre-Split surface in background.

**Plate 9.** Small bore crawler drilling rig with accompanying air compressor to provide power.

Control Blasting Techniques Used In Road Construction
8 & 9





**Plates 10 and 11.** Examples of Pre-Split cuttings during the construction of Highway 15 at Carr Fork, Eastern Kentucky, USA.

Control Blasting Techniques Used In Road Construction
10 & 11

## CONCLUSION

*Advantages.* Control blasting in the form of pre-splitting has the following advantages:—

a. Reduces overbreak to a minimum.
b. Produces a neater, safer and more stable rock face than can be achieved otherwise, and therefore reduces maintenance costs.
c. No trimming up of the face is required after excavation.
d. Plant is able to work close to the wall immediately after the shot. See Photograph No. 7.
e. Reduces ground vibrations caused by primary charge, and so allows blasting operations to take place much closer to existing structures than was before possible.

*Difficulties and limitations*

a. It is nearly impossible to predict how a given strata will react to any combination of hole diameter, spacing and loading. It is therefore imperative that trial shots be conducted wherever possible.
b. The user must be flexible, ie, be prepared to modify the loading pattern as the rock strata changes.
c. To achieve maximum depth with one shot requires good drills and good drill operators. Poor alignment gives bad results, this is especially true for line drilling.
d. Both line drilling and pre-splitting take time and increase drilling costs, but this is usually offset by the advantages gained.

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2. Overbreak Control, by Atlas Chemical Industries, Inc., Delaware, USA.
3. Hercosplitting, by Hercules Powder Company, Delaware, USA.
4. US Corps of Engineers Specifications for Blasting and Pre-Splitting.

* * * * *

# Geodesy by Satellite

A review

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"Space will yield many things to man in the coming decade . . . He will use space as an observation post. Satellites will map the earth and keep track of ships, spot icebergs, locate vessels in distress, and make other aerial observations."

*National Aeronautics and Space Administration*

## INTRODUCTION

WITH the advent of orbiting satellites the earth became a base for exploring space—literally, a jumping-off place. But even with his head in the stars, man's feet must be on the ground. For success in space, exact knowledge is needed of the size, shape, and configuration of the earth—knowledge gained from geodetic and topographic surveys, and presented in the form of maps and charts. In a sense, topographic maps are an inventory of the physical features of the land surface, a historical record of man's achievements and a modern blueprint for future planning.

The Director of Military Survey has been collaborating in satellite geodesy in the U.S.A.; with the Department of Defense since 1963 and the Department of Commerce since 1966. This article aims to review the requirement for geodetic satellite survey systems, the methods used and in use, and the progress achieved. At the same time, it serves to record something of the role of 512 Specialist Team RE, a unit participating in the geodetic satellite survey programmes of U.S. Army Topographic Command (formerly Army Map Service) and the National Ocean Survey (formerly the Coast and Geodetic Survey).

## GEOPHYSICS

Geodesy is often thought of as a dark and forbidding area of study whereas it is merely a specialised application of many familiar facets of basic mathematical and physical principles. In simple terms, it is the science concerned with the precise positioning of points on the earth's surface, the determination of the exact size and shape of the earth and the study of the earth's gravity field. Geometric geodesy considers the size and shape of the earth, the location of geodetic control points on or near its surface and the location of its centre. Physical geodesy is concerned with the earth's gravitational field, inner structure, mass distribution and centre of mass. It would be impossible to determine the precise size and shape of the earth ignoring the orogenic and seismic forces which build mountains, form the seas and otherwise influence the earth's structure and dimensions. We are therefore concerned here with the study of geophysics.

## EARLY DEVELOPMENTS

Although a relatively unpublicised branch of science, geometric geodesy is by no means a new one. The speculation of the early Greeks ranged from the concept of the flat disc, advocated by Homer, to Pythagoras' sphere. Anaximenes believed that the earth was rectangular. The spherical shape became the most popular during the Greek era (the gods would create only a perfect figure). Efforts to determine its size followed. Plato guessed the circumference to be 40,000 miles while Archimedes estimated 30,000 miles. Meanwhile, Eratosthenes set out to make more explicit measurements and concluded that the circumference was 25,000 miles. The currently accepted value at the equator is 24,899 miles—a difference of only four-tenths of one percent.

Another ancient measurement of the circumference by Posidonius supported a value of 24,000 miles. A revision of Posidonius' value favoured a circumference of 18,000 miles. This was used by Ptolemy in his early world maps. It is probable that Columbus, using such maps, was thus led to believe Asia to be only three or four thousand miles west of Europe. During the 15th Century, Mercator made successive measurements of the size of the Mediterranean and all of Europe which had the effect of increasing the size of the earth.

The telescope, logarithmic tables and systematic triangulation were introduced during the 17th Century. Picard's measurement of a base line, continued by Cassini, revealed that one degree in the north was shorter than one in the south. This unexpected result could have emerged only if the earth was egg-shaped or from observational errors. An intense controversy ensued between French and English scientists, the English claiming the earth to be flattened (Newton's and Huygen's theory) while the French defended their convictions that it was egg-shaped.

In 1735, the French Academy of Sciences sent geodetic expeditions to Peru and to Lapland to measure the length of meridian degrees at those latitudes. The results proved conclusively that the earth was flattened. Since all computations involved in a geodetic survey are related to a mathematical surface resembling the shape of the earth, these findings were vitally important.

### PRESENT DAY REQUIREMENTS

In a global concept of navigation over long distances and through space, small errors in the assumed location of a launch site on the one hand, in relation to a desti-

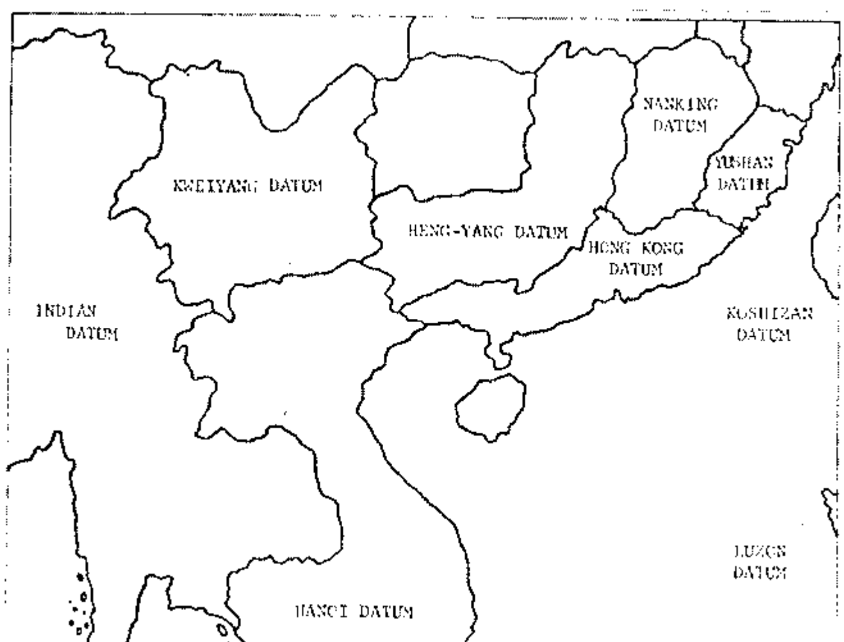



Fig 1.

Figure 1 illustrates the confusion that existed in Southeast Asia. Regardless of the accuracy of individual systems, and they are usually very accurate indeed, there was no reliable means of determining distance and direction between unconnected geodetic systems—certainly not to the accuracy required today.

nation on return to earth on the other, and in the influence exerted by gravity during launch, and in flight, can grow and magnify to an extent that will prevent the achievement of the intention. The questions where, how far and in which direction must be answered with exactness. Advanced instrumentation and data collection systems together with many other technological developments have given a new stimulus to geodesy, expanding its application.

In areas of overlapping geodetic triangulation networks, each computed on a different local assumption of the shape of the earth's surface, the co-ordinates of points given with respect to one shape and a datum on it will differ from those given for the same points with respect to the other.

The discrepancies, arising from the use of different assumed shapes or ellipsoids and the different degrees of deflection of the vertical that occur due to variations of gravity, result from shift and rotation between the systems and stretch in otherwise corresponding lines of geodetic networks. Vertical relationships are similarly inconsistent and equally important because space navigation is a 3-dimensional problem. Prior to World War II, all technically advanced nations had developed their own geodetic systems to satisfy economic and military needs. There was no recognized economic requirement at that time for common geodetic information and the use of common datums was considered contrary to the military interests of most countries.

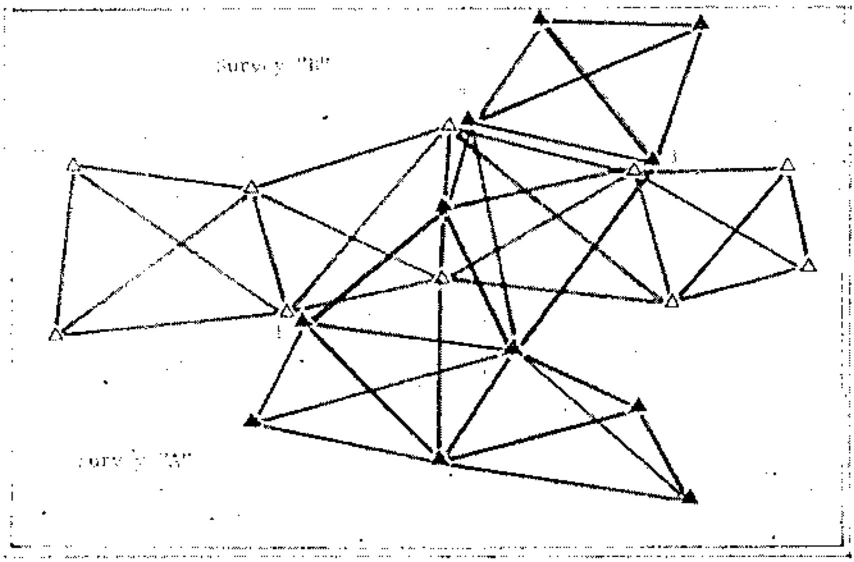



Fig 2.

The traditional process of connecting various datums by means of intermediate triangulation ties (Fig 2) generates errors that reveal themselves when newly observed data is introduced.

If such a system could be established, all of the major geodetic networks of the world could be unified; the coordinates of all points on major datums and many isolated islands on earth would be compatible.

For some areas of the world there still is little or no observed data—there has been no physical or economic requirement. For these areas, additional and new surveys are required. Large gaps will otherwise exist in the world network.

Four primary objectives emerged. Firstly, to create a worldwide reference network to which all geodetic and topographic data could be related thus providing a unique facility for the storage of collected data in a permanent and economical

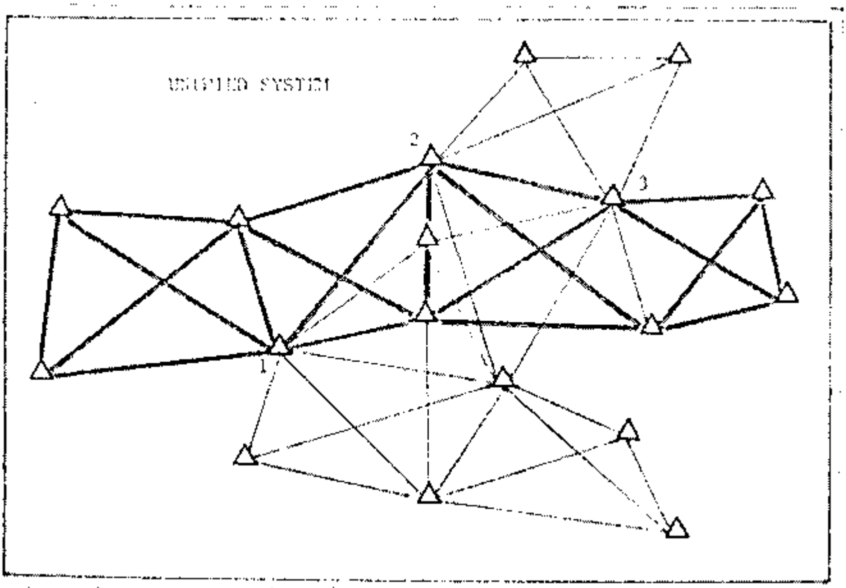
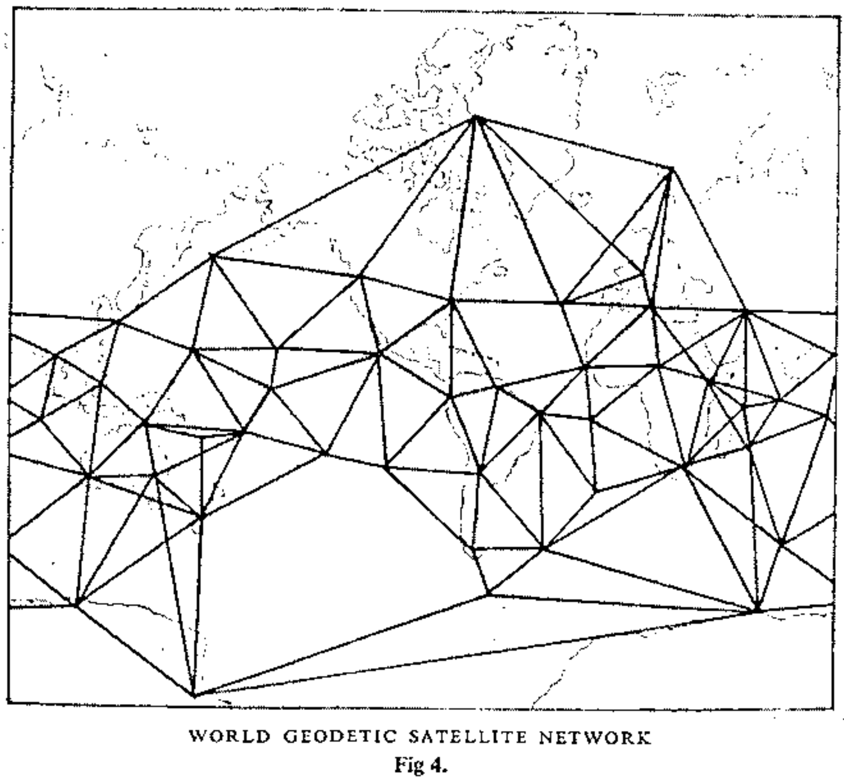



Fig 3.

The best solution was the establishment of preferred datums for large areas and the integration of contained systems by adjustment to the whole (Fig 3).



WORLD GEODETIC SATELLITE NETWORK

Fig 4.

Because of the failure of local or even preferred systems to provide inter-continental geodetic information, a unified world system became essential (Fig 4).

manner. Secondly, to overcome the classic time-consuming methods of triangulation, adversely influenced by gravity and inhibited by limited observation due to the curvature of the earth, and the extent of oceans. Thirdly, to eliminate discontinuities in map and survey systems over national frontiers. Lastly, to develop a system for the accurate determination of satellite orbits providing data suited to the analysis of gravimetric and related geophysical parameters, data essential for the determination of the position of the centre of mass and overall shape of the earth.

To the geodesist, geodesy is not an end in itself. Geodetic benefits are measured in terms of their value towards the progress of other achievements. Edward E. Hale, better known as the author of "The Man Without a Country" wrote in 1869 to the effect:

> "If from the surface of the earth we could shoot a pea upward and northward from Greenwich so fast and far that when its power of ascent was exhausted, and it began to fall, it should clear the earth, and pass outside the North Pole; if we had given it sufficient power to get half way round the earth without touching, that pea would clear the earth, forever, continuing to rotate above the North and South Poles and Greenwich, forever. If only we could see that pea as it revolved, then we could measure longitude, as soon as we knew the height of its orbit."

Hale had proposed the construction of an artificial satellite for reasons which are surprisingly modern. More important at the time was the need for a rocket capable of placing such a satellite in space.

## THE BREAKTHROUGH

The Chinese invented rockets in the 12th Century. Subsequent developments lead to the first serious consideration of establishing an earth satellite by Hermann Oberth and his group in Germany in the 1920's. In 1923 he proposed a manned space station to serve as an observatory. The German V-2 Ballistic rocket developed near the end of World War II had a range of 118 miles and reached a height of 50 miles. Thus, the practical feasibility of earth satellites advanced during the war with the development of large rockets and telemetric techniques. The possibility of collecting information in space without human observers and of returning it to earth by radio transmitter became a reality on 4th October 1957 when Russia launched her first Sputnik and on 31st January 1958 when the U.S.A. launched her first satellite, Explorer I.

The prospects for early connexions among major geodetic surveys were instantly brighter. The realisation of worldwide satellite triangulation was no longer a question of technical feasibility, but one depending ultimately on convincing the continuously expanding political world that the earth had shrunk technologically to such an extent as to require worldwide cooperation in order to enhance our geophysical knowledge.

The first U.S. satellite of geodetic significance was the Vanguard satellite, a 6-inch sphere. It was a sign of the times that the Navy put the great battleship Wisconsin into mothballs just one week prior to the launch of their Vanguard satellite. The tracking system for this first geodetic positioning project, was developed before Vanguard was conceived.

## ORBITAL CHARACTERISTICS

Before embarking on an explanation of tracking systems it is appropriate at this stage to consider orbital characteristics. When a satellite is launched away from the earth and into the air, except for the minor effect of atmosphere, it is free from the earth's rotation. As it goes higher in the atmosphere, where densities become very low, it is then truely free from the rotation of the earth. An earth orbiting satellite assumes an orbit at the end of its powered launch because of the influence of the earth's gravitational field. The satellite therefore sees the earth essentially as a point located at the centre of the earth, the geocentre. That centre of the earth must therefore lie in the plane of the satellite's orbit. This is significant for geophysical purposes.

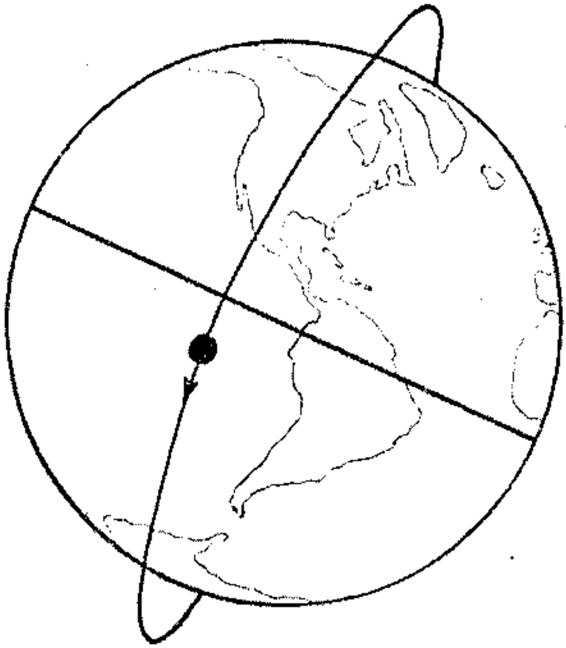


Fig 5.

If launched towards the south, once free from the earth's rotation the satellite would, at one time or another, pass over all locations on the earth. Such an orbit, a polar orbit, has obvious advantages for geometric purposes (Fig 5).

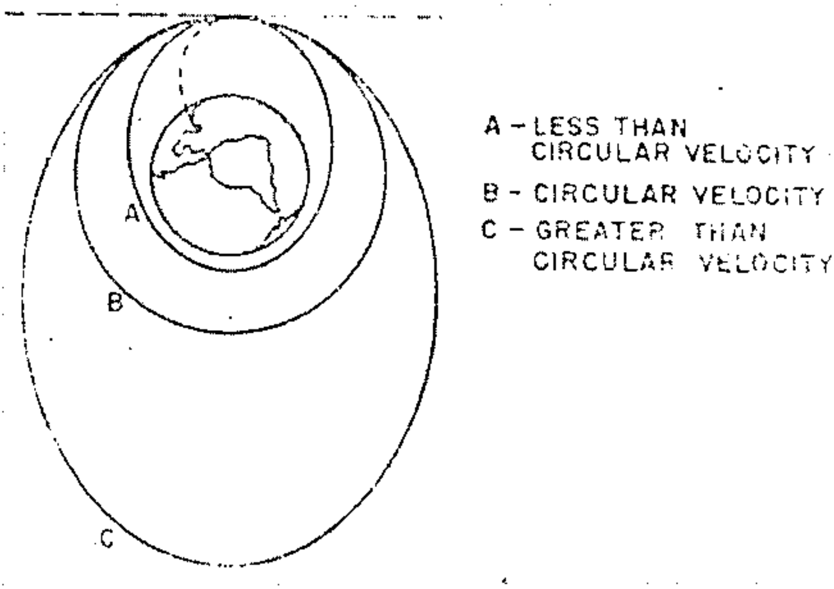



Fig 6.

Most orbits are eliptical in shape, rather than circular. If a satellite is launched at a certain angle with exact velocity it can be put in a circular orbit (Fig 6B).

However, extra velocity for safety's sake, will introduce an eliptical shape exterior to the circle (Fig 6C). Such a safety measure is normally provided. If the rocket is below specified performance and the velocity less than that required for a circular orbit, it would again be an elipse but of smaller magnitude and inside the circle (Fig 6A). It is thus possible to predetermine the proximity of the satellite to the earth's surface for a wide range of geometric observational purposes.

The period of the rotation of a satellite around the earth in its orbit is a function of the size of the orbit. For a circle it's a function of the semi-major axis. If there were no atmosphere and no mountains, a satellite launched along the earth's surface would have a period of about 83 or 84 minutes. As the altitude above the earth increases the period increases to the three halves power of the semi-major axis. For example, at an altitude of 250 miles the period is 90 minutes.

If the orbit is made big enough and, for instance, the altitude is 22,500 miles, the period extends to one day in which case a satellite launched in such a circular orbit eastward from the Equator would remain over the point on the earth at which it reached an altitude of 22,500 miles and for an indefinite period; in a synchronous orbit. Launched at a latitude other than the Equator, the satellite would move approximately up and down the same meridian of longitude in one day and remain indefinitely over that meridian. Thus, the position of a satellite in relation to points on the earth's surface can be controlled to suit the instrumentation in use for tracking and the direction from which observations are to be made.

In order to relate the positions of known and unknown points on the ground using a satellite the first requirement is knowledge of the satellite's speed, direction, elevation and the influences acting on the satellite. In short, the satellite's unique orbital characteristics. This data is obtained by observing the satellite from known points and computing its behavior; a pattern of orbital elements will emerge. In the early days of Vanguard such observations were undertaken by "Moonwatchers" positioned around the world with telescopes and astronomical instruments. Telemetric developments have long since provided much more convenient and precise methods for the acquisition of accurate orbital data, and more rapidly.

With knowledge of the relative positions of known points on the earth's surface together with firm parameters for the satellite, it is possible to arrange simultaneous observations from unknown points and solve for position from the known geometry. Therefore, there are two main reasons for tracking for geodetic purposes: To determine orbital parameters and subsequently, relative or absolute positions on the earth's surface.

## SATELLITE TRACKING

Tracking systems used and in use fall into two general categories: Optical and radio.

| *System* | *Technique* |
| --- | --- |
| Baker Nunn & Schmid | Direction (Optical) |
| PC 1000 | Direction (Optical) |
| BC-4 | Direction (Optical) |
| TRANET | Range rate (Radio) |
| SECOR | Phase shift (Radio) |
| ITT 5500 (Doppler) | Range difference (Radio) |
| Geoceiver (Doppler) | Range difference (Radio) |

The PC 1000 stellar camera system, operated by the U.S. Air Force to provide precise directions to objects in space, was used for the calibration of tracking equipment and for establishing geodetic control. The technique is similar to the BC-4 used during the PAGEOS Primary Geometric Network programme, a description of which follows.

In 1966, a camera system developed and proved in the field by the Coast and Geodetic Survey was selected to accomplish a primary world geometric network consisting of approximately 40 stations to obtain geodetic control required by the

Department of Defense. The task was assigned jointly to United States Army Map Service (now U.S. Army Topographic Command) and United States Coast and Geodetic Survey (now U.S. National Ocean Survey).

The observing programme, started in June 1966 and concluded in 1970, involved the occupation of the stations listed at Annex A. When analysis of data has been completed in 1972, the network illustrated at Figure 4 will provide a three-dimensional reference system independent of both the direction and magnitude of the force of gravity. To this all geodetic, topographic and navigational data could subsequently be related on a global basis (to an origin which coincides with the centre of mass of the earth and with axes coinciding with the earth's rotational axis) if absolute

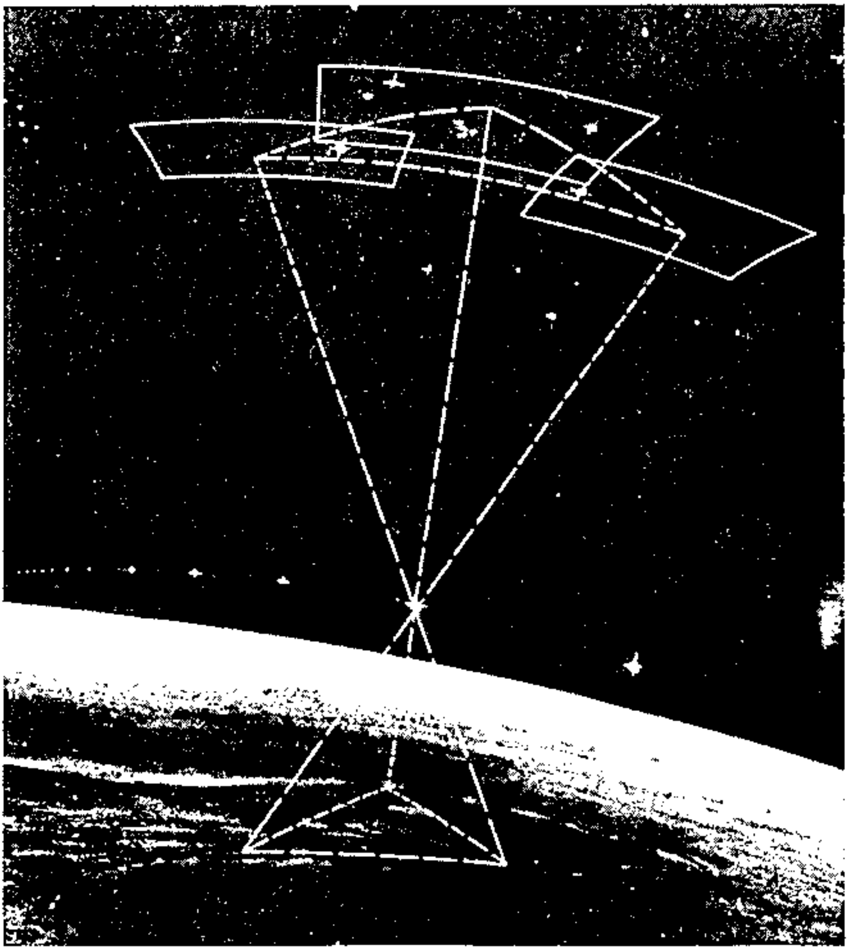


Plate 1.

Use of star background for trajectory measurements of shells and small rockets.

## USE OF STARS

The use of the star background for orienting cameras in connexion with the triangulation of auxiliary target points was applied for the first time during the 1930's by Hoppman and Lohman in Germany for trajectory measurements of shells and small rockets.

positions (Doppler) and azimuth or direction (BC-4) can both be determined at every station occupied.

The principle of the system is the geometric triangulation of selected non-intervisible points on the physical surface of the earth by a process of spatial triangulation using a satellite target sufficiently elevated above the surface of the earth. By photographing the satellite simultaneously from two or more stations (Plate 1) against a background of stars and by using photogrammetry as a tool of interpolation, precise direction measurements can be carried out despite the motion of the satellite. The reference system into which the direction to a satellite can be interpolated is the right ascension declination system of which one axis is conveniently parallel to the rotational axis of the earth. Stars of magnitude 8 and 9 are easily identified on the glass plate photographic image. Since stars are for all practical purposes at infinity their direction co-ordinates cannot be used for any scale determination. As will be seen, scale can be provided by the radio systems and, of course, by precise measurements on the surface of the earth.

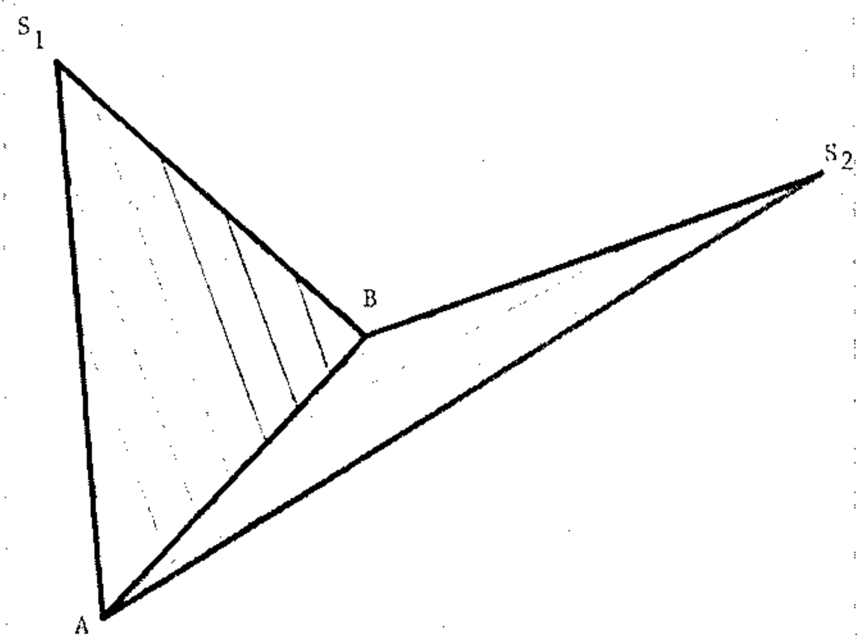



Figure 7

Professor Vaisala, Finland, suggested the same principle in 1946 reasoning that two conjugate rays emerging from the end points of a base line define a plane in space whose spatial orientation can be computed from the measured direction cosines of the two rays. If, as in Fig 7, two such planes $AS_1B$ and $AS_2B$ containing a common base line A-B are observed, the direction of the base line can be computed as the line in which the two planes intersect.

BALLISTIC CAMERA OPTICAL SYSTEM

*The BC-4 System*

The system consists of the passive geodetic earth orbiting satellite PAGEOS, stellar camera theodolites, station clocks and electronic synchronization between stations.

The satellite, PAGEOS (Plate 2), is a 100-foot diameter aluminumised mylar inflatable sphere with a highly reflecting surface which is launched as a package and inflated when in the required orbit. The resulting satellite has no integrated equipment.

The BC-4 (Ballistic Camera), specially designed for the programme, is a modified Wild RC-5 aerial camera fitted with a 450 mm focal length Astrotar lens and a modified left-hand trunnion pivot carrying a vertical circle and split-bubble vertical collimation mark. The camera (Plate 3) is mounted on a modified Wild T-4 astronomical theodolite base. In order to code the images or trails of both reference stars and satellite for subsequent measurement and analysis, three rotating discs are incorporated between the lenses to chop the trails. Two of these are high-speed counter-rotating exposure shutters producing exposures of 1/60, 1/30 and 1/15 of a second. The third disc or capping shutter, is synchronised to the exposure discs to reduce the exposure rate by ratios of 2 or 5. Further exposure rate reduction and coding can be accomplished using an auxiliary iris-type capping shutter in front of the camera lens (Plate 6). The rotating shutters and shutter mechanism are shown in Plate 3.

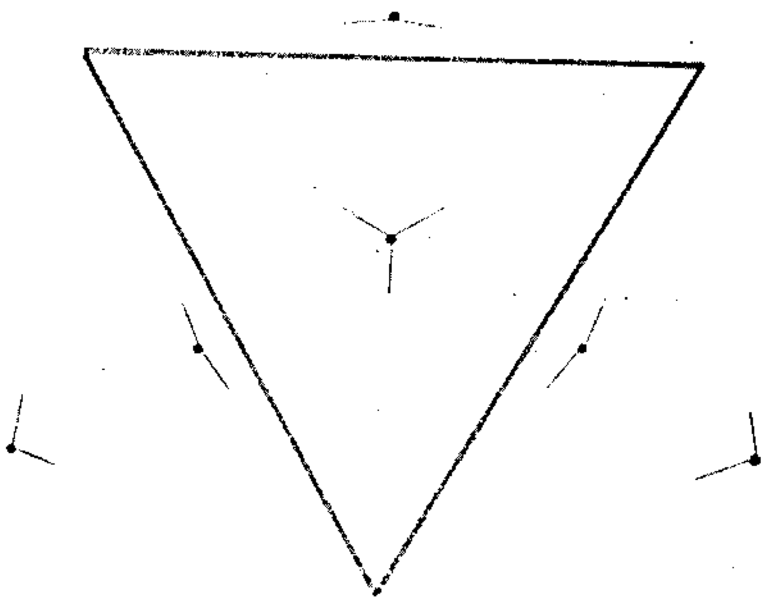


Fig 8.

In actual practice, a redundancy of observations is obtained by observing the satellite at many more positions than shown in Figure 7. It is desirable to obtain at least three planes intersecting along each baseline of the triangle. The desirable arrangement is illustrated in plan view in Figure 8, where one three station event occurs over centre of the triangle and an additional two station event over each line. The three station event provides geometrical strength. Three two-station events, however, are acceptable.

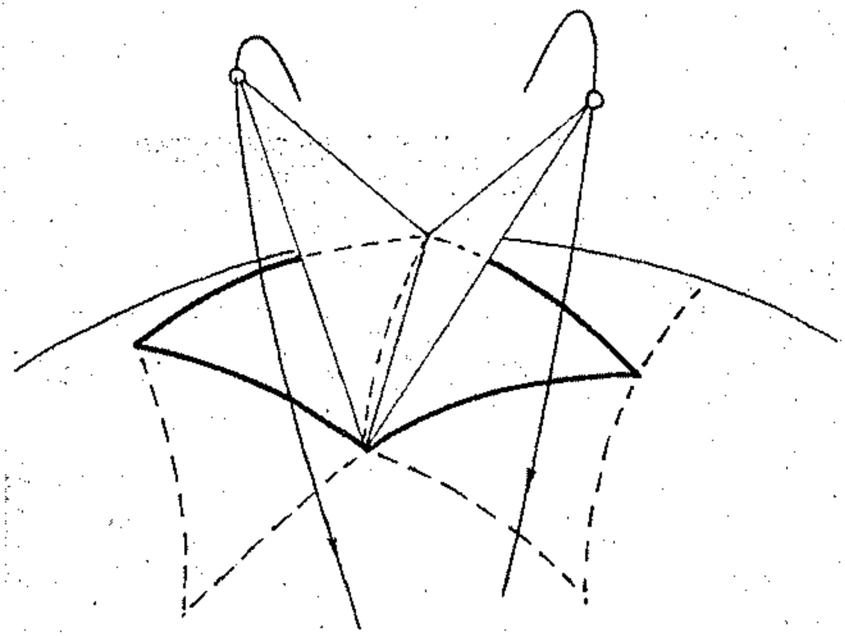


Fig 9.

The geometry of the spatial model must satisfy certain conditions: Firstly, the lines of sight to the satellite should be at least 30° above the horizon to avoid refraction anomalies, secondly, the angles subtended by each pair of planes should be at least 60° to provide geometrical strength and thirdly, the distance to the satellite should be roughly the same as the length of the base line separating the observing stations to avoid scale degradation. These conditions call for as much symmetry as possible with regard to the locations of the observing stations as is illustrated in Figure 9.

*Timing*

During tracking, synchronisation between disc-type shutters and time is essential in order, subsequently, to relate star trail and satellite trail images. The use of passive satellites imposes stringent timing requirements. Relative timing of the chopping shutters is maintained within $\pm$ 150 microseconds which for all practical purposes, eliminates time error. During simultaneous observations of the satellite from widely separated camera stations, shutter mid-opening times must be known to a common time standard (not necessarily with respect to a standard time) in order to represent homogeneous raw data for spatial triangulation. For star trail observations carried out before and after the satellite is tracked (for the determination of the orientation of the camera during the entire observational period) timing requirements are less demanding. For this purpose it is necessary to know shutter times to about $\pm$0·05 seconds with respect to universal time.

Timing is achieved using a master clock, a portable clock and a station clock. The master clock used as a common time standard is a highly stable quartz crystal oscillator maintained by the National Bureau of Standards.

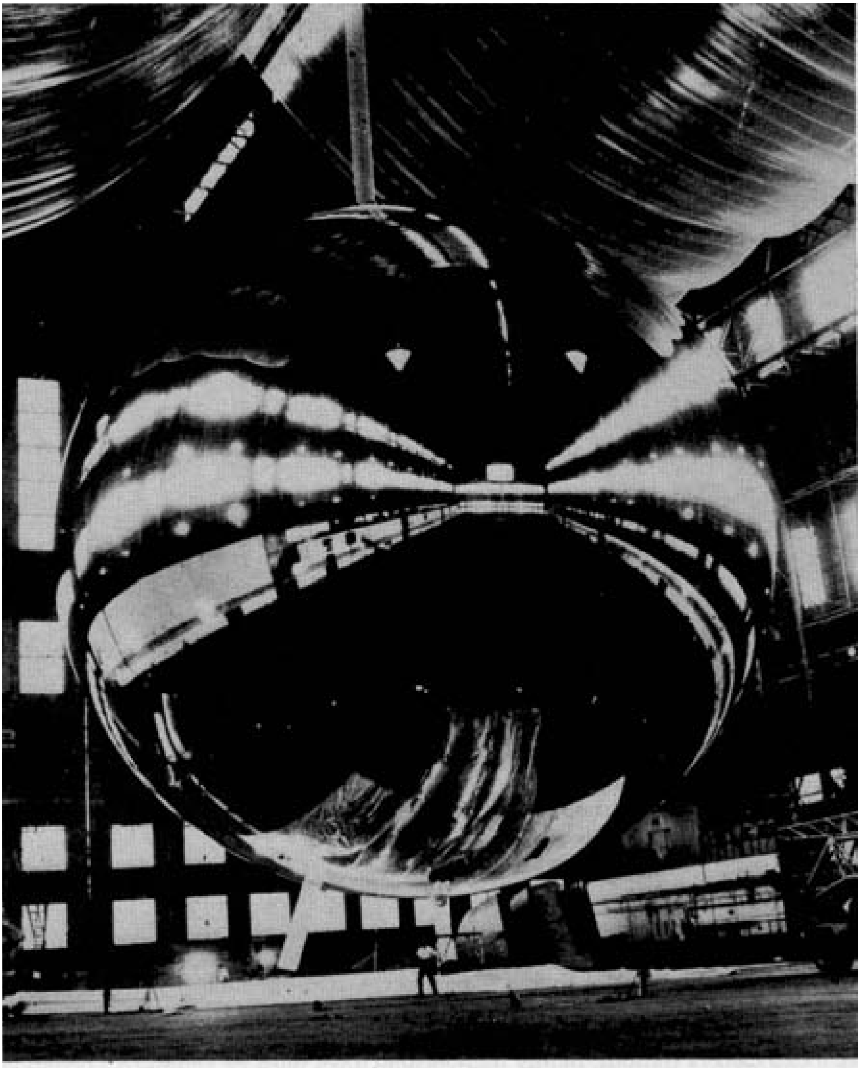


**Plate 2.**

A portable crystal clock is used to transport time from the master to each station clock. To check the performance of the portable clock it is synchronized to the master clock before departure and checked immediately on return from the field station. Experience has shown an uncertainty of less than ±10 microseconds after a five-day absence. The station clocks can therefore be set to within ±10 microseconds of the master clock. Exceptionally, station clocks have been set from LORAN-C, or via synchronous timing satellites or by doppler satellite time signals.

Each station clock has a time-code generator deriving 100 kilocycle-per-second frequency from a precise crystal oscillator manufactured to the same specifications as the portable clock. The performance of the oscillator and corresponding time corrections could conceivably be calculated from the results of daily or weekly comparisons but this is impracticable. Instead, very low frequency (VLF) transmissions provide a practical and accurate method for the determination of day-to-day variations.

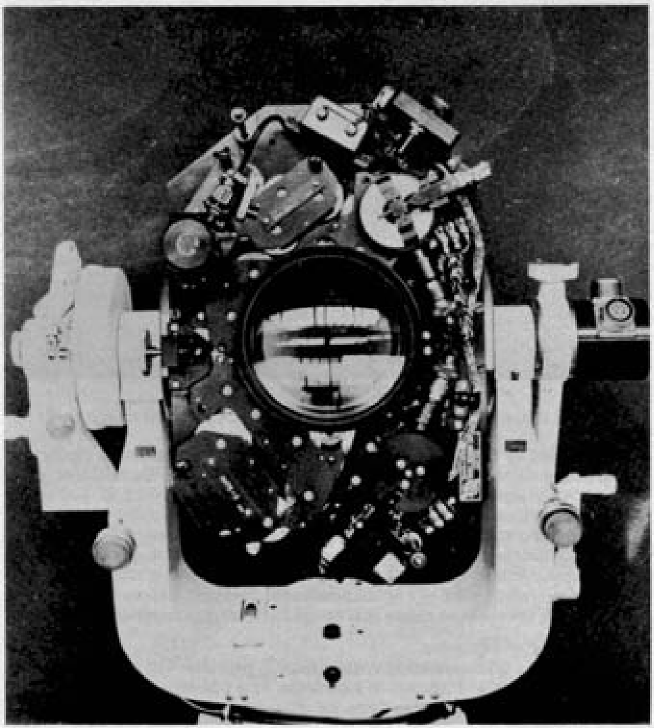


**Plate 3.**

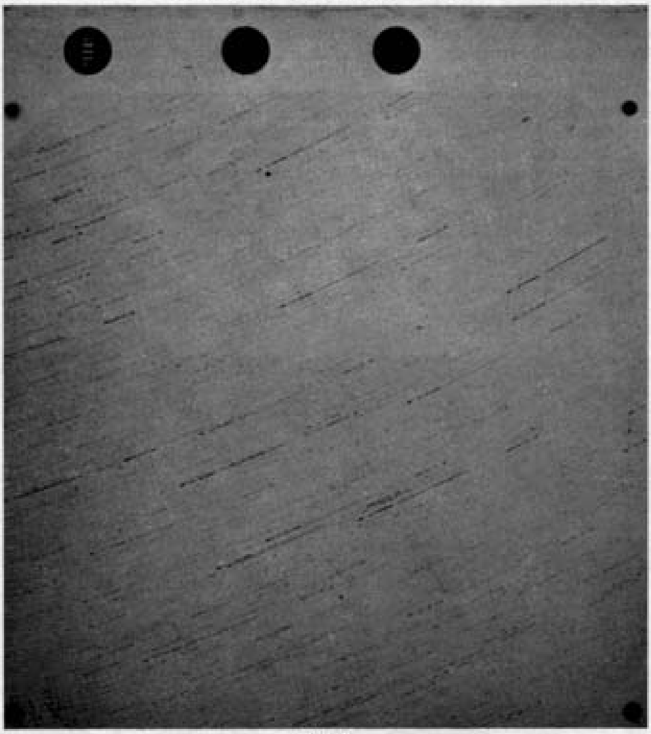


**Plate 4.**

A typical exposed positive plate showing chopped star and satellite trails is shown

Jitter caused by small mechanical and electronic disturbances in the shutter gear system causes slight variations in the actual intervals between the reference pulses supplied by the station clock to the camera. Jitter varies from ±20 to ±40 microseconds. The amount of jitter can be monitored on a oscilloscope during observations.

Thus, the uncertainties of timing are: ±10 microseconds when starting a station clock, ±40 microseconds of accumulated variation in day-to-day records, and ±100 microseconds in the jitter of the shutter mechanism. The total uncertainties are therefore better than ±150 microseconds. Periodic comparisons with the portable clock are made to ensure that acceptable timing is maintained at stations.

*Synchronization of Exposures*

The electronic synchronization system (Plate 5) provides: For corrections to the time-code generator with respect to a common time standard; synchronization of disc shutters with timing pulses from the time-code generator; programming of camera operations on punched tape; controlling both discs and auxiliary capping shutter; exposing fiducial marks and camera information and for the production of a detailed record of the observing programme on a ten-channel paper recording tape.

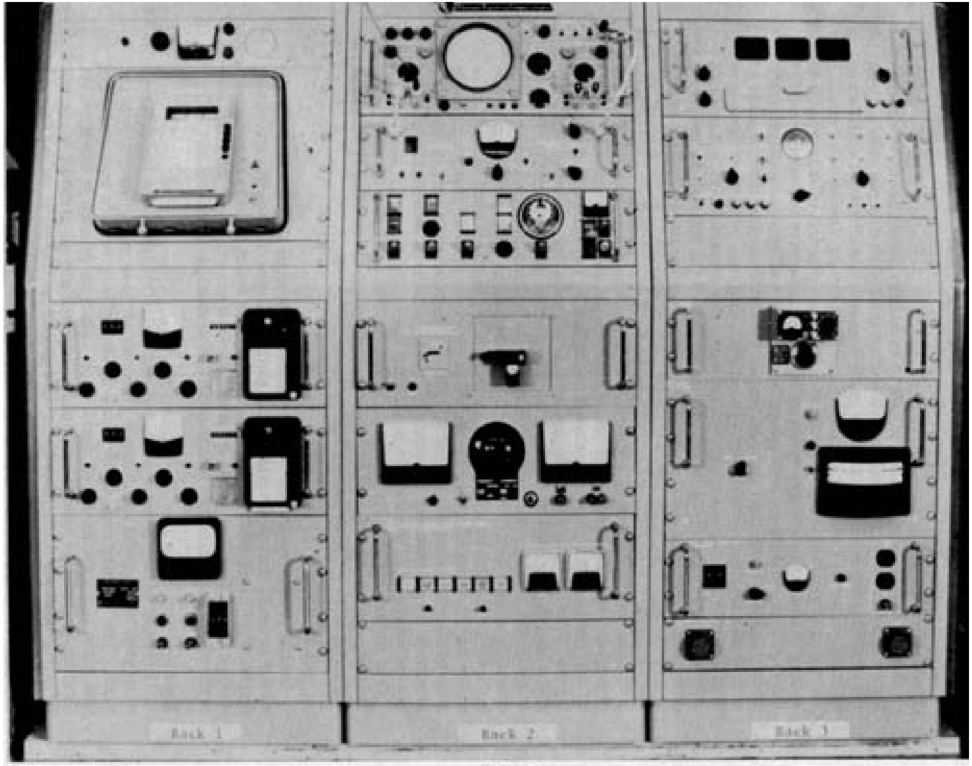



**Plate 5.**

The required disc-shutter rate for a particular satellite pass is established electronically in the synchronization system and mechanically in the camera.

*Aiming the Camera*

Orientation of the camera in azimuth prior to observing is achieved by sighting through a principal point eyepiece to an azimuth light. Predicted azimuth and elevation settings are made to within about 10 seconds of arc.

*Synchronization Between Stations*

Due to the finite time required for light to travel from the satellite to each observing camera, the image recorded on each photographic plate does not coincide with the corresponding satellite position in space. For each 300 kilometers difference in slant range there is 1 millisecond difference in image timing. During data reduction the mid-open position timings are adjusted. It is of no practical value to attempt to arrange precisely synchronous mid-openings on all cameras or to attempt to offset the local time standards by anticipating the travel time of light to each station. The essential consideration is to know accurately the correction that must be made to each shutter mid-open time to achieve a common time base. After corrections have been applied to the satellite image measurements, time-correlated least square fitted polynominals are computed for approximately 600 of the 800 satellite images on each plate. Also shown are approximately 1000 usable star images for reference.

*The Equipment*

The camera is housed in a 6-foot, 6-inch diameter astrodome (Plate 6) for protection from wind and weather during observations, and from the heat of the sun by day. Anticipated night temperature is maintained by day using an air-conditioning unit. Thermal expansion in the camera and pedestal is thus minimized. Additionally, a dehumidifier protects the camera from corrosion by high humidity. The base of the camera is secured but not constrained to the pedestal, itself on a concrete pier extending several feet into the ground. The astrodome floor provides complete isolation for the camera's supporting pedestal. The pedestal is filled with water (or with a mixture containing anti-freeze) which resists temperature changes and adds mass to absorb external shocks and vibrations. Operators avoid the vicinity of the camera during observations. The electronic synchronization system console is housed in a mobile shelter 12 feet long, 7 feet wide and 7 feet high.

The shelter also provides limited darkroom facilities and space for small stores including spare parts. It is also mobile on its own trailer, can be lifted by helicopter and transported by all air and surface methods.

*Predictions*

Orbital predictions for the satellite contain look-angle data for each camera station in terms of azimuths from north, elevation angles, slant ranges and orbital heights. Predictions are transmitted to the field in a coded format consisting of 9 six-digit words. Predicted data is updated for greater accuracy using the actual time of satellite passage at stations for the correction of subsequent predictions.

*Results*

The results of field observations are transmitted by teletype to the Headquarters where plots of successful simultaneous observations can be made. The quality of the star and satellite images and of the prescribed shutter programme is examined in the field where plates are developed. Small errors cannot be detected at this stage. At Headquarters, all field records are critically inspected and plates carefully checked for overall quality and adherence to standard procedures. The plates are re-evaluated on a monocomparator on which images are ultimately measured.

*Reduction of Data*

Data reduction begins with the photographic plate and shutter timing records.

Plate 6.

The solution of the triangulation problem proceeds in three stages: First, camera calibration and orientation are determined for each photograph by measurement of the co-ordinates of numerous star images in known positions; secondly, many satellite images are related to the plate co-ordinates and thirdly, a network of satellite observations involving several fixed camera orientations at each of several camera stations is adjusted in such a way that individual camera station positions are determined by minimizing the sum of the squares of the plate co-ordinate residuals of corresponding satellite images.

The reduction process requires meticulous plate measurement and a number of special computer programmes. Atmospheric refraction, diurnal abberation, temperature and atmospheric pressure are a few of the corrections applied. The comparators, with high quality optical systems and linear magnifications up to 40 times plate scale, are operated in a controlled environment where temperature is specified to $\pm\frac{1}{2}^{\circ}$ centigrade and relative humidity to $\pm 5$ percent. A standard error of measurement within the range 0·7 and 1·3 microns is maintained. Total measurements on each photographic plate exceed 3,500 in order to obtain the optimum possible assurance with regard to errors and for statistical reasons. The measurement of one plate takes approximately 40 man hours.

*Accuracy*

Ignoring the possibility that some insufficiently resolved bias errors may still exist, the accuracy of the final direction to the satellite should be about $\pm 0{\cdot}3$ seconds of arc.

*Scale*

As already mentioned, scale must be obtained separately. It can be applied by measuring the distance between two stations, also by introducing the co-ordinates of two or more ground stations with appropriate weighting. Scale has been provided also from data acquired using the radio systems at selected sites previously occupied by BC-4 systems. Five transcontinental geodimeter traverses for scale, in which the standard error does not exceed one part per million, have been completed on four Continents.

## RADIO SYSTEMS

*Doppler Effect*

When an express train moving at high speed passes an observer on a station platform he will note a sudden fall in the pitch of the noise.

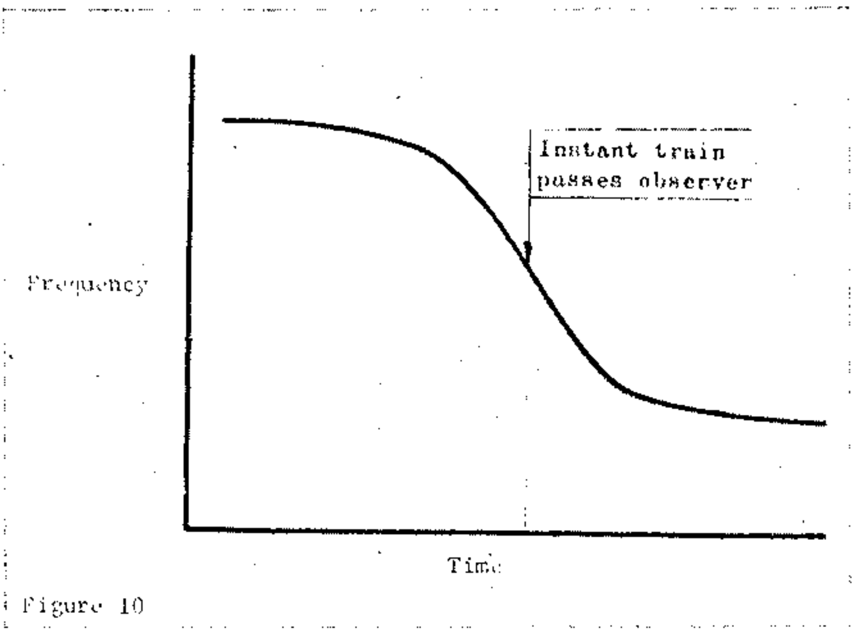



**Fig 10.**

Alternatively, imagine a gunner in an aircraft firing at a stationary ground target. As the aircraft moves towards a point over the target (the gunner firing at a constant rate) more hits per second than the actual rate of fire will be registered due to the velocity of the aircraft. The number of hits per second diminishes until the precise instant when the aircraft passes over the target. Then the same number of hits as the rate of fire are registered. As the aircraft recedes (the gunner shooting back towards the target) the hits per second continue to diminish. In each case the frequency of the source is constant. The Austrian physicist Christian Doppler (1803–1853) was the first person successfully to explain the relationships involved. As a result, we use the term Doppler effect meaning the relationship between velocity and rate of change of range to a stationary object as described above using acoustical and mechanical analogies.

Substituting a satellite radio transmission for the aircraft gunner and a receiver in a tracking station for the target, a Doppler shift was observed in a transmitted signal emitted by Russia's Sputnik I in 1957. The same relationship which exists between the frequency shift of radio signals emitted by a satellite and the rate of change of range to the satellite can be expressed mathematically.

The U.S. Navy radio Doppler Tracking Network (TRANET) system consists of a linked network of Doppler-data acquisition stations around the world, a Control Centre for the receipt and analysis of data and for the operational control of the system.

There are sources of error inherent in Doppler systems, and in reduction techniques, which influence the overall accuracy of the geodetic result. For instance, in reduction techniques, there is error due to inadequate modelling of orbital dynamics and refraction, and timing noise associated with the Doppler receiver system. Steps are taken to minimise the modelling error. In the case of refraction the Doppler shift is measured on radio waves of different frequency. Two frequencies, each emitting a coherent harmonic, can be combined to produce a corrected single frequency of a type that would have been received had little or no refraction taken place. Errors due to tropospheric refraction (local atmospherics) are modeled from weather information submitted by the tracking stations.

It is possible to determine the satellite's position in space from data received at six tracking stations of known position without knowledge of the dynamic orbital characteristics. The TRANET system acquires Doppler data from a worldwide tracking network for the determination of the satellite's orbit. Orbital data based upon refined earth models, predicted ahead of time, is injected into the navigational satellites. A tracking station of unknown position can thus be located by interrogating the satellite. Hence, by using the earth's centre of mass as a point of reference for ground positions occupied by tracking stations it is possible to establish a world geodetic datum. As more tracking stations are taken into use and more data becomes available, the datum can be refined, also the earth's gravity field.

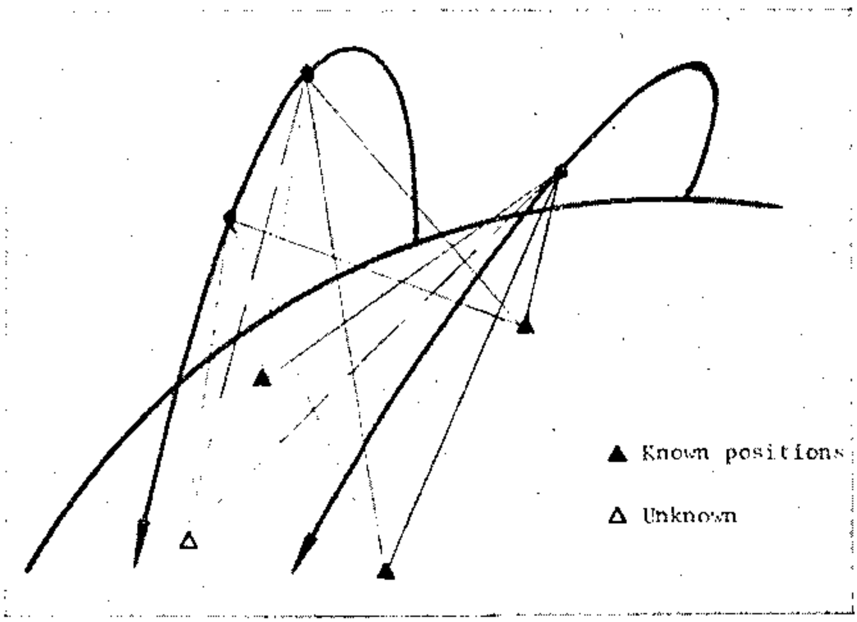



Fig 11.

The system provides data for an accurate mathematical description of the earth's gravity potential and for the determination of "earth centre-of-mass coordinates" for selected observation sites; positions of ships at sea, aircraft in the air and stations on the ground.

*SECOR*

Another radio system known as SECOR uses a technique involving sequential collation of range (Fig 11). Each of three ground stations transmits in sequence a phase modulated signal which is received by a transponder in the satellite and repeated back to the ground station on an offset carrier wave (Fig 12).

The phase shift, which is a function of the wave frequency and the distance travelled, is measured at the ground station to produce range. Example:

An electromagnetic wave travelling 15,000,000 metres (9,300 miles) at 300,000,000 metres per second is phase delayed by 0·050 seconds. One wavelength is 360°. The distance the signal has travelled may thus be represented as a function of the degrees of phase shift.

If the interrogation of the mobile satellite from several stations was simultaneous, that is, to achieve data at one position and at one time, there would be interference. The satellite must therefore be interrogated sequentially. The cycle is of 50 milliseconds duration in four 10-millisecond zones each separated by 2·5 milliseconds.

Any combination of station transmission times could occur during a satellite pass. The important factor is the signal arrival time.

Both systems are susceptible to inherent random errors due to ionospheric and tropospheric refraction. As will be seen, such errors can be minimized for all practical purposes. On the credit side, both systems are free from the severe limitations adversely affecting the optical systems; namely, weather, visibility and thermal conditions.

The SECOR system, taken into operational use in late 1964, was the U.S. Army's

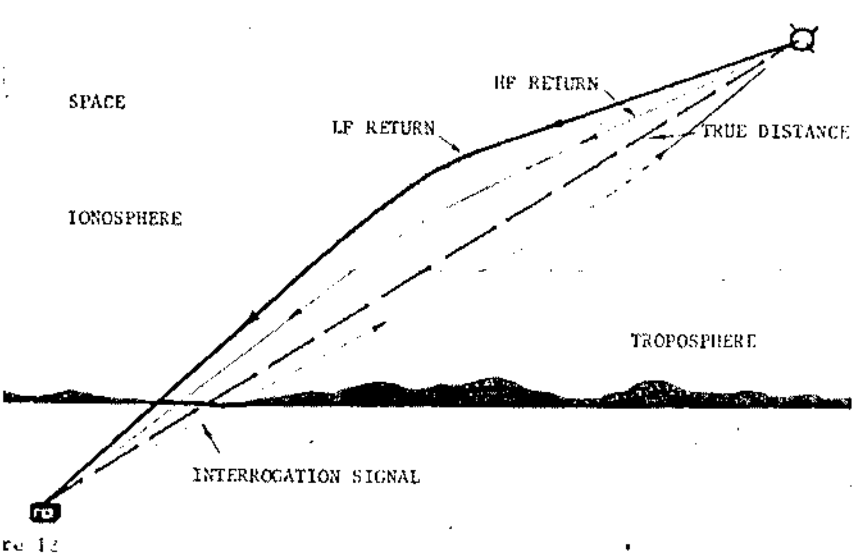



Fig 12.

first major effort in satellite geodesy. Using an all-weather electronic ranging technique to derive the position of an unknown station from the measurement of the distances between the satellite and four ground stations, three of which are known positions. A tie was established, in December 1964 between the Tokyo, Australian and North American datums. An equatorial network of satellite triangulation between 40 stations was accomplished between 1967 and 1970.

The final adjustment of the network must await the introduction of directional constraints to be derived from the analysis of the BC-4 worldwide network. In a complementary sense, the SECOR network is providing baselines and scale for the BC-4 project. A combination of the results of both programmes is providing precise geodetic connexions between all the major datums of military interest, also an improved determination of the size of the earth, and thus the length of the semi-major axis of the ellipsoid used for geodesy and mapping and missile trajectories.

The Army SECOR, Air Force PC 1000 and National Ocean Survey BC-4 systems have recently been phased out for Department of Defense purposes in preference for the Navy's Doppler system. Although a technique of earlier vintage, and in use continuously for navigational purposes, the development of Doppler equipment capable of meeting geodetic standards of accuracy is a more recent achievement. Moreover, there are inherent operational and logistical advantages over the SECOR, PC 1000 and BC-4 systems:

Simultaneous or sequential observations demanding exact timing correlation are no longer necessary; one station, the unknown, is sufficient using Doppler as a positioning device but accuracy is improved using two stations simultaneously in the translocation mode.

No tracking station-to-satellite communications are necessary; signals are emitted by the satellite.

The volume of weight of the equipment and the manpower needed for its operation have been reduced from 4500 cubic feet, 39,000 lbs and 6 to 8 operators to approximately 14 cubic feet, 200 lbs and 2 or 3 operators, respectively, as a result of technological development and miniaturisation during the past 12 years. Modern Doppler equipment is truely portable and mobile.

The system is based on radio Doppler measurements of the relative velocity between the transmitter and the observer. One of the satellites in orbit (normally four) can be observed within 45 minutes from any point on the earth's surface. Interrogation of more than one satellite accelerates the data acquisition process. Doppler measurements combined with known orbital data are used to compute the observing station position in terms of geocentric coordinate values directly related to the earth's centre of mass. There are two modes of operation: Firstly, for single point positioning to position a point with respect to an earth centred coordinate system. This is accomplished by observing 30 to 60 satellite passes together with the satellite's time history or ephemeris determined by the TRANET Network. Secondly, in the translocation mode for the determination of the relative distance between two receivers using simultaneous observations during approximately 60 passes. In the translocation mode, any satellite ephemeral errors will hopefully affect observations at both stations to the same degree. Tests continue.

Positions subsequently computed relative to each other will in consequence be more accurate than their single point positions. In either mode the observation of 60 passes can be completed in about two weeks compared with about nine months occupation of the average SECOR or BC-4 Station. A simple fix of lesser accuracy can be undertaken in a few days, a navigational type fix to within a tenth of a nautical mile on one satellite pass in minutes.

The geoceiver system employs two dual frequency receiver channels so that either of two satellite frequency pairs can be received. Ionospheric refraction error is corrected by measuring the difference in phase coherency between two phase coherent signals transmitted by the satellite. The number of cycles of the Doppler signal are measured continuously. Timing signals are obtained from the satellite for the

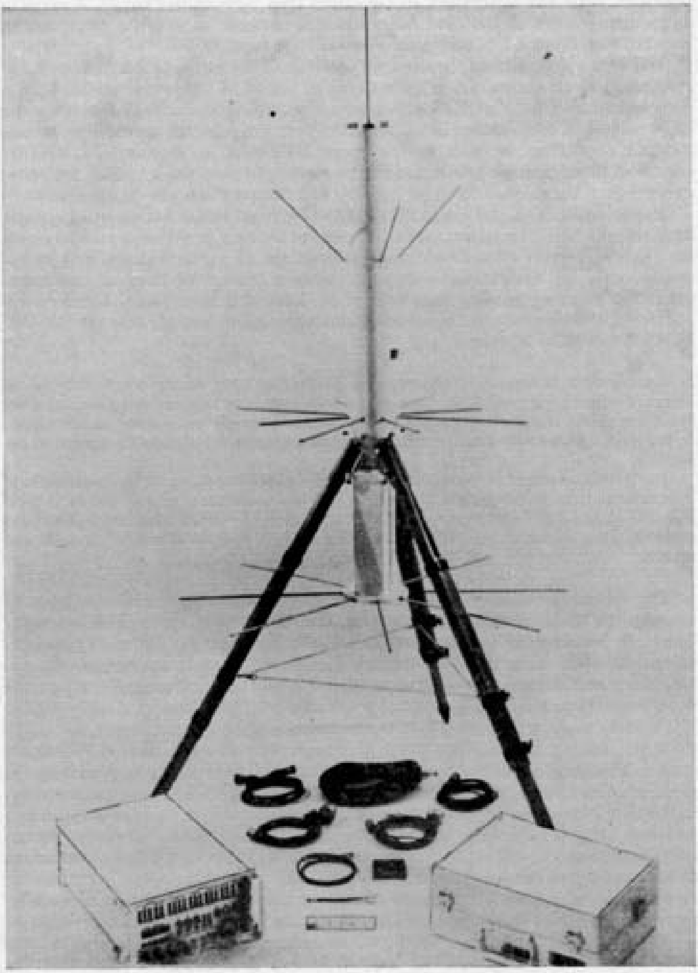


**Plate 7.**

The Doppler system being adopted for geodetic purposes in support of Department of Defense programmes is the commercially manufactured Geoceiver (Plate 7).

calibration of an internal clock in the observing station's equipment. The output data for each satellite pass is in three parts punched on teletype tape: The header, a set of data points and the trailer. The data points consist of time, Doppler count and refraction count. The trailer provides for local weather conditions for use in subsequent correction for tropospheric errors and for other miscellaneous data concerning operations.

The equipment can be moved easily in commercial transport. Site requirements are:

A clear optical horizon above 10° elevation in all directions from the antenna normally 100 to 200 ft away from the receiving equipment.

An area free of radio transmissions on receiving frequencies or subharmonics of 150, 162, 324 and 400 MHz, and of background radio and electrical noise sources such as vehicle ignition, high voltage transmission power lines, high power transmitting equipment, etc.

Electric power of 500 watts, 50 to 400 cycles and 110 to 220 volts AC is required. Alternatively, 24 to 32 volts DC may be used.

Observations made in response to predictions notified to the observing station produce Doppler measurements and refraction data on paper tape for transmission by teletype systems to the Base location. Data received at the Base location is reduced and analysed to provide position coordinates to an accuracy better than 10 meters.

The Geoceiver measures two quantities: The integrated Doppler count meaning the number of whole cycles of beat frequency during an interval; and the time of the zero crossing of the last cycle. Provided each cycle crossing is counted, spurious crossings omitted, the count should be error free. Thus, in principle, all of the error in Geoceiver observations can be attributed to the error in the timing. In practise, however, some cycle counts elude detection. Although a nuisance, it is possible to detect and remove them so that they do not compromise the accuracy of the system.

During single point solution investigation along the east coast of the United States, the discrepancy between the results derived from satellite observations and the existing geodetic survey positions of three test stations revealed total vector errors in latitude, longitude and height of 3·9, 4·9 and 6·6 metres compared with the precise traverse. Tests for the translocation solution indicated a vector error of 4·3 metres at the test station. Chord distances were:

| *Derived from* | *Distance* |
|---|---|
| Satellite | 398,016·99 metres |
| Triangulation | 398,016·64 metres |
| Traverse | 398,015·50 metres |

From the tests undertaken to date it can be concluded that:

The Doppler point positioning procedures in the field and during reduction at Base have an estimated operational accuracy of 10 metres or better.

Approximately 60 passes having good geometry are desirable. Additional passes do not improve the solution significantly.

With 60 passes the internal consistency of the solution will be better than 2·5 metres with a 90% confidence.

The accuracy of a translocation line will be better than 5 metres compared with a precise ground survey.

The most difficult station occupied during the BC-4 programme was Heard Island in the Southern Indian Ocean, 900 miles north of Antarctica. During reconnaissance in November, 1968, 100 tons of fuel and supplies were dumped. The six-man observing party brought a further 50 tons of supplies in March, 1969 at the beginning of their nine-month operational visit. The BC-4 equipment weighed an additional 7 tons. The same task could now be undertaken by three men in 15 days using one

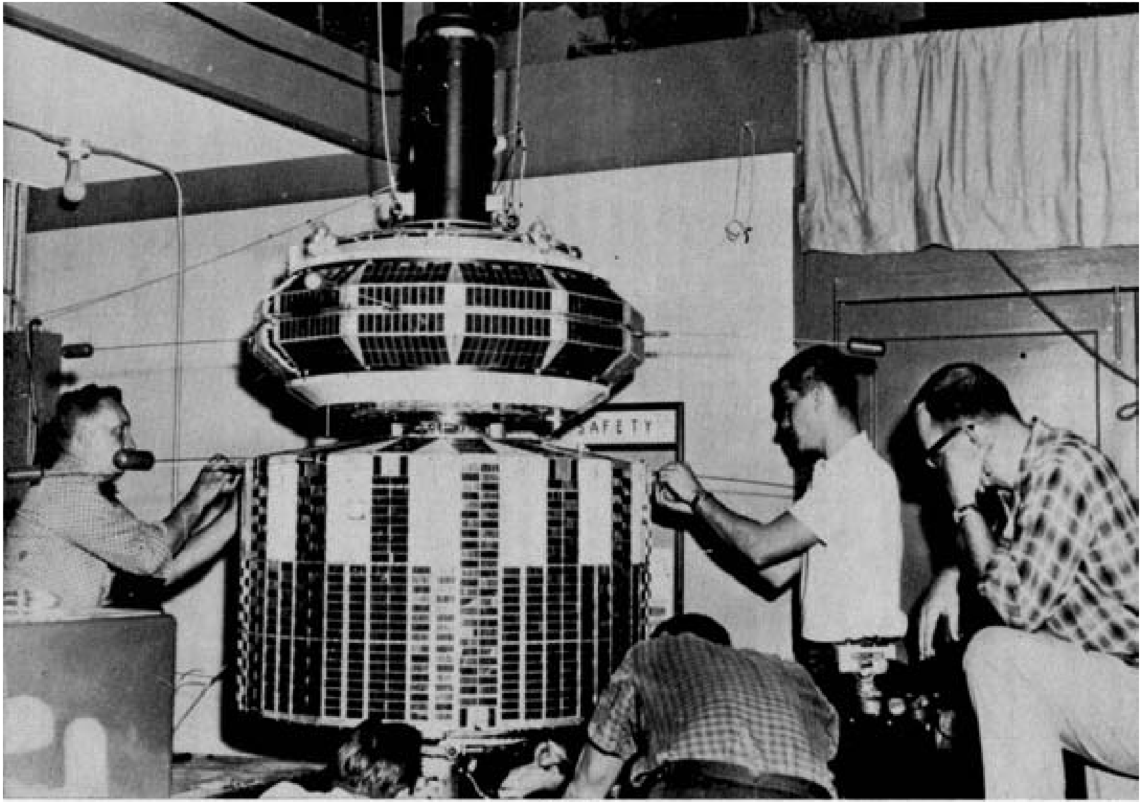



Plate 8.

of the four satellites, a miniaturised Doppler receiver, a hand portable generator, a barrel of fuel, a tent and a few boxes of rations. The personnel and equipment all fit in a helicopter for a single ship to shore transfer.

The tactical applications of the system as a multi-range positioning device are outside the scope of this paper. The potential of the Doppler System to resolve a variety of positional and navigational problems in the battle area can, nevertheless, be readily deduced. Meanwhile, the accuracy of the World Geodetic System is continuously improving as more data is added.

## CONCLUSIONS

For centuries, geodesy has progressed from primitive and coarse assumption to the refined knowledge of our present time. Like all sciences, each stage has been marked by a pressing requirement. Unlike most, however, the accomplishment has often been obscured by the functional success of some dissociated but nonetheless important development.

Modern navigational devices are utterly dependent upon geodetic data. In order that they may progress, the demands of geodesy must be accorded emphasis. The ultimate objective is the capability of supplying point positions anywhere on the earth's surface, in the air and under the sea, in terms of universal three-dimensional coordinates and rapidly, reliably and accurately.

"Nature knows no pause in progress and development, and attaches her curse on all inaction."

Johann Wolfgang von Goethe

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## ANNEX A

### PRIMARY NETWORK BC-4 GEOMETRIC SATELLITE PROGRAMME (SEE FIGURE 4)

Argentina
- Villa Dolores

Australia
- Thursday Island
- Perth
- Cocos (Keeling) Island
- Heard Island
- Mawson Station, Antarctica
- Culgoora
- Casey Station, Antarctica

Brazil
- Natal

Chad
- Fort Lamy

Chile
- Easter Island
- Punta Arenas

Denmark
- Thule, Greenland

Ecuador
- Quito

Ethiopia
- Addis Ababa

Germany
- Hohenpeissenberg

Japan
- Kanoya

Iran
- Mashhad

Italy
- Catania, Sicily

Mexico
- Revilla Gigedo Island

Mauritius
- Mascarene Island

New Zealand
- Invercargill

Norway
- Tromso

Philippines
- Zamboanga

Portugal
- Terceira Island, Azores

Senegal
- Dakar

South Africa
- Johannesburg

Surinam
- Paramaribo

Thailand
- Chiang Mai

United Kingdom
- Pitcairn Island
- Christmas Island
- South Georgia Island
- Tristan da Cunha
- Mahe, Seychelles
- Ascension Island
- Chagos Island

UK/France
- Vila, New Hebrides

United States of America
- Beltsville, Maryland
- Moses Lake, Washington
- Shemya, Alaska
- Maui, Hawaii
- Wake Island
- Pago Pago, American Samoa
- Palmer Station, Antarctica
- McMurdo Station, Antarctica

# Project Management in Motorways

LIEUT-COLONEL W. COOK, RE,
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## INTRODUCTION

In 1967 a new organization, for speeding the construction of British Motorways, was established by the Ministry of Transport. It had been apparent for some time that delays were occurring in design of motorways and administration of their contracts caused by the remoteness of the Ministry from the design offices and the motorway construction sites.

To eliminate these administrative delays a series of Road Construction Unit Headquarters were established in the regions. These headquarters exercised most, but not all, of the functions previously exercised by the Ministry of Transport in London.

Each headquarters had subordinate to it two or three Road Construction Sub Units whose tasks were the design, and the supervision of the construction, of the motorways.

The sub-units were formed from selected County Councils whose Highways and Bridges Departments were invited to participate in the new organization. The staff of these newly formed sub units consisted partly of members of the Highways and Bridges Department and partly of Ministry of Transport personnel.

An arrangement was made for the Corps to provide five officers to fill Ministry of Transport posts and at the start of the new organization in early 1968 one officer was appointed to a unit headquarters and four to sub units.

It may be of interest to consider in general terms how the officers on attachment to the Ministry of Transport are employed, and this may best be done by examining the processes involved in design and engineer management of motorways.

## MOTORWAY SELECTION

At some stage it becomes obvious that increased road capacity is necessary between two or more points. Ideally this is discovered by forward planning long before the traffic has built up and roads are overcrowded. More usually however the weight of the traffic is such that political or commercial pressures, or both, force the Local Authorities, or the Ministry, to act.

Before any planning can begin the traffic patterns must be known. These are discovered by traffic counts and traffic censuses, invariably involving numerous policemen, junior engineers, or students, on all roads through the area being studied.

The results of this census, when analysed, usually with the help of a computer, show the existing traffic patterns and the expected patterns some years hence, giving the planner sufficient data to decide whether an improved trunk road, or a motorway, is necessary to carry the traffic. For the engineer this is the real starting point of the motorway design, and the planners report can usually be rewritten as the "Aim" paragraph of the next procedure—an appreciation to select the best route for a motorway between point X and Y.

The process of route selection for a motorway is similar to military route selection, except that much more effort, time and money, is expended on reconnaissances. In addition factors of a purely civilian nature are considered which in operational circumstances would be ignored. Under this heading could come the interference with amenity, e.g. routing the motorway across special playing fields, or unsightliness where no effort is made to fit the motorway contours into the landscape.

From a large scale plan, normally 1:2500, a study is made and a band of interest selected along which the motorway will be routed. As a rough guide the band width is about one third of the distance between two adjacent fixed points. For example, if the motorway between X and Y must pass through towns A, B and C then the band width at the various sections would be 1/3 XA, 1/3 AB, 1/3 BC and 1/3 CY.

Once the band of interest has been decided detailed reconnaissances are made. A preliminary soil survey to establish foundation conditions is required; mining in the area is studied for subsidence problems, and river and drainage boards consulted to provide data of past and probable future flood levels. Note is taken of existing railways, power lines, gas and water mains and their future extensions.

A knowledge of land ownership and tenancy is necessary to study severance problems, and local authority views on the routing and its effect on the district are important.

With this information route selection can start. After consideration two, possibly three, routes suggested by the reconnaissances and researches are examined in detail and the most satisfactory alignment recommended. If approved by RCU Headquarters design of the selected route starts and progresses to a stage where it is presented to the public for their approval or objection.

## DESIGN

Concurrent with this design work it is likely that a second and more detailed soil survey will be made, probably by one of the specialist soil survey firms under contract and also there will be a land, or more often, an aerial survey. With computers universally used in design offices it is imperative that the survey, apart from mapping the area astride the centre line of the proposed motorway, will be presented in Digital Ground Model form. This will enable design work by computer to be tied into coordinates on the ground giving precise locations and levels.

With the aid of a computer, the route alignment is accurately calculated. Curves, both horizontal and vertical with their associated transitions and/or super elevations are designed, and the centre line of the motorway is plotted.

The Highways Act, Section 11 requires that the public is given notice of all new special road schemes. This is done by depositing drawings of the motorway centre line, on 6-in to 1-mile scale plans, at public offices, and by advertising in local newspapers and on notice boards in the vicinity of the proposed motorway.

The notices give instructions on how to object to the motorway. As the objections and petitions arrive, the engineer managing the project is expected to see the objectors, calm their fears and persuade them to withdraw their objections. These are made often from ignorance or fear of consequences which will not arise, but after discussion they may be withdrawn. However some objections have more substance and if these are not withdrawn the Minister acting through the RCU either overrules them, or orders a public inquiry.

Dealing with individual objectors or attending a public inquiry involves the engineer in charge of a project in considerable preparation. The case must be presented simply, logically and fairly. The objector, often accompanied by legal and professional advisors, will be satisfied only if replies can be given with confidence which comes from knowledge of the scheme in detail. At the same time counter suggestions from an objector must be analysed and refuted with sensible arguments.

Assuming this legal stage is passed, design in detail continues leading to the next procedural hurdle which is section 13 of the Highways Act requiring notice to the public of proposals to close, open or reroute all roads, tracks, pathways and the like, crossing the line of the motorway. For this the design must have advanced considerably as very precise details of construction are necessary before side road alterations can be planned. For example, should the motorway be on an embankment, a road crossing the motorway could continue as before along its same alignment at the crossing point, provided of course that the embankment were sufficiently high to permit the construction of an underbridge. This analysis is applied to each route affected. It may seem sensible to close some routes completely; on the other hand, because of land severance, it may be equally sensible to provide motorway crossings, where no road existed before. This process requires a knowledge of the locality, habits, land ownerships and so on, as well as current competent knowledge of the state of the engineering design.

A procedure similar to the one used for Section 11 is used to inform the public of the side road proposals, which are now shown on 1:2500 scale drawings. Objections are dealt with in a similar way, and failing solution are overruled or taken to a public inquiry.

The design work that has led to the formulation of side road proposals will have reached the stage where the embankments and cuttings have been designed, drainage has been considered in some detail, if not fully completed; and the location of the motorway boundary fence has been fixed.

With the approval of the side road orders the stage is reached for land purchase and production of the contract drawings and documents. Before the motorway can be constructed the land on which it, and any new or diverted side roads, shall stand must be purchased. Land is bought by the District Valuer, but for him to function each individual plot of land, irrespective of its area, must be measured. It must be described and its legal owner, and tenant, if the land is let, identified. This involves much research as errors here may lead to endless delays later should some small parcel of land be overlooked. All this information is presented to the District Valuer in the form of a highly coloured drawing with an accompanying schedule, detailing land plots, owners, and tenants. At this stage, for the final time the public, more specifically the land owners or occupiers, may raise objections to the land purchase and therefore documents similar to the plans produced for the District Valuer must be prepared and used for the issue of a Compulsory Purchase Order. The mechanism for applying this once again involves public notification, objection and inquiry.

While design and land purchase progresses the project manager must be looking ahead towards the construction stage. He must know enough of the area to have a very shrewd idea how the contractor will operate, where he will get his heavy plant, where he may get his construction material and where he may dispose of surplus excavated material should there be any. As this picture is built up from knowledge of the area and familiarity of the design, it may be seen, for example, that the likely haul routes are not fit to carry the construction traffic and must be strengthened prior to construction starting. It may also become apparent that the best route for disposing waste excavation is through the nearest village. Dump trucks of wet peat thundering through the village street would cause complaints, hence an alternative route must be selected and written into the contract documents to enable tenders to reflect this in the pricing.

### CONTRACT

Eventually most of the work leading to the preparation of the contract documents will be completed, much having been done with the help of a computer. In the final stages the computer will have produced a complete cross section giving carriageway levels with super-elevations, where appropriate, top of embarkment levels, toe of embarkment levels and levels out to the boundary fence, and from these detailed cross-sections will have calculated quantities of cut and fill.

All these earthwork quantities, and other data will be applied to yet another programme which will enable the computer to print out the bill of quantities. This is the final scene; the drawings and the bill, together with the Standard Conditions of Contract, complete the tender documents and the motorway is ready for the contractors.

### SUMMARY

The above is an abridged and highly simplified account of a motorway project. I have glossed over many details which take time and knowledge to complete. Drainage was dismissed in a phrase, but will have taken many weeks to design and may have involved research into local drainage laws and even special Acts of Parliament. Each side road affected is a study in itself. Each new or altered junction has to be calculated for capacity and designed for location and sight lines as well.

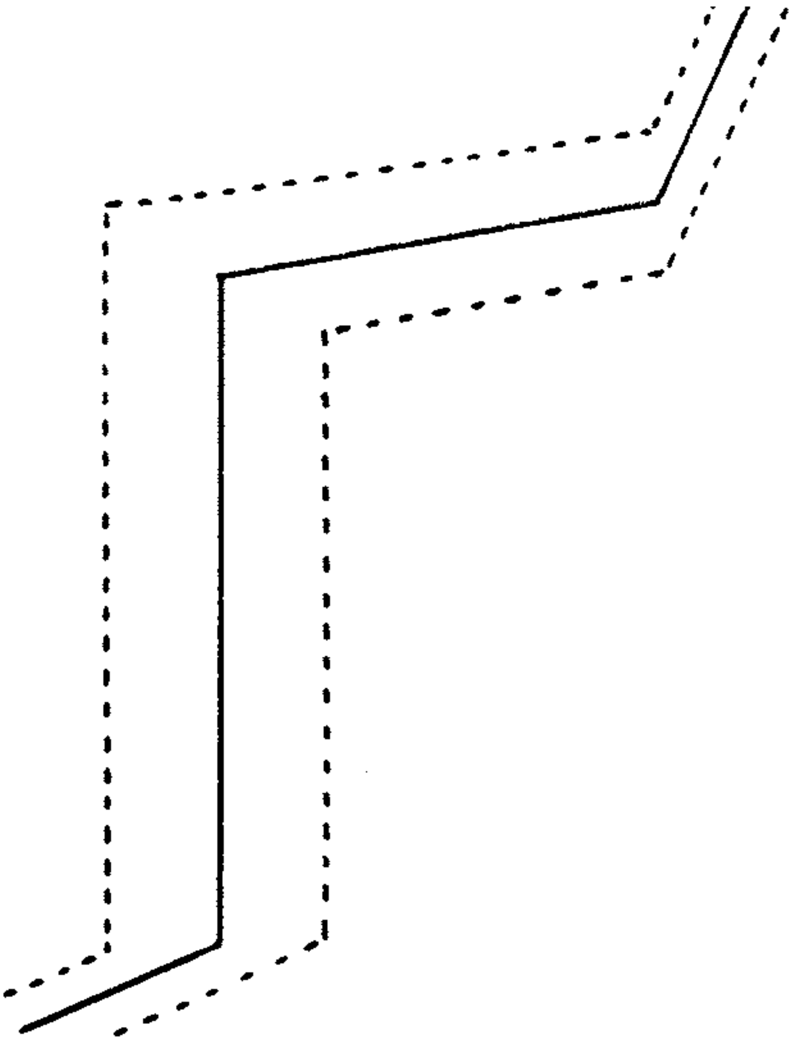


Fig 1. Route between X and Y showing width of band investigated.

However, while avoiding this kind of detail, I hope I have succeeded in showing the problems involved in exercising project management-problems which are not far different from those met in management of any military project. The requirements to overcome the problems are, a clear aim, plenty of knowledge of site conditions from thorough reconnaissances, a coordinated effort to meet each succeeding goal, and professional competence.

ACKNOWLEDGEMENTS

I am very grateful for the opportunity of being able to be in a position to write an article such as this and would like to thank Mr H. Hall, Director of the North Eastern RCU, Colonel S. M. Lovell, CBE, County Survey of the West Riding of Yorkshire and his successor, Mr J. A. Gaffney, and in particular Mr F. R. Oliver, OBE, Deputy, County Survey, in charge of motorways and his Superintending Engineer Mr A. T. Hutchinson, all of whom permitted me to exercise the management techniques I have described.

# End of an Era
# The Withdrawal of the Royal Engineers from Singapore

LIEUT-COLONEL B. R. LAMBLE, RE

## INTRODUCTION

On 2 September 1971 the CRE, Second-in-Command and Adjutant of HQ RE Singapore flew out from Changi thus virtually completing the withdrawal of the Royal Engineers from an area of the Far East that has both pleasant and painful memories for many Sappers. A British Sapper troop remains as part of the engineer squadron supporting the multi-national brigade group, but to all intents and purposes the large comprehensive engineer presence, that for so long supported both the Services and civilian agencies, is at an end.

In past years, much information of a domestic nature has either not been recorded or has become buried in the wealth of official reports and diaries that the system demands. The Bureau of Archives now goes a long way to remedying this defect, but still the answers to many queries of interest to the Corps in later years are to be found in the pages of *The Journal*. This, therefore, is the reason for the following article.

## AIM

It is by no means a definitive work on the multitudinous aspects of withdrawal from an area in which Sappers can trace their history back to Raffles. Rather, it is a very general and readily available reference about the major events, and fate of units, property and assets, within the context of the last two years of Sapper presence. It will not include, for instance, more than a passing reference to The Gurkha Engineers, now based in Hong Kong, who for years worked and trained in the Peninsula and further afield. That must come later from a more qualified author.

## THE SITUATION AS AT NOVEMBER 1969

By late 1969 the engineer plans for withdrawal were well advanced. Within a few months the post of Chief Engineer in HQ FARELF would be downgraded to Colonel, and disposal of plant and stores was already well under way. The old Engineer Group (see Annex "A"), with its varied history dating back over two decades, was about to be broken up into three lieutenant-colonels commands, one of which would be a new organization, HQ RE Singapore. This organization was to be a steadily reducing group gradually taking over all responsibilities until such time as the engineer presence was at an end in late 1971. On 1 November 1969, HQ RE Singapore was formed with its location still in the old Group Headquarters in Gillman Barracks, and still being responsible for much of the administration of the FARELF Engineer Park (FEP) and 63 CRE (Construction). Annex "B" shows the organization and actual disbandment dates that were finally agreed. It also includes 70 Trg Sqn, The Gurkha Engineers who came under command in mid-70 having moved down from KLUANG.

Gillman Barracks, run and administered by the Singapore Engineer Squadron (SES), remained the home of all unmarried sappers, including Locally Employed Personnel (LEP), who returned there at the end of the day from their nearby unit barracks. Gillman Officers Mess although still largely an RE affair was a Garrison Mess and included RMP, RAPC and RAEC officers as well as three SSAFA Sisters. The WOs and Sgts Mess remained completely Sapper.

The withdrawal plan, as envisaged at this time, was conventional and was based on all families leaving by 31 August 1971 followed by the final withdrawal being covered by 3 Command Brigade Group in December 1971.

With still two years to go, major engineer projects were still being carried out, the largest at the time being the BUKIT MENDI project (Journal, March 1971) and the DUNGAN airfield complex in Malaysia. Numerous smaller MACC tasks, known as "Concord" tasks, were constantly occurring giving both good training value and good community relations—an important aspect when carrying out a peaceful withdrawal with its accompanying civilian labour problems.

## COMPLICATIONS

An already known complication was the large exercise due in mid-1970 called BERSATU-PADU (Complete Unity). The British Government had decided to demonstrate its ability to honour its treaty obligations to Malaysia and Singapore by deploying a brigade group direct from UK. This five nation exercise (Australia, Malaysia, New Zealand, Singapore and UK) was to take place in Trengganu and was set in a Viet Nam situation of the future.

Much engineer work was needed in 1969/70, particularly in relation to the provision of a Hercules airfield for the fly-in and maintenance of the British brigade group, and a smaller neutral headquarter complex and Andover airstrip for the Exercise Control. As both these areas were over 300 miles from Singapore much of the engineer withdrawal plan could not take place until the recovery phase of the exercise was completed in August 1970. Thus, Sappers were subjected to two conflicting pressures from various groups of planners. On the one hand, the administrative planners were exhorting all units and departments to thin out to avoid overloading the system towards the end of the withdrawal, whilst on the other, a separate group were adamant in stating that for various reasons the exercise must be a complete success. These pressures, coupled with the Sappers natural and justified suspicion of other nations planned capabilities, meant that a fine balance had to be maintained between the sensible and the dangerous. Nearly all engineer units were involved, with SES doing most of the earthmoving and 54 Sqn the utilities (power, water, cold storage). 59 Sqn had the unique task of being split three ways—enemy, friendly forces and neutral control. However, all went well, albeit not without a certain amount of internal trepidation.

The second complication was unforeseen in that the 1970 election brought a change of government and policy. This was more a worry for the Staff than for the engineer units, since it was obvious that the remaining Sapper presence would be very small. However, with a British residual presence now a fact, many of the previous assumptions connected with withdrawal plans were invalid. No longer would a Covering Force be required and there was little point in spending money on keeping units in Singapore until the end of 1971 when they could go earlier. After much discussion over what should be the balance of engineer support until such time as the new force arrived, the effect was an advance of withdrawal and disbandment dates from the original plan. This, as can be imagined, led to many housekeeping, disposal and posting problems, all of which were, naturally, overcome. In this respect the stirling service of RE Records and AG7 should be appreciated.

The third and last major complication was the acceptance by the Pakistan Government of a British Amphibious Force to go to the relief of East Pakistan after the cyclone disaster in November 1970. This was a major operation (OP BURLAP) involving much of HQ RE Singapore either actually in the Ganges delta or supporting it from Singapore. It came in the middle of the last large peacetime engineer project taking place in Malaysia. As part of the final goodwill gesture combined with good training value, a road had been started in Johore for the Malaysian Federal Land Development Agency. This was a three month task due to be carried out by 59 Fd Sqn and supported by 54 (FARELF) Sp Sqn with a non-extendable dead-line of 31 December 1970. The flood operation meant that the Support Squadron had to assume full responsibility half-way through the job whilst at the same time taking over the FEP and supervising its continued rundown. However, by mid-December a very satisfactory result had been achieved and the road was formally handed over to the FLDA by the Chief Engineer.

Minor complications, such as the Malaysian Floods in January 1971 (Op EPIGRAM), continued until the end but did not appreciatively affect the rundown plans.

DISPOSAL OF REAL ESTATE AND ASSETS

Basically the system for handing over ground and barracks was similar to that used throughout the Army. The Singapore Government set up an organization known as the Base Economic Conversion Department (BECD) which accepted the land from the Area Land Agent, the buildings and fixtures from the DOE and the equipment from the unit. However, since both the ALA and DOE were extremely hard pressed it meant that to get a smooth handover the unit had to do all the work. In some cases where the barracks were small this was a relatively simple task. In others where the organization was to be handed over as a "going concern" the position was more complicated. Naturally, the British removed all items of equipment that they required elsewhere, but under the agreement the majority of fixtures were handed over. Thus, 84 Svy Sqn handed over a going concern to their newly set up counterparts in the Singapore Armed Forces (SAF) in December 1970.

This was the start of the disposal of engineer barracks, and various area continued to be handed over throughout 1971. Hard work and meticulous attention to detail were required in each handover since the BECD was staffed with officials who had a thorough eye for detail. It is great credit to all units and particularly to the quarter-mastering side of the Corps that every acre of real estate was handed over quietly and amicably and without deficiencies. The FEP and Gillman Barracks could have been particularly difficult valued as they were at £4·1 and £3·6 million respectively. However, in each case the traditional $1 changed hands with goodwill on both sides.

The FEP with its large engineering workshops is already part of the Jurong Industrial Estate and is destined to be developed into a Light Engineering Complex. Gillman Barracks on the other hand is still retained for military purposes and now houses the Singaporean Engineers. The 1,500-pupil Bourne School, which sits inside the barracks, has been leased to the American School of Singapore until 1973. After this date it will be interesting to see which Ministry finally acquires what is considered by many to be the most attractive barracks on the island. Cloutman lines (59 Fd Sqn) will probably be developed by the Singapore University extension, and Morris Lines (54 Sp Sqn) may well go to Jurong.

It would be impossible to discuss real-estate without a special mention concerning the Gillman Officers Mess. Originally this was destined to close with the final withdrawal in late 1971. However, with the new plan it was agreed that Kent (RAMC) and Marina (RCT & RAOC) should close early and their members concentrate on Tanglin and Gillman. This was greatly to the Sappers advantage and on 1 July 1971 the Mess was handed over to 3 BOD who provided most of the members. In due course they will hand it to the SAF who aim to turn it into an officers club.

Long before this date all Sapper property had been redistributed. The two stone mosaics, temple scroll and stone lions are now in the Postal Mess at Mill Hill. Silver and money were largely split between the now 59 Indep Cdo Sqn and 54 (Hong Kong) Sp Sqn (old Hong Kong Pk Sqn), with smaller items and amounts being sent to the HQ Mess, Trg Bde, REYC, REGS and the LEP Benevolent Fund. Some property was auctioned off to help support the farewell functions, whilst odd items went to the Gurkha Engineers Mess in Hong Kong.

As with Officers Mess assets, the two squadrons (59 and 54) that remain on the orbat also benefited greatly both from the WOs and Sgts Mess and the PRI. Even the UK troop that makes up part of the 9 (ANZUK) Engr Sqn of the ANZUK Bde now owns a Nuffield mini-bus and ski boat. The very thriving Gillman Youth Swimming Club continues under the name at the SANDES Home for Soldiers and Sailors, and much of the Gillman swimming pool equipment together with a small amount of money was handed over to them. This pool is likely to be the only one

Handover of Gillman Barracks 20 August 1971 for the traditional dollar:
Mr LEONG FOKE MENG (BECD); Maj GURUCHARAN SINGH (CO S'pore Engrs)
Lt-Col B. R. LAMBLE RE (CRE S'pore); Mr T. STEERS OBE (Area Land Agent)

End Of An Era

readily available for families of the new force since both Gillman and Dover Road will belong to the Republic. Although withdrawal is a painful business, for some at least the ill wind blew fair.

### THE CONTINUING PRESENCE

As is generally known, the brigade group stationed in Singapore is composed of Australian, New Zealand and UK contingents. Basically, the British contribution is an infantry battalion, a battery of guns and a troop of sappers, together with a proportion of logistical support. Until the new force formed up in September 1971 a troop of 59 Indep Cdo Sqn remained with its Commando in Singapore.

Although one troop is the only permanent RE presence in the area, it is planned that a continuing rotation of infantry battalions with their supporting batteries and Sapper troops will spend up to six weeks at a time undergoing training at the Malaysian Jungle Warfare School in Johore. The proposed Commonwealth JWS proved too difficult to impliment, but already the first UK battalion group has been through Kota Tinggi. In future years, therefore, many sappers will continue to get their sight of the jungle.

### CONCLUSION

There are no special lessons to be learnt from this withdrawal—rather a reaffirmation of old principles. Plans must often be based on a minimum of information and will be subject to constant change. Planning and execution phases will occur simultaneously and will stretch flexibility to the limit. Balance remains of paramount importance and if impossible to achieve by formed units, must be maintained by tailoring organizations and capabilities within those units remaining. Finally, a sense of humour is a great advantage.

The following signal was received from the G-O-C FARELF on the day HQ RE Singapore disbanded:

"From Commander to CRE. Before HQ RE closes after half a century of organized operational presence in Singapore/Malaysia, I would like to thank you for the fine work put in by the Sappers over the years. More recently we remember your great efforts during the Relief Operations subsequent to the Pakistan Flood Disaster which brought relief to millions of helpless people. I am glad that a Sapper presence is to remain with the ANZUK Force. Goodbye and Good Luck to you all.

Signed W B Thomas, Maj Gen"

## ANNEX A

## PAST COMMANDERS RE SINGAPORE

### SINGAPORE ENGINEER REGIMENT

| | |
|---|---|
| Lieut-Colonel P. F. White, OBE, RE | March 1948 to May 1949 |
| Lieut-Colonel J. O. Dwyer, OBE, RE | May 1949 to May 1952 |
| Lieut-Colonel R. W. Obbard, RE | May 1952 to May 1953 |
| Lieut-Colonel J. M. W. Howe, OBE, RE | August 1953 to July 1956 |
| Lieut-Colonel J. L. Nicholson, OBE, RE | July 1956 to June 1959 |
| Lieut-Colonel Æ. J. M. Perkins, RE | June 1959 to July 1960 |

### ENGINEER BASE GROUP SINGAPORE

| | |
|---|---|
| Colonel D. C. S. David, MC | August 1960 to June 1961 |
| Colonel H. F. G. Boswell, OBE | June 1961 to June 1964 |
| Colonel P. S. Baines, MBE | June 1964 to May 1966 |

### ENGINEER GROUP SINGAPORE

| | |
|---|---|
| Colonel P. S. Baines, MBE | May 1966 to October 1966 |
| Colonel D. Kenwrick-Cox, MBE | October 1966 to October 1969 |

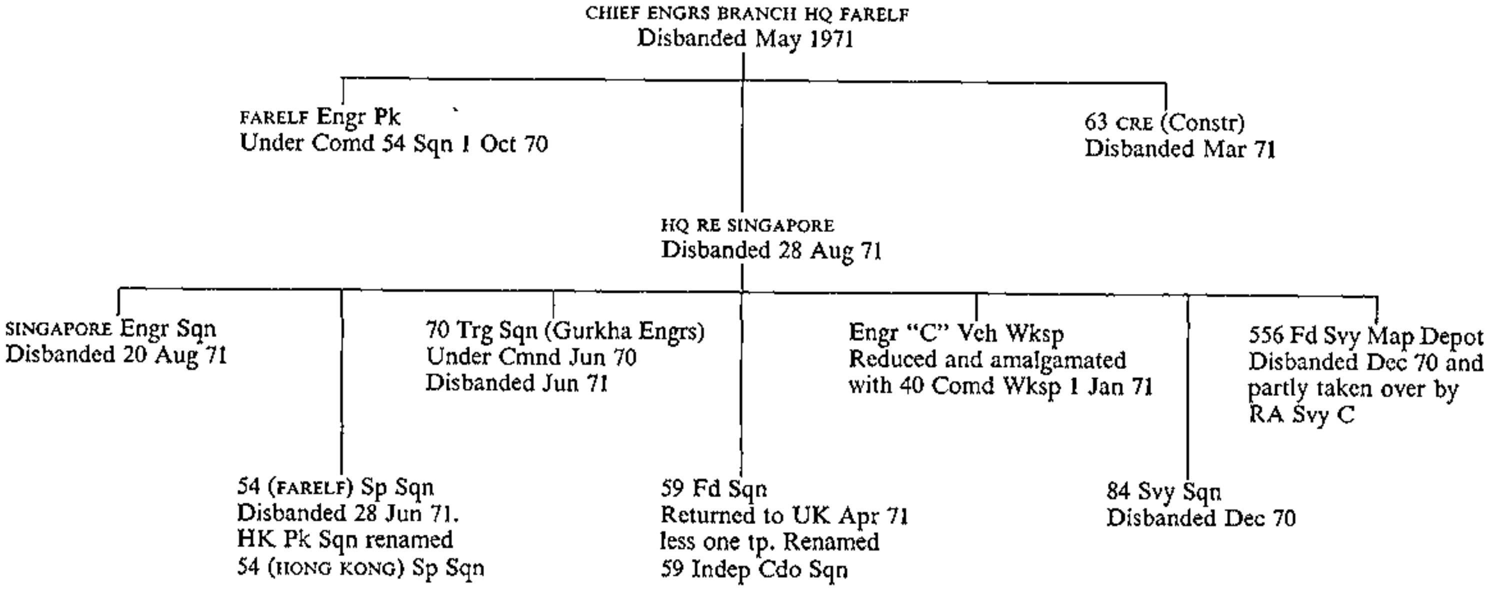
### HQ RE SINGAPORE

| | |
|---|---|
| Lieut-Colonel B. R. Lamble, RE | November 1969 to August 1971 |

# ANNEX B

## ORGANIZATION RE SINGAPORE NOVEMBER 1969

(Arranged by disbandment or withdrawal dates)



# The Engineer & Railway Staff Corps T & AVR—A Personal View

LIEUT-COLONEL A. J. HARRIS, CBE, BSC(ENG), FICE
FISTRUCTE, MCONSE

IDLE to pretend that there is not something faintly comic about this body, devoted as it is to wining, dining and exalted brooding. All rank and no file; Colonels, Lieut-Colonels and Majors, not to mention the supernumaries—gentlemen of immense distinction, knocking on a bit in years, but still dangerous. An irreverent echo of Slattery's Mounted Foot will not be repressed.

All right. It is none the less an engineering élite, drawn from the ranks of managers and engineers of railway and port undertakings and of senior consulting engineers and contractors; membership is highly prized by members. It is also a manifestation of the immense fund of goodwill on the part of civil engineers towards the RE, something which the serving officer commonly has all too few opportunities of appreciating. Its explicit purpose is to place at the disposal of the Army its members' knowledge and experience of engineering and transportation matters.

The idea of the Corps dates from 1860 and its formation from 1865; the initiative in its founding came from the Secretary of the Institution of Civil Engineers and its immediate purpose was to drag the Army into the railway age. The days when the word engineer had had an exclusively military connotation were then still not far off, when the very idea of a civil engineer had been a paradox, something of an Irishism, much as if one referred to a pacific gunner. The railways had changed all that—and it was interesting that so short a time had elapsed (the railway boom was in the 1840s) before civil engineers turned back to the Army to offer a helping hand.

The history of the Corps has been written, albeit from incomplete records (the War Office files had been disposed of) and its development and activities may be studied in detail. A curiosity: in time of war, the Corps disappears from sight; presumably its members are otherwise engaged. Another: when a reserve of railway tradesmen was organized by the Corps, it was thought unnecessary to give them military training since their discipline as Railway employees was already "very strict". That was in 1897.

The function of this body is easily stated—it is to solve such problems as are placed before it. So simple-seeming; just locate a problem and describe it in a letter. Perhaps a meeting will follow; powerful minds are brought to bear and the solution soon comes back. On again to the next one.

In reality, things are not so easy. The robust characters whom we picture as coping with the daily life of the RE find little profit in discovering problems. They meet them, of course, all too many of them; all life is subject to Murphy's Law.[1] Either they solve them as best as they can—or they dodge them. A problem defined may well be half solved, but to the practical man a problem avoided is no longer a problem at all. The elegant statement of a problem to which no solution can be suggested earns few good marks—and time presses.

For an advisory body to be of more than marginal value, it must be in the picture. It is a dog and rabbit situation; A has something to offer and B has a need, neither knows quite what nor ever will until A happens to meet B in circumstances favouring

[1] Murphy's Law "If it can go wrong, it's bound to".

conversation. Every well-organized profession has its market place, its forum, at which this very function is fulfilled. A to-and-fro on military matters between military and civil engineers has obvious difficulties; there are those who think that something along these lines, however limited, could nevertheless be organized.

In the meantime, there they all are, the officers of the Engineer and Railway Staff Corps, yearning to help. They could be useful.

EDITOR'S FOOTNOTE

Copies of the History of the Engineer and Railway Staff Corps RE (T & AVR) may be obtained at a price of £3·15p, from Colonel D. C. Coode the Acting Adjutant at: Headquarters Engineer and Railway Staff Corps RE (T & AVR) Abbey House, 2 Victoria Street, London SW1.

Any additional information concerning the Engineer and Railway Staff Corps, or on how Sapper officers can obtain advice from the members of that Corps on engineering and similar problems, may at any time be referred to Colonel D. C. Coode if the inquiring officer has not got an immediate contact with another member of the Corps.

# The Kenya Army Corps of Engineers

CAPTAIN S. K. KHANNA, RE

## INTRODUCTION

THE Kenya Army had no engineers before 1965. The Army consisted of three infantry battalions without assault pioneers and a few supporting elements. Its role was to maintain law and order within the country though it should be noted that a much larger army fought and distinguished itself in many countries during the two world wars and during other campaigns. It was between 1963 and 1967 that the need for engineers and assault pioneers was felt acutely when the army was engaged against the Shifta in the remote and desolate North Eastern Province. During the early part of these operations the ground forces had no trained men to detect and neutralize mines which the Shifta started using and no plant to repair the resultant damage to tracks. In the last seven years the army has raised and trained a fine corps which has accomplished many major tasks. This article traces the history and achievements of the Kenya Engineers.

## ROLES

The Kenya Engineers have two roles. First, to support the Kenya Armed Forces and, second, to assist the Civil Community in conjunction with the Ministry of Works. Support to the Armed Forces involves mines and demolitions, bridging and ferrying, water supply and the construction of temporary roads and air strips. It also includes assistance with self-help projects like construction of buildings in remote areas and of playing fields in barracks. Assistance to the Civil Community has offered the Engineers opportunities for big projects like the construction of roads, causeways and airstrips suitable for medium range transport and strike aircraft.

## RAISING

In 1965 Major I. P. Haines, RE, was seconded to the Kenya Army to help raise, equip and train one field troop which was later to be expanded into a field squadron. He was assisted by other RE officers and NCOs. Initially Sappers were recruited from two main sources. The majority were apprentices from trade schools and others were tradesmen in civilian jobs. Officers were enlisted either direct from schools or universities or from infantry battalions. The unit initially had no local NCOs. Suitable men were promoted after training.

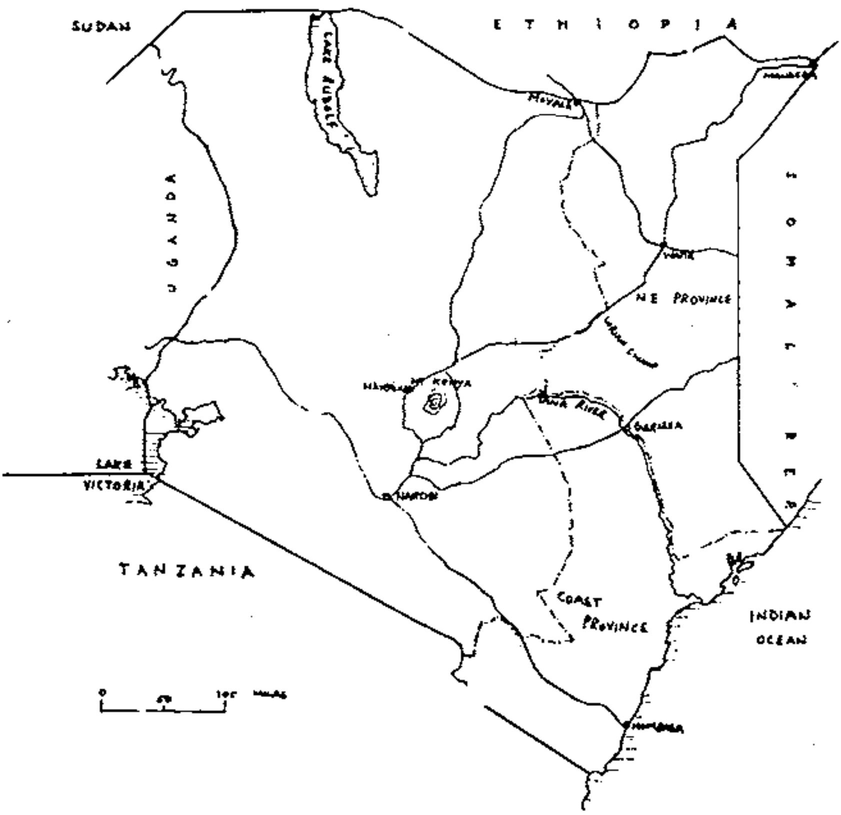
During 1966–7 the troop expanded into a field squadron. In this phase some soldiers transferred from the infantry to become sappers.

The organization and equipment of the field squadron was very similar to that of the Royal Engineers. The equipment was mainly British and a troop AFG 1098 store looked almost identical to that of a Strategic Reserve troop. The Squadron, however, had more plant.

TRAINING

The initial training of the officers and soldiers was, naturally, a long process because of the small numbers of training staff, few facilities and very little equipment. There was also some wastage. The officers first received basic officer cadet training at the Armed Forces Training Centre, Lanet, for six months and then attended a YO course at the RSME, Chatham. One of the officers had a university degree on enlistment. Other degree officers are being recruited for an eighteen-months probationary period. In the past many of them have proved to be unsatisfactory soldiers and officer wastage has been fairly high. Recently some officers have been posted in from the infantry. They have proved to be very good sappers even before attending YO training at Chatham where the Kenya Engineers cannot get as

MAP OF KENYA



many courses vacancies as they would like. One officer has just completed degree training at the RMCS, Shrivenham and another is due to attend an advanced course for six months in India.

Soldiers do their recruit training also at the Armed Forces Training Centre. They are then posted to the engineer unit where they attend appropriate sapper courses which are run by the Training Wing. These courses cover all established trades which are:

| | |
|---|---|
| Combat Engineers | Plant Handlers |
| Signallers | Plant Operators |
| Drivers | Plant Mechanics |
| Driver Operators | Fitter Machinists |
| Carpenters | Survey Engineers |
| Plumbers | Bricklayers |

Upgrading courses to Class I standard and courses for infantry assault pioneers are also run by the Training Wing. The course syllabi are based on those used by the RSME but some courses are of a longer duration than they are at Chatham. On combat engineer courses training on equipment bridging is confined to the Bailey Bridge. Time saved is spent on concrete, improvised bridging and roads and airfields.

The Kenya Army also gets vacancies on QMSI and combat engineering upgrading courses at the RSME whenever they are needed and available. Military refresher courses like NCOs cadres, weapon training, tactics, drill and duties for soldiers and platoon and company commanders for officers are done at the Armed Forces Training Centre.

## FURTHER EXPANSION

By 1970 the 1st Field Squadron had again increased in number and had taken over more plant than it could man and manage. It had performed valuable tasks throughout the country and both the Armed Forces and the Ministry of Works appreciated its value. Greater demands were being made on the Engineers. To cope with these two problems it was agreed to increase the establishment again in order to provide more trained officers and NCOs to plan and carry out projects. This is in progress now.

Between 1966 and now British officers and NCOs have been phased out slowly and their jobs have been taken over by trained Kenya personnel. Kenyan officers have commanded the unit since 1967. The only British representation now is an SO II Engineers at Defence Headquarters, whose main job is to give advice on engineer matters, and a MPF with the Park Sqn. This assistance ends in December 1972.

## PROJECTS UNDERTAKEN

To date the Kenya Engineers have undertaken a large number of projects throughout the country. The smaller projects include the construction of playing fields for the Kenya Navy at Mombasa, the grading of a square at the Armed Forces Training Centre, building of numerous small tracks, culverts and bridges, and giving assistance to infantry units in constructing substantial but simple buildings in remote garrisons of Garissa, Wajir and Mandera (see map). The Army has to construct most of these buildings on a self-help basis because sufficient money is not available from the Ministry of Works. The sappers also assisted the Army in building a Community Hall at Garissa (see plate 1).

In Nairobi the sappers helped to build the Forces Hospital near the Army Headquarters in 1969–70. They cleared the 6-acre site, dug the foundations and built the shells for the wards. They also built the hard top road network and landscaped the site.

Major projects have been undertaken with the Ministry of Works in the North Eastern Province. This province is remote, sparsely populated and very underdeveloped. The relief ranges from semi-desert to desert with very few sand and gravel racks which get washed away in the low-lying land every time it rains. The Tana River provides water to a thin southern strip whilst the Daua Parma in the north-east forms part of the border with Ethiopia. The eastern boundary of the region is also the boundary with the Somali Republic. During the monsoons a few seasonal streams and ponds form.

In general the Ministry of Works produces the requirement, the specifications, the plant, the finance and the consultants whilst the sappers do the job with the assistance of local labour.

Garissa, the Provincial capital, is linked to Nairobi by a 225-mile road most of which is made of sand and gravel. The last two miles of the road adjacent to the Tana River was often washed away by flooding and this cut off Garissa and the rest of the region. Between July 1969 and September 1970 the Kenya Engineers built a causeway over this stretch. The causeway was surveyed and designed by recently trained engineer officers and the troop commanders were in charge of the work in rotation. The work force consisted of a large composite troop. There was little plant—twelve 3-ton tippers, one grader, one D6 shovel, one roller and a traxcavator—and work was interrupted by the monsoons which last a total of about five months every year, two in the early part and three during the European autumn. In some places the fill was 18 ft high (see plates 2 and 3). The causeway has stood up well to subsequent monsoons and provided an all season link with Garissa where a company of infantry is stationed permanently. To provide this company with facilities for training the sappers have carved out a 400-metre rifle range from waste land. This necessitated realignment of the main road to Nairobi by the sappers (see plate 4).

Mandera is in the north-eastern tip of Kenya on the border with Ethiopia and Somalia. It is about 600 miles from Nairobi and the farthest point in the country from the capital. An infantry company is stationed there permanently. To support it the Kenya Engineers have built a 1,400 yd long and 25 yd wide bitumenized air-strip suitable for medium range transport (see plate 5). Labour consisted of fifty sapper and sixty civilians. Plant allocated was four tippers, one grader, one roller,

**Plate 1.** The Community Hall at Garissa built by Kenya Army self-help.

**Plates 2 and 3.** Part of the Garissa Causeway showing flooding on the upstream side and 18 ft of fill downstream.

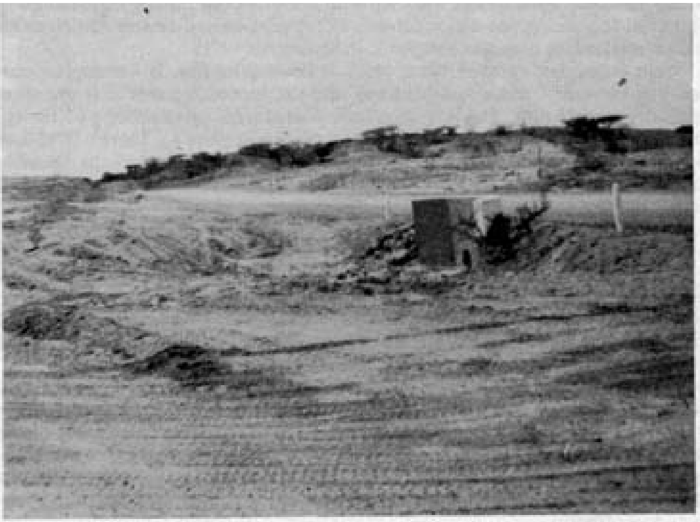


**Plate 4.** The Range Bypass.

**Plate 5.** The Mandera Airstrip. It is difficult to see the black top because the strip is covered with blown sand. The township can be seen on the top right and the connecting road to the left of the strip. The Sapper detachment camp is amongst the acacia trees on the left.

The Kenya Army Corps of Engineers 4 & 5

one TS 200 bucket, one stone crusher, one compressor, one D6 dozer, one dumper, one water tanker and a vibroller. Phase 2 of this project was the construction of a 3-mile macadam road to link the strip with the small but rapidly expanding town. This road containing one major culvert, a four-pipe 48-in diameter Armco culvert, and several smaller ones was completed in September 1971.

Wajir is another garrison town which is developing fast. It lies approximately half-way between Garissa and Mandera and the approach roads to it are useable in the dry months only. The Engineers have started work on improving on the existing airstrip by expanding the bitumenized surface (see plate 6). There will also be a ½-mile taxiway to the Army camp. This project was also prepared by the officer who designed the Garissa causeway. The planned construction time according to his arrow diagram is 28 weeks.

### PROBLEMS AFFECTING PROJECTS

Projects in the North Eastern Province are affected by many problems. The remoteness of the area makes transportation very expensive. Resupply of food, materials and spares is difficult and time consuming. The Kenya Army does not have the facilities to hold stocks of spares in these remote parts. Sandy conditions wear the plant out fast. The very hot weather reduces operator efficiency and the lack of water near work sites enforces long trips to rivers or boreholes. Flooding during the rains affects work. At times there was up to 6 ft of water around the Garissa Causeway. In March 1971 a cholera epidemic not only took away labour but also cut off the water supply because nearly all water was infected. Dust slows down work and snakes and scorpions make labourers work cautiously. There is also a shortage of manpower and plant because of the number of top priority jobs which have to be done concurrently.

### FUTURE PROJECTS

The Kenya Engineers have a document produced by the Ministry of Works which lists a large number of jobs that need doing. Most of these are major projects and the Engineers take them on whenever they can. The next proposed project is the im-

**Plate 6.** The Wajir Airstrip where the Kenya Engineers are extending the bitumenized surface.

**Plate 7.** Stone crushing at Wajir.

**Plate 8.** Some Kenya Engineers plant in the North Eastern Province.

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provement of 212 miles of the track between Garissa and Wajir. Work was due to start on it in August 1971. There are, of course, smaller jobs to be done and sappers to be trained.

CONCLUSION

Since their formation the Kenya Engineers have managed to produce a very fine and well trained unit. Their officers and NCOs are every bit as good as their RE equivalents. The soldiers are good at combat engineering tasks and at project work. In time the new battalion will get more bridging, plant and other engineer equipment and will have created a larger pool of trained men. The burden of running courses may then ease. In the meantime it is desirable for the Royal Engineers to maintain a close liaison with the Kenya Engineers and to continue to provide course vacancies at the RSME. Units that go out to Kenya on exercises should make a particular effort to foster good relations with the local sappers; there is not much evidence of this at present although 9 Independent Parachute Squadron, Royal Engineers have had some assistance on exercises. We will gain a lot from maintaining such a liaison because there can be little doubt that many Royal Engineers can learn much from the experiences of the Kenya Engineers.

ACKNOWLEDGEMENT

I want to thank the Army Commander, Major-General J. K. Mulinge, MBS, his staff and sapper officers for the assistance they gave me in producing this article. I also want to thank Major R. G. Shaw, RE, SO II Engineers, Kenya Army, who arranged all trips for me and also checked and cleared the manuscript.

# Correspondence

William Reid Esq, FSA
Director
National Army Museum
Royal Hospital Road
London SW3
10 January 1972

MEMORIALS TO INDIAN ARMY

Sir,—I wonder if I may trouble you to correct a misconception in Colonel Cotton's article Memorials to the Indian Army. As I expect you know the Indian Army museum is an integral part of this institution. All of its contents including the Indian Army Memorial Room are as much a part of the National Army Museum as are the exhibits on display at Chelsea. They are looked after by the staff of the National Army Museum and any enquiries about them should be addressed to the Director of the National Army Museum at this address.—Yours sincerely, W. Reid.

Brigadier G. MacLeod Ross, MC, O St J,
3 Cobourg Street, Goderich, Ontario.
30 October 1971

LIEUT-GENERAL SIR HAROLD WILLIAMS

Sir,—When you come to write an obituary on Lieut-General Sir Harold Williams, you might care to add a note to the effect that while he died on 17 October my first news came in an air letter on the 28th from Shri Vasdev Kakar, who was my Finance Clerk on the Reconstruction of Quetta Cantonment in 1938–39.

While E-in-C India, Bill Williams righted an injustice in respect of seniority and pension for Vasdev long after the Independence of 1947, on my representation. Vasdev in his letter refers to "the Greatman General Williams" and adds, "This is really great shocking news".

I bring this up because first Bill, Vivian Dykes, L. O. Clark and I were together for a year in Supplementary Number 11, but also to draw attention once again to the very happy relationship which RE Officers enjoyed with all ranks of the Military Engineering Service. Vasdev's concern is just another expression of a very endearing quality possessed by the Indian, a faculty for friendship of a most enduring character.—Yours faithfully, G. MacLeod Ross.

Colonel C. A. Landale, BA
Headquarters
Royal School of Military Engineering
Chatham, Kent

12 January 1972

## ENGINEER INTELLIGENCE

Sir,—For years, even generations, the Corps has taken upon itself the responsibility for providing intelligence (or information) about ground or terrain. I would submit that this self-imposed task is one which should properly be undertaken by All Arms with the guidance and coordination of the General Staff.

Engineer Intelligence is surely that information needed by Engineers in order to carry out engineer tasks. This may indeed involve some knowledge of ground and terrain, but that knowledge is likely to be specific to the task in hand and limited to the area in which it has to be performed. Thus the immediate approaches to and from a bridging or rafting site require specific engineer intelligence. The nature and conditions of the actual banks of the gap to be bridged require even more detailed information which is engineer intelligence. Such information is required specifically by engineers and not by other arms and services in the Army.

Of course information is needed by All Arms about going and routes (their state and load classification), but this is Combat Intelligence and should be sought by the General Staff in their normal course of duty. Naturally the General Staff may seek the advice and expertise of the Corps to obtain the information that they want. But the General Staff should also realise that it is quite impractical to expect the Corps to produce the answers that they want at the "drop of a hat". As Major Gisby said in his article, there is no shortage of material. There is in fact an unlimited quantity of material. The General Staff should state what they want to know and then task the agencies under their control to find and collate this information. It will then become apparent—very quickly—that the task cannot be performed solely by engineers, (unless, possibly, all other engineer work ceases while engineers are deployed almost entirely on ground reconnaissance) and that there are many other agencies already and automatically deployed who can provide the information needed. In particular I refer to the reconnaissance elements of all Mechanized Battalions and Armoured Regiments. In these days every soldier, particularly those driving a vehicle, whether wheeled or tracked, is an additional source of information, and can provide a mass of detail intelligence on ground conditions, routes, going and the like. This is not Engineer Intelligence but Combat Intelligence required by, and of interest to, All Arms.

The Corps may indeed be tasked to collate and even disseminate this sort of intelligence, but it cannot do so on its own. I have heard it said that a Squadron Commander in Germany is required to hold and maintain up-to-date ground intelligence about the whole of 1 (BR) Corps Area. Surely this is nonsense? I would, therefore, submit that we must accept three basic precepts:

(*a*) Engineer Intelligence is that required by Engineers for use only by Engineers.
(*b*) The responsibility for stating what Intelligence is required about ground or terrain is that of the General Staff who must allocate all possible agencies to collect the information required.
(*c*) All Arms have a part to play in the collection of what in the past has been called Engineer Intelligence, but which is information about ground which is Combat Intelligence.

There is so much potential information about ground, much of which changes daily with changing weather conditions, that the staff must state what they want to know. An appreciation can thus be made of all available resources to find the necessary information and then a plan can be made to use modern technical facilities to hold, record and disseminate what is needed. The Corps will obviously have a major part to play in this process but it is, I suggest, wrong to expect the Corps to carry this baby on its own any longer. No wonder the baby, prematurely born, does not thrive!—Yours faithfully, C. A. Landale.

# Memoirs

## LIEUT-GENERAL SIR HAROLD WILLIAMS, KBE, CB, C Eng, FICE, MIE (Ind), MIS (Ind)

Colonel Akbal Singh, Commandant Bengal Sappers, presenting a momento to Lieut-General Sir Harold Williams, KBE, CB, at the Regimental Dinner, held in his honour, in the Roorkee Mess on 16 Mar 70

LIEUT-GENERAL SIR HAROLD (BILL) WILLIAMS who, in the days of the British Raj and after Independence, had devoted almost a lifetime of service to India died at Mussoorie on 17 October 1971, aged 74.

Son of Hillas Williams of Douglas, Co Cork, he was educated at Mountjoy School, Trinity College Dublin and the RMA Woolwich and commissioned in the Royal Engineers on 28 September 1917.

After a shortened Junior Officer Training Course Williams was posted to India and joined the 51st (Field) Coy KGVO Bengal Sappers and Miners, then serving with the Aden Field Force. After short leave in the UK and a two-year period at Roorkee he was recalled to the UK in October 1923 for the RE Supplementary Course which included a year at Gonville and Caius College Cambridge followed by a short spell at the RE Mounted Depot Aldershot. In 1927 he was back again at Roorkee where, after a further series of Depot duties, he was appointed Corps Adjutant in 1929—an onerous post which he filled with marked distinction and ability, recognized by a brevet majority.

In 1933 Williams moved to the Indian Military Academy, Dehra Dun as an



Lieut General Sir Harold Williams KBE CB C Eng FICE MIE (ind) MIS (Ind)

Instructor, and three years later to the Thomason Engineering College Roorkee as Professor of Civil Engineering with the specific charge of the Junior Indian Engineer Officer students. The College later became the Roorkee University of which Williams was awarded in 1970 the honorary degree of Doctor of Engineering.

On transfer to the Home Establishment shortly before the outbreak of World War II, Williams was appointed CRE 1st Armoured Division of which the Support Group, comprising the RE HQ and the 1st Field Squadron, went to France in 1940 and joined up with the 51st (Highland) Division after the German break-through. Williams and some other members of the RE HQ and part of the Squadron were evacuated from Le Havre and Fécamp the remainder unfortunately being captured at St Valery.

In 1942 Bill was back in India and, on a fleeting visit to Roorkee, met the complete Orderly Room Staff of 1932 miraculously assembled to meet their former Corps Adjutant.

From June 1943 to August 1944 Williams was Chief Engineer IV Indian Corps during a period of desperate struggle in Upper Burmah: then Brigadier Engineer Staff at E-in-C's HQ New Delhi and later Commandant of the Indian School of Military Engineering.

In 1948, following Partition, the Governments of India and Pakistan asked for a quota of RE Officers to stay on and assist in the organization of their respective Engineer Corps. Williams, now a Major-General, was selected as E-in-C. India and held that appointment until his retirement in 1956 with the Honorary rank of Lieut-General in the Indian Army and that of Colonel Commandant, Indian Engineers 1951–1958.

Always a keen mountaineer Williams led in June 1952 an Indian Engineer Himalayan Expedition that so nearly reached the summit of Kamet (25,447 ft). Two years earlier he had been a member of the Gibson party which first climbed Bandar Pünch (20,720 ft). He continued to spend much of his time in India, and immersed himself wholeheartedly in other activities, professional and otherwise in the service of the country and the people he loved. He became Director of the Government Building Research Centre at Roorkee for seven years: Advisor to the Council of Industrial and Scientific Research, India, and later Consultant to the Planning Commission India under the Colombo plan. He also served a period as President of both the Institute of Engineering (India) and Institute of Surveyors (India).

In the United Kingdom Bill Williams was a Corporate Member of the Institution of Civil Engineers, a Member of their Council for two periods and attended their functions whenever possible. Within the Corps he maintained a most lively and enthusiastic interest in its technical activities and social functions and, for the particular benefit of those who had served in India, his annual newsletter provided a much valued and welcome link which will be sadly missed.

In the course of his stay in the UK this year, Bill was present at the unveiling ceremony by Her Majesty the Queen of the Memorial Plaque to the Indian Army in St Paul's Cathedral. He visited Chatham to hand over a number of albums of photographs and other records relating to the Bengal Sappers and Miners to the Corps Library and also went to Weymouth to see the historian of the Military Engineer in India—Lieut-Colonel E. W. C. Sandes—for whose book *The Indian Engineer 1939–47* he had written a fine foreword.

Bill was well aware of the dangerous condition affecting his heart but he would not allow this to deflect his purpose in any way and he died "in harness" as he himself would have wished. Greatly revered and respected he was buried with full Military Honours accorded by the Bengal Group, Indian Engineers, and with full Masonic Honours, at Roorkee where he had spent so many happy and eventful years.

In a letter to the Chief Royal Engineer, the Engineer-in-Chief India referred to his personal friendship with "Bill" extending over 31 years and the affectionate regard in which he was held by all with whom he came in contact and added that a headstone or memorial plaque would soon be erected by the Corps of Indian Engineers to commemorate his close association with them, to which the Chief Royal Engineer replied "I and all in the Corps are deeply grateful to you and to the Corps of Engineers for paying your respects, as you did to 'Bill' Williams. It was splendid of you to organize a military funeral at Roorkee and now to think of erecting a headstone or memorial plaque to commemorate his close association with the Corps of Engineers. 'Bill' Williams was a great man, and will be sorely missed both in India and here."

And so "Bill" ended his "service" where it began leaving many to mourn his passing but to rejoice in an unforgettable memory of steadfast friendship.

Lieut-General Sir Clarence Bird writes:

At a very early hour one morning in 1917—when communications of every kind were understandably uncertain —a somewhat bewildered young officer, 2nd Lieutenant H. Williams, RE, later known to us all unforgettably as "Bill", appeared at my bungalow to be greeted by me, as Corps Adjutant, on his first arrival at Roorkee. Some fifty-four years later, just before he left on what was to prove to be his last return to India, my wife and I joined him for a farewell luncheon in London.

On taking up my appointment as Commandant in 1930 it was my very good fortune to find Bill occupying the Corps Adjutant's chair, and it was during the following three eventful years that I had ample opportunity and occasion to appreciate his outstanding qualities of loyalty, transparent honesty of purpose, sound common sense and a shrewd ability to solve problems, all combining to establish confidence and mellowed by a keen sense of humour. But the impetus that lay behind the application of all these attributes was the dedicated spirit of kindly helpfulness that permeated the whole web of his life, and extended over the broad range of his activities, professional, social and humanitarian alike. This is evident throughout all the tributes to him from a wide circle of brother officers in the corps, the Engineer-in-Chief India and the three Groups of Indian Engineers, the High Commissioner for India and the Masonic Fraternity.

Examples of Bill's versatility are shown by his sponsorship of the Himalayan Mountaineering Institute of Darjeeling, the Society for the welfare of backward Indian children in New Delhi of which he was a founder member and his interest in bird watching. He always managed to find time for everything and everybody.

We who enjoyed his buoyant friendship now pay our tribute to Bill, fortified by the ineffaceable memory of his endearing example. "SALUT."

Major-General R. L. Bond writes:—

"Bill" Williams as he was known to us all was an outstanding character, who devoted his life to the service of India and since the last war has done more than anyone to enhance the British reputation in many spheres in that country.

He re-joined the Bengal Sappers & Miners in the 1920's and was under my brother, then Superintendent of Instruction, at Roorkee. I know what a high opinion my brother had of him and the affection in which he was held by his brother officers. In the last war he was one of my senior staff officers in the Engineer-in-Chief's office. His great burly figure, infectious good humour, his great knowledge of the Sappers and Miners and of India, his wisdom and his serenity made him an invaluable and affectionately admired member of our team. Having attained the rank of Lieut-General before retirement he subsequently spent the greater part of his life in India in the service of the Indian Government. On more than one occasion when he wished to retire the Indian Government urged him to stay on in Delhi.

To the end of his life he maintained close touch with the Bengal Engineer Group and was a constant and highly appreciated visitor at Roorkee as the half-yearly news letters from the Group always testified.

The warmth of Bill's character and his unqualified friendliness will be deeply missed by all of us who had the privilege of his friendship.

Finally it should be recorded that he was an outstanding Freemason. As Deputy Grand Master in India when Indian Freemasonry received its own constitution, he did more than any man to smooth the transition from the English to the Indian Constitution. He accompanied the Grand Master of India to England when India sent a deputation to be present at the various functions marking the 250th anniversary of the Grand Lodge of England in 1967. In this sphere too he will be an irreplaceable loss to Anglo-Indian relations, and to a wide circle of friends.

Brigadier L. O. Clark writes:

I was privileged to be a friend of "Bill" Williams for over fifty years. We joined together as GCs in November 1916. At The Shop Bill was already an individual and unusual character. He was a Southern Irish Protestant, and came to us from Trinity College, Dublin. He was taller than most of us, and looked considerably older. He conformed with discipline, but did so with a disarming air of independent toleration and humour.

Our Batch (Barker's) was commissioned in September 1917, and posted to Chatham, where he and I shared a quarter. From there Bill was posted to India and thence to Aden, and our ways parted temporarily.

After the war we met again in the Bengal Sappers and Miners at Roorkee. Here Bill made his mark, and, I think, discovered his vocation. He was not a good linguist, but had a wonderful faculty for friendship and mutual respect in dealing with Indians of all creeds and levels of society, princes and politicians, soldiers and servants. Even then he was convinced that India should some day gain her independence, and consciously sought to help in any way that he could. As recreation he played polo, tennis, and stické, but his favourite pursuits were shooting in the Meerut jheels and Siwalik forests, and climbing in the Garhwal Himalaya. He was a keen Freemason, and was already interested locally, a work which was to expand much more widely later.

In 1923 we were recalled for a Supplementary Course at Cambridge and Chatham. Bill and I were allocated to Caius, and shared lodgings in Peas Hill. Bill was always a good participator, and he made the most of his opportunities at the University. He played Rugger for Caius. With the true Irishman's love of oratory he attended most Cambridge Union debates. He was a fair pianist, and went to any performance by well-known pianists, and to the theatre whenever there was a good play on.

Together we joined an institution peculiar to Caius, the Raleigh Club, whose entry qualification was birth outside the United Kingdom. Bill, with tongue in cheek, successfully claimed that Southern Ireland was not part of the United Kingdom. At Cambridge he continued to pursue his Masonic interests.

At Chatham he was one of the outstanding personalities of our Supplementary Class. It was here that another facet of his character emerged. He treated women of all ages with a charming mixture of Irish blarney and Victorian courtesy. In our batch sweep on who would marry first, Bill was unanimously chosen. But we were wrong; he never married.

On return to India Bill became a much respected Adjutant of the Bengal Sappers. For my return, married, from leave Bill laid on for us all the amenities possible in a cantonment of that period. He went further. With his irrepressible love of a harmless jest, he ordered one of the Corps elephants to parade on our first evening, to carry us, in evening dress, by way of the Mess, to dine with the Lethbridges. A new bride in India would not appreciate (till later) that the Lethbridges lived next door, and that there were more usual ways of going out to dinner. During these years Bill kept in close touch with the staff of the Thomason Civil Engineering College, and got to know leading Indian scientists and engineers.

Later he became an Instructor at the Indian Military Academy, Dehra Dun, and established an easy friendship with nearly all those young Indians, who were to become the leaders of India's forces after Independence. These were the years which laid the foundations of his later work on behalf of Independent India.

Our ways parted in 1939, but we met again in India after the war. From then on, as a senior Engineer officer, as Director of the Building Research Institute, and in retirement, he followed his chosen interests, Himalayan climbing, helping and advising Indians whenever asked, furthering the cause of Indian Spastics, and guiding the growth of the newly-constituted Grand Lodge of Indian Freemasonry, whose tenth anniversary in November 1971 was just too late for his participation.

The death in 1969 of his sister Ethel, a great personality in her own sphere as housemistress at Sherborne, affected him deeply. He continued to use her flat as his home base in the summer, returning to India every autumn.

It was here that my wife and I periodically renewed our long-standing friendship with Bill, the final occasion being only a month or so before his death. He was the godfather of our son. His death was a sad blow to us all, but his life will remain a very lively, happy memory.

REH writes:

Bill Williams's outstanding quality of kindness was exercised in full in the years just before and after Independence when the respect and affection in which he was held made those working under him do their best. The success with which young officers of the Indian Engineers met and continued to meet challenges of heavy work and responsibility could be attributed to Bill Williams's influence in their early years and his guidance and sympathy at the time. Bill's activities and interests seemed innumerable. He made time for all, remaining always majestically unruffled. He was a generous host and fascinating companion at all times, in a crowded room or in the mountains. One hopes that a large and genial ghost may long carry field-glasses along the Solani and beside the canal, observe the distant snows, and contemplate the progress of the institutions which he fostered so devotedly in Roorkee.

* * * * *

MAJOR-GENERAL A. T. de Rhé PHILIPE, CB OBE
COLONEL COMMANDANT ROYAL CORPS OF TRANSPORT

MAJOR-GENERAL ARTHUR TERENCE DE RHÉ PHILIPE, a distinguished Movements Staff Officer, died in Warminster Hospital on 10 October 1971.

The son of George William Vitalli de Rhé Philipe of the Indian Public Works Department, he was educated at Cheltenham and the Royal Military Academy, Woolwich and was commissioned into the Royal Engineers on 3 September 1925, the day after his twentieth birthday. During his Young Officer training he went to Clare College Cambridge as an undergraduate. His first posting after completing his YO course was to the Railway Training Centre, RE at Longmoor and he was to spend the greater part of his service thereafter in Movement Control and Transportation duties. Whilst at Longmoor from 1929 to 1933 he served in the 8th and the 10th Railway Companies, RE.

Major-General A T de Rhe' Philipe CB OBE
Colonel Commandant

Posted to Malaya in October 1933 he became Garrison Engineer Tikong for a year and then Garrison Engineer at Changi.

He returned to the home establishment in 1937 and was posted to the QMG Department at the War Office then engaged in deliberate preparations for the vast Movement Control problems that an inevitable war would produce.

de Rhé Philipe spent the whole of the Second World War in Movement appointments. At the outbreak of war he was a Staff Captain in QMG 13 Branch at the War Office. At its conclusion he held the rank of Brigadier as Deputy Quartermaster General (Movements) in Italy. Between these two appointments he was employed on the Movements Staff of the Combined Operations Training Staff and the preparation of Operation TORCH—the landings on the North African coast by British and American Forces after a "long sea voyage" from the United Kingdom Base, the campaign in North Africa, the invasion of Sicily and the Italian campaign. For his war services he was awarded the OBE in 1943 and created CB in 1944. He was also awarded the American Order of Merit.

Returning home after the war he became Deputy Director of Movements (freight) at the War Office and in 1948 he was selected to attend the Imperial Defence College. On graduating from there he was posted as Director of Administrative Planning at the War Office after which appointment he became in 1951 the Brigadier General Staff at Scottish Command. In November 1953 he assumed his last appointment that of Director of Movements at the War Office, a fitting culmination to a distinguished career. He retired on 5 December 1955.

As a result of the McLeod reorganization a Royal Corps of Transport was formed from the Royal Army Service Corps and those Royal Engineers experienced in Movements and Transportation duties. Major-General de Rhé Philipe as a Director of Movements, had been consulted by the McLeod Committee during their deliberations and on 31 December 1964 he was appointed a Colonel Commandant Royal Army Service Corps and later a Colonel Commandant Royal Corps of Transport when that new Corps was born on 16 July 1965.

In 1939 he married Moira Evelyn, daughter of Captain Alexander Leckie Cameron. They had two daughters. Our deepest sympathies are extended to his widow and family.

C.A.S. writes:

Terence de Rhé Philipe was one of five Old Cheltonians in 14 YO (C. P. Jones's) Batch—a Batch which included three other future general officers. By his absolute integrity, his cheerfulness, his friendliness and helpfulness to everyone, including those who differed from him in outlook and temperament, he made a big contribution to the happy progress of a close-knit Batch through the SME and Cambridge and finally on the Mounted Duties Course at Aldershot.

He bore uncomplainingly the results of a thigh-break sustained when tackled against a goal-post whilst scoring in a Cheltenham inter-house rugger cup match. This handicapped him at games both at the "Shop" and at Chatham and Cambridge.

His career as a Movements Sapper limited his contacts with his Field Unit and Works contemporaries. It was, however, always a pleasure to meet again someone whose unaffected friendliness was absolutely untinged by any awareness of the distinguished wartime and post-war career which had been well earned by his quick brain and practical common sense.

During retirement he became Director of a West-Country engineering firm, and settled at Upton Scudamore near Warminster where he took an active part in local and parochial affairs.

A memorial service was held in Upton Scudamore Parish Church on 15 October 1971, which was attended by the Chief Royal Engineer, Sir Charles Jones and Lady Jones and other Sapper Officers and their wives as well as many other colleagues, friends and neighbours.

Major-General Sir Noel Holmes, KBE, CB, MC, Late Deputy QMG (Movements) writes:

The sudden death of de Rhé Philipe has come as a personal sorrow to all his friends in Movement Control.

I myself had known him, and worked in close touch with him, during the war years 1939/45. He joined me in Movement Control at the War Office in 1939 as Staff Captain in QMG 13 and his work and ability were quite outstanding at all times. He was ever cheerful even when hours were long and troublesome. He certainly was a devoted servant of Movement Control.

When the 1st Army were forming for the North African landings in 1942 Rhé was put forward by me as T/Colonel in charge of Movement Control 1st Army. It was said by the then Powers-that-Be that he was too young (then 37) for the appointment. However my recommendation was approved. How right we were in the appointment, which was proved by Rhé's ability and the success of Movement Control in North Africa and Italy.

He was an officer of outstanding character in which kindness, unselfishness and integrity were only three among his many virtues. Perhaps above all he was remarkable for his understanding of the difficulties of other officers both in and outside the Movement Control organization which was a very young organization in those days.

He was a most stimulating and forward looking officer with whom to work. He had innumerable friends in the Services and I am certain he never lost one during his Service.

* * * * *

COLONEL N. E. L. PEARSE, MC

NAPIER EDWARD LEWIS PEARSE was born on 12 January 1895, the son of Colonel Napier Pearse, Sherwood Forresters. He was educated privately.

He joined up at the age of 19 at the beginning of the First World War and was granted an Emergency Commission in the Royal Engineers. He was posted to France in 1915 and served with the Sappers until the Armistice in 1918. During his service there he was mentioned in despatches, decorated on the Field with the Military Cross for gallantry and distinguished service and became an acting captain.

On the conclusion of hostilities he was granted a Regular Commission as a Lieutenant in the Royal Engineers, backdated to 1 July 1917. He was then posted to India, where he joined the Madras Sappers and Miners in Bangalore. He returned to Chatham in 1922 for his Supplementary Course, after which he spent a year as

Colonel N E L Pearse MC

Garrison Engineer, Holywood, Belfast. He was then again posted to India where he served with the Madras Sappers, as Garrison Engineer Delhi, Technical Officer (Works) at Naini Tal in the United Provinces, and as Garrison Engineer on the NW Frontier at Manzai and at Razmak.

He returned to the Home Establishment on promotion to Major in 1933, when he commanded 7 Field Company RE, then stationed at Colchester. In 1935 he went to London District as a DCRE (Works) for a year, before returning once more to India for a third tour of duty.

From January 1936 to July 1937 he was Garrison Engineer for a second time at Razmak, and was then sent to Quetta to help with the reconstruction work there after the earthquake disaster of May 1935. In 1937 he returned to Bangalore to command a Company of Madras Sappers.

In 1940 he was posted home, on promotion to Lieut-Colonel, and was appointed CRE South Highlands Area in Scottish Command. In October 1942 he was moved further North as CRE Orkneys and Shetlands. On promotion to Colonel in November 1943 he was posted as Deputy Chief Engineer South Midlands Area in Oxford. From April 1944 to February 1946 he was Chief Engineer Highlands District.

His last years of service were spent as a CRE works in India, until he retired at the end of 1948.

After retirement he toured the world and spent some time in South Africa before he settled down to live in London. In 1957 he met, and married, Mrs Patricia Kane, the widow of R. W. H. Kane, Esq, and with her lived for many years at Rivermead Court, Hurlingham. He died suddenly in his home on 26 June 1971, leaving his widow to survive him to whom our sympathies are extended.

D.C.T.S. writes:

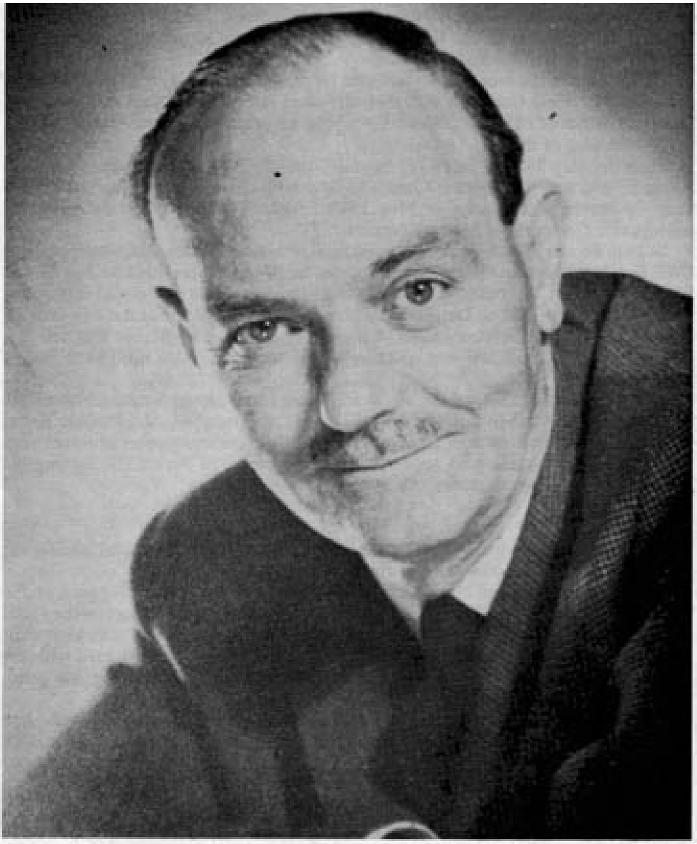
Those who served with "Attie" Pearse, will always remember him for his unfailing good humour, and kindliness in all circumstances.

He spent many years of his service in India, both with the Madras Sappers, and in the Works Organization. Wherever he was stationed he took a full part in the social activities of his Mess and of the Station. Although not blessed with "with an eye for a ball", he played hockey with the troops, and "Station" polo; he hunted with the local hounds, and went out shooting in the cold weather. He was always a good, and an amusing companion.

As a Garrison Engineer on the NW Frontier of India for many years, his approach to his problems was always individualistic and sometimes unorthodox! This attitude stood him in good stead in his dealings with his Pathan Contractors and labour force and he was able to get more work done by his perhaps eccentric methods than a more Regulation-bound officer could hope to achieve.

As he grew older, as a bachelor, he led a somewhat lonely existence and became shy and retiring. All this, however, changed after his marriage. He settled down to a period of great happiness, living a full social life, and making a large circle of friends, who will remember his kindly and friendly nature and his always unfailing courtesy.

* * * * *



## LIEUT-COLONEL F. T. STEAR

WITH the passing of Fred Stear we all lost an able colleague, many of us lost a true friend and the Corps lost a loyal and willing servant.

Lieut-Colonel Frederick Thomas Stear gained his success the hard way. He joined the Army as an Apprentice Tradesman, at the age of 14, in the Royal Tank Corps, but soon transferred to be an RE Boy at the School of Electric Lighting at Gosport.

His original ambition was to be an artist, as he showed great promise in this subject at school and won a scholarship to an Art College, but his father, a down-to-earth Devonian could see little future in such a way of life, so Fred had to buckle down to learning electrical and mechanical engineering.

He passed a Military Mechanist course at Chatham in 1934 and was promoted S/Sgt. Before the 1939 war he served in Ireland and Singapore, one of his jobs in Singapore being the installation of the heavy naval guns which formed part of the seaward defence of the island.

Lieut Colonel F T Stear

In the peaceful days before 1939 Fred was a keen sportsman, excelling at hockey at which he represented the Corps, and he retained his interest in sport for the whole of his life.

He was first commissioned in 1942 and, naturally enough, was employed in the main on electrical and mechanical duties. As a Captain he joined HQ 21st Army Group and went with them to France where he was employed on the job of putting back into working order the power station and electrical distribution system at Caen. Later he was employed in the Antwerp docks on similar work. In 1945 he was mentioned in despatches.

He was granted his regular commission in 1946 and then went on a Regular Officers' Supplementary Course at the SME. Afterwards he held Staff Officer RE appointments before becoming the Trades Training Officer in 10 Regiment at Chatham. Finally he commanded what is now the Depot Regiment RE.

It was during this appointment that the Sappers were called upon to help in the East Coast flood disaster. It was typical of Fred that he should elect to undergo all the privations that his men had to suffer. As a result of long hours spent cold and wet through he contracted a serious chest complaint that put an end to his service career and was to cause him pain and discomfort for the rest of his life.

He retired because of this disability and, after a long period in hospital undergoing a very serious operation, with his customary courage he took up the reins again to build a career in civilian life.

After a short spell with an engineering firm the opportunity arose for him to take a Retired Officer post in the Corps of which he was so proud. He joined the staff of the RSME and, with his usual enthusiasm, threw himself whole-heartedly into the job.

He was hardly fair to himself. He was far too conscientious for the good of his own health. Only the very best was good enough for him, and he drove himself to this end. In the ten years he was with us he never spared himself—nor did he ever use his poor health as an excuse for doing less than his best.

He was always smart, and upright in stance—and he was upright and straightforward in all his dealings. There was nothing mean or petty about Fred—if he could not say anything good about a person he kept quiet. He was proud, and rightly so, that if he undertook to do anything it would be done well. He had pride of workmanship and could recognize work well done—and he was humble enough to accept the advice of others.

He was a friendly man with a vast store of patience that allowed him cheerfully to pursue even the most trivial of problems.

He was a loyal man, proud of the Corps to which he belonged and to which he gave so much of his life. He was loyal to his friends, to those he worked for, and to those he worked with. He had time to listen to other people's troubles and the kindness to offer them his always sensible advice.

By nature he was quiet and reserved but he had a good sense of humour—and a Devonian streak of stubbornness when he knew he was in the right.

Despite increasing pain he drove himself on and would never give up—on our after-lunch walks from the Officers' Mess to the library he would often have to stop two or three times to recover himself—but he would not use his physical condition as an excuse for shirking his duties.

His achievements as Manager Corps Publications, as Corps Librarian and as Secretary of the Royal Engineers Historical Society will be long remembered.

He was a devoted family man and his wife, Kathleen, his daughter, Sylvia, and his two grandchildren gave him great pleasure and comfort. We hope that time will alleviate their grief and that they will remember with pride that here was a good man, a brave man, a man who took great pride in his work, and one who has set a good example for those coming after.

H.J.

BRIGADIER GENERAL W. HENSELWOOD, DSO, CD

EDWARD W. HENSELWOOD was born in Winnipeg on 14 September 1915 and was educated at St John's College and the University of Manitoba.

Brigadier General W Henselwood DSO CD

He enlisted in the Royal Canadian Engineers in 1939 and served in Canada and Britain with various engineer units until 1944 when he was given command of the 9th Field Squadron. During the invasion of Normandy in 1944 he was wounded, returned to action, and won the Distinguished Service Order for leadership in the Northwest Europe campaign.

He was promoted to Lieut-Colonel in 1945 and appointed to headquarters 1st Canadian Army. Later that year, he became Commander Royal Canadian Engineers at headquarters 2nd Canadian Infantry Division.

He left the army after the war but returned to the active force in 1948. He served at headquarters Central Command, Oakville, Ontario as a staff officer with headquarters, Active Force Brigade Group, and in 1951 was posted to army headquarters. In February 1952, he was appointed to the directing staff of the Canadian Army Staff College, Kingston, Ontario.

He returned to army headquarters in 1954 as assistant director of works (engineering) in the office of the chief engineer. From 1958 to 1959 he was a liaison officer with the US Army Chemical Corps in Maryland. A military attaché appointment in Bonn, Germany followed and, in August 1962, he became director of financial management at Canadian Forces Headquarters, Ottawa.

In December 1964, he became director of establishment production at CFHQ and director general of works in July, 1965. He was appointed deputy chief of construction engineering in April, 1966.

He was from 4 November 1968, until his retirement on 24 September 1970, the Corresponding Member of the Council of the Institution of Royal Engineers for Canada, and he retained his membership of the Institution after retirement.

He died at the National Defence Medical Centre, Ottowa on 2 December 1971.

* * * * *

# Book Reviews

## BRMCA GUIDE 1971

(Published by British Ready Mixed Concrete Association,
Fir Tree Place, Ashford, Middlesex. Price £2)

The book contains an introduction to the origin aims and organization of the BRMCA together with names and addresses of suppliers.

Standards and practices of production and control are detailed for authorized depots producing Ready-mixed concrete. Much of this detail can be applied to site produced concrete, and is covered under the headings of:

- Personnel
- Materials
- Plant and equipment
- Materials storage and handling
- Batching Plants
- Measurement of materials
- Mixing
- Control of concrete in the wet state
- Documentation
- Quality control procedures
- Quality control analysis

A glossary of Ready Mixed Concrete terms is included. A check list of British standards and BSCP is included and this list is applicable to site work as well as RMC. Full coverage is given to specifications for RMC, much of this information is of the type required on sites whether using RMC or site produced concrete.

Enquiries and ordering procedures for RMC are given in detail. This forms a good check list for personnel planning and organizing concreting projects of all types. Information is included on transportation, handling, and placing of concrete to and on sites. Notes on concreting in cold weather is helpful whether using RMC or site-produced concrete. Sampling and testing of cubes is well covered, and applies to all concreting jobs.

The guide is primarily for use in ordering and using RMC but much of the information given is applicable to concreting work wholly carried out on site. It would assist planners, organizers and quality controllers, on all concreting jobs and is a "must" if RMC is being used on a particular job.

B.J.P.

# Technical Notes

## CIVIL ENGINEERING

*Civil Engineering and Public Works Review*, October 1971

TEMPORARY AND EMERGENCY PUMPING EQUIPMENT. In this three-page illustrated article, Mr H. P. S. Paish, Chairman and Managing Director of Henry Sykes Ltd, traces the history of contractors pumps and brings the reader up to date with the various types of pump available today. For anyone who has to remove large quantities of unwanted dirty water from excavations or for flood relief the article is of considerable value.

THE ROLE OF THE INSPECTOR IN THE PROTECTIVE COATING OF STRUCTURES. Although we all realize the importance of inspection at each stage during any painting operation, Mr F. G. Dunkley, Consultant to British Inspecting Engineers (Anti Corrosion) Ltd, describes the essential points and quantifies the improvements which can result from full inspection. Put another way, he shows what is lost by inadequate inspection. To borrow a phrase, it seems that whether or not you carry out inspection you nevertheless pay for it.

NEW TECHNIQUE FOR UNBONDED TENDONS. W. W. Young and R. Irons of Stirling Maynard and Partners describe a new system of unbonded tendon prestressing to be used on the proposed Huntingdon Bypass bridge over the River Ouse. Macalloy bars are coated with grease and then a plastic Thermofit sheath is slid over and shrunk in place by gentle heat. Advantages claimed for the system are bar protection during storage and erection, easier handling, continuity of protective cover and reliable concrete proof connections for couplers and anchorages. Compared with a greased tape which gives a bond stress of 0·012 N/mm², this system has a bond of no more than 0·002 N/mm².

W.C.C.

*Civil Engineering & Public Works Review*, November 1971

ST GOTTHARD ROAD TUNNEL. Although a railway tunnel was driven a hundred years ago from Airolo to Goschenen, motorists have to cross the St Gotthard pass nearly 1000 m higher than the villages involving a very tortuous route. Work on the road tunnel was started in 1969 and it is expected to be open for traffic in 1978. After a slow start due to poor rock (Tremola Schist) the heading is now being driven full face i.e. 90 m². Two Atlas Copco Promec T219 rigs each with four booms are used for drilling. The tunnel direction is controlled by four laser beams and 108 holes are drilled for each round. The sequence of drilling charging and blasting takes 3½ hours and mucking is accomplished by two CAT 980 Loaders. A feature of the work is a 241 m long sliding floor and a 39-m long cover bridge which avoids much of the danger from falling rock and assists with scaling, rockbolting and shotcrete treatment. Three rounds are fired daily and currently the daily advance of 10·5 m.

W.C.C.

## THE MILITARY ENGINEER

SEPTEMBER–OCTOBER 1971

An army only fights as well as it is allowed to, and logistical support is always a problem. An article entitled "Army Mobility for Logistical Support" considers this problem and discusses current types of equipment in use in the American Army, it considers recent developments in commercial transportation and finally deals with new logistical support hardware to meet the distribution systems demands.

An article on "Blast Effects on Strategic Structures" describes the equipment developed by the Army Engineer Waterways Experiment Station for experimentally obtained blast and shock effects data associated with the detonation of nuclear devices. Some experiments, using this equipment, are described.

Not of great engineering interest, but of general interest to the soils expert is a brief article on "Lunar Soil Mechanics".

In the field section there are notes on the construction and positioning of a submerged pipeline Installation and the design and construction of gun pads in Vietnam.

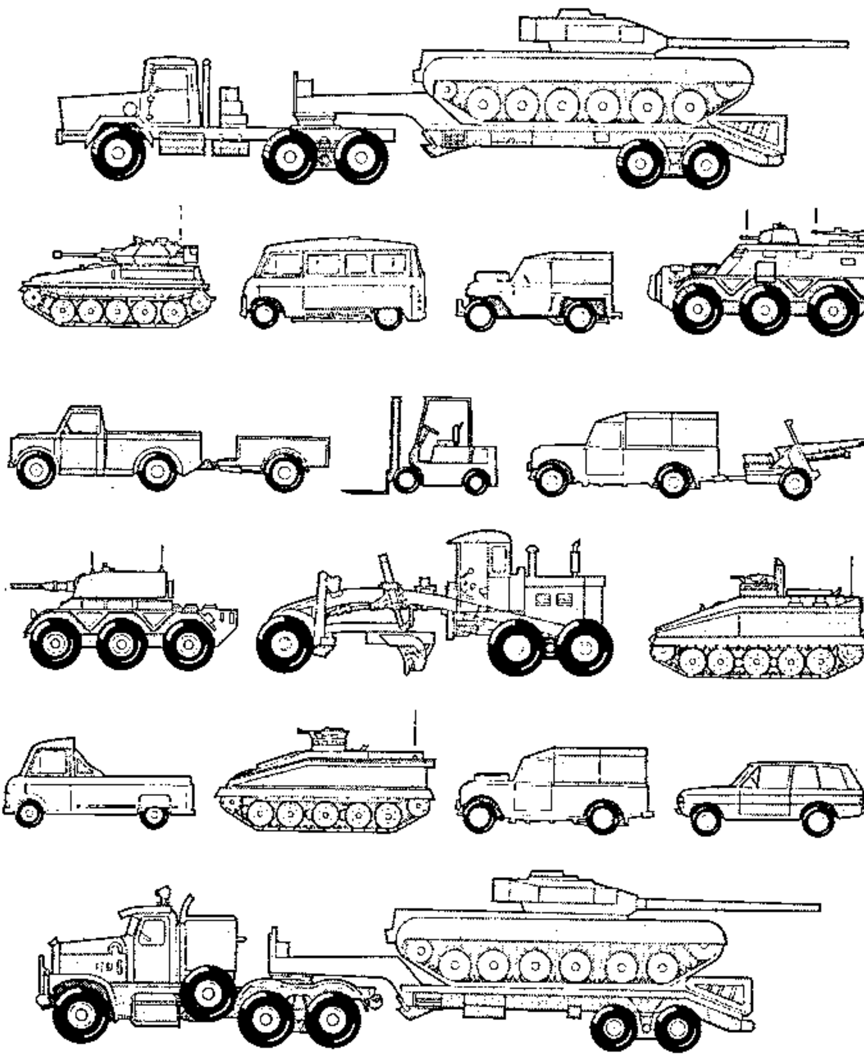
"Long Bridge at Bong Son" deals with the construction of a 1,634 ft long bridge with a 24-ft wide roadway. The work was planned on a CPM analysis which showed up welding and crane deficiencies and allowed these areas to be controlled. The construction operations are described and the bridge was completed in under 8 months.

For the tunnelling enthusiast there is a general article on "Tunnel Drilling for the Carters Project". This deals with the construction of a diversion tunnel and 4 penstock tunnels during the construction of a 450-ft high rock filled dam.

M.F.R.C.

# Forthcoming Events

| | | |
|---|---|---|
| 6 March | Parade to Commemorate the Bi-Centenary of the Formation of The Soldier Artificers | Gibraltar |
| 18 March | RE Hunt Ball | RE HQ Mess |
| 23 March | REYC AGM and Dinner | Brompton Study Centre and RE HQ Mess |
| 24 March | Branch Meeting Institution of Royal Engineers | Newcastle |
| 15 April | RE Dinner Scotland | Edinburgh |
| 21 April | Branch Meeting Institution of Royal Engineers | Cambridge |
| 30 April | Memorial Service and Luncheon | Rochester Cathedral and RE HQ Mess |
| 1 June | 48 YO Batch Night | RE HQ Mess |
| 28 June | Corps AGM and Dinner | London |
| 29 June | Colonels' Commandant RE Garden Party | Hurlingham |
| 7 July | Summer Ball | RE HQ Mess |



# BRITISH LEYLAND MILITARY VEHICLES

## *Back-bone of the modern army*

An army today must be totally mobile. As well as armoured vehicles, it needs transporters to carry them, heavy lorries and transport of every shape and size for the movement of troops and equipment, fork lift trucks to relieve man power, road making equipment to smooth out difficult terrain.

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# Articles for the Journal

The *Journal* depends for its existence on articles submitted for publication on historical, professional and technical subjects of interest to Military Engineers.

They may be of any length, but preferably not more than 6,000 words. They should be typed in duplicate on one side of the paper only, double spaced with one-inch margin. A third copy should be retained by the author for checking with proofs.

Photographs to illustrate an article should be black and white prints on glossy paper. Usually not more than four photographs will be published to illustrate each article. More photographs may, however, be submitted from which the Editor will make a selection. The size of the photographs does not matter as they can be reduced in size for publication. Line drawings, maps, etc must be in black ink, and all lines, lettering, etc must be bold and clear to allow for reduction in size when reproduced. Scales must be drawn and not worded.

The copyright of all articles published in the *Journal* is assigned to the Council of the Institution of Royal Engineers.

Payment for articles is at a rate decided by the Publications' and Library Committee. An extra £10 award is made at the discretion of the Committee for articles of particular merit published in each issue of the *Journal*. In addition two prizes, the Montgomerie and Arthur ffolliott Garrett Prizes, are awarded each year for outstanding articles by RE officers, not above the rank of substantive major, published in the *Journal*.

Articles may be submitted at any time and correspondence is always welcome. However, the following dates are normally the latest for inclusion in the issues shown:

| | | | |
|---|---|---|---|
| March issue | 1 December | September issue | 1 June |
| June issue | 1 March | December issue | 1 September |

For articles requiring clearance attention is drawn to Military Security Instructions Part 1 Army Code No 14610 Appendix B to Chapter 5.