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Presentation of the Queen's Challenge Cup to 432 (City of Edinburgh) Corps Engineer Regiment (TA)

(Photo reproduced by courtesy of Photo Illustrations, Scotland)

Presentation of the Queens Challenge Cup to 432

Corps Notes

THE year 1962 which lies ahead will witness several famous Sapper anniversaries. On 23 April the School of Military Engineering, Chatham will celebrate its 150th Birthday. 1 April 1962 will mark the hundredth anniversary of the amalgamation of the officers of the Honorable East India Company's Madras, Bengal and Bombay Engineers into the Corps of Royal Engineers. On 12 October 1962 the Royal Engineers Association becomes fifty years old. On 13 May 1912 the Air Battalion Royal Engineers disbanded and handed over responsibility for military flying to a newly formed Corps which, known now as the Royal Air Force, has developed during the intervening fifty years beyond even the wildest dreams of early Sapper pioneer aeronauts—a most bonnie baby indeed of the Corps.

* * * * *

The frontispiece of this issue of the *Journal* shows the Chief Royal Engineer, General Sir Frank Simpson, presenting the Queen's Challenge Cup to Lieut-Colonel P. Whyte, the Commanding Officer of 432 (City of Edinburgh) Corps Engineer Regiment (TA). The Queen's Challenge Cup is awarded to the best unit at sport in the Territorial Army, and this is the first time that the Cup has been won by a Royal Engineer TA unit. Also shown in the photograph are Colonel J. M. Flint, Commander 29 Engineer Group TA, Brigadier H. R. Greenwood, Chief Engineer Scottish Command, and Brigadier A. D. M. Teacher CBE, Joint Honorary Colonel of the Regiment.

* * * * *

Exercise SPEARPOINT, carried out in Germany this year, was concerned with operations involving the employment of tactical nuclear weapons. The exercise proved without doubt the tremendously important part the Corps must play in such operations. 36 Corps Engineer Regiment moved from Maidstone to take part in the exercise complete with equipment and vehicles, embarking at Upnor in craft of the RASC LCT Squadron.

* * * * *

In the Near East a very comprehensive engineer exercise was held in North Africa. The exercise was unhappily marred by a tragic accident when on its conclusion an RAF Hastings aircraft, carrying officers and other ranks of the Malta Fortress Squadron, crashed while taking off from El Adem airfield in Libya. Eight persons lost their lives and eight were seriously injured.

* * * * *

During the Edinburgh Tattoo, held last August, a troop of 48 Field Squadron of 38 Corps Engineer Regiment competed with 4 Field Squadron Royal Canadian Engineers in a bridge building competition. This international competition was most popular with the spectators and competitors alike.

* * * * *

34 Independent Field Squadron from Kenya, one troop of 9 Independent Parachute Squadron from the United Kingdom, one troop of 10 Port Squadron from FARELF and a Works Detachment RE formed part of the force sent recently to Kuwait. No active operations took place and one of the main Sapper tasks was to provide hot weather amenities for the force. In

this work the Kuwait Oil Company gave a great deal of assistance; similarly, thanks to the excellent co-operation of the Port Superintendent a wartime Transportation Officer, the military requirements in the dock area were met in part largely by local effort.

*   *   *   *   *

A troop of 20 Field Squadron of 36 Corps Engineer Regiment that had been supporting the Grenadier Guards infantry battalion group in the Cameroons returned home last October.

*   *   *   *   *

During last September 12 Field Squadron of 38 Corps Engineer Regiment, supported by 501 and 506 Bulk Petroleum Specialist Teams AER, were engaged on Exercise GO DEVIL held at West Moors, Dorset. The exercise, which involved the construction and operation of a bulk fuel installation and lasted for four weeks, was a great success.

*   *   *   *   *

An emergency request from the Military Commander in the Carribean area for Engineer assistance to the hurricane stricken parts of British Honduras was received on Friday 3 November. As a result a reconnaissance party of five headed by the CO 38 Corps Engineer Regiment flew out via Jamaica over the week ending 4/5 November, closely followed by the greater part of 12 Field Squadron. On Monday 6 November the Commander 12 Engineer Group followed with advance elements of his Headquarters to take control of all Military Units in the Colony. An element of the Regimental Headquarters, 36 Corps Engineer Regiment and 24 Field Squadron from Maidstone, flew to Kenya on 21 November for flood relief operations.

*   *   *   *   *

In October the War Office acceptance trials of the Gillois Amphibious River Crossing Equipment (described in the June 1959 issue of the *RE Journal*) was held at Chatham. The trials unit, found by 50 Field Squadron of 25 Corps Engineer Regiment stationed in Germany, gave an excellent demonstration of the potentialities of this type of equipment. The equipment has been accepted by the War Office for introduction into the Corps.

*   *   *   *   *

During the period July to November the rate of recruiting into the Corps has continued to show an improvement. There must not, however, be any relaxation of effort and regular recruiting still remains a task of the highest priority.

*   *   *   *   *

An old press cutting was recently sent to the RE Museum describing the climbing ability of a Private James Weir of the Royal Sappers and Miners. He would scale heights inaccessible to others. He climbed to the top of the spire of Thaxted Church (180 ft) on 11 April 1844, sat on the wind vane and whirled himself around on it. His other climbs included the highest peaks of Ely Minster, Norwich Cathedral and Swaffenham Church.

Members of the RE Mountaineering and Exploration Club and Sapper Officers up at Cambridge should not however take this as a challenge.

Rock Tunnelling

By Major G. Horne, AMICE, RE

Introduction

As rock tunnelling was the main Sapper task of the Company of Soldier Artificers raised in Gibraltar in 1772 and as its importance may well increase in any future major conflict it is felt that a straightforward treatise on the subject will be of interest to the average Sapper officer.

The process of rock tunnelling extends from work in the hard igneous rocks, where the roof is self supporting, down through the various types of ground to the "rotten" rocks and shales where a continuous roof support is required. Broadly, rock tunnelling can be classified as tunnelling where blasting is required, though there are the exceptions where blasting is used to loosen clays or compacted soils.

As well as "rock" there are two other main types of tunnelling. First is the soft ground tunnelling where roof supports have to be driven forward ahead of the face so that excavation is always being carried out under some sort of protection, a process which is very slow compared with tunnelling in rock. Then there is compressed air tunnelling in very soft wet ground or sand where not only would the roof and walls creep through any strutting, but the face would come in and "pipes" would blow up through the floor due to outside earth pressure. This latter type of tunnelling is carried out by driving forward a "shield", fixing tunnel linings as one proceeds and working in sufficient air pressure to prevent the tunnel from "coming in". Attendent with this are all the complications of passing men and materials through an air lock and slowly "decompressing" miners coming off duty to prevent "bends". The article "Compressed Air Work in Civil Engineering" by Captain J. N. Joiner, RE, published in the September 1960 issue of the *RE Journal*, fully described this method of tunnelling.

In the service the amount of soft ground work likely to be carried out will be very little and on a very small scale whilst "pressure" tunnelling is very much a specialist operation requiring a large amount of equipment and any such work required by the services would undoubtedly be undertaken by specialist civilian contractors.

Rock tunnelling is, however, a very different matter in which the Corps has had considerable experience and any Sapper officer should be able to supervise a tunnelling project. Covered in detail it is a very extensive subject owing to the many methods and practices carried out throughout the mining profession. It does, however, fall into a number of fairly well defined operations and it is the object of this paper to describe these various operations and, in each case, to discuss some of the ways in which they are carried out. Obviously all the methods for carrying out any one "operation" cannot be covered, especially as in some cases, like marking out a "drilling pattern", nearly every "tunnel boss" has his own private theory on the subject. However, the basic requirements for each phase of the work will be dealt with and the methods discussed will be the ones most suited to service conditions. Large scale tunnelling is a specialist job and the equipment used is, on the whole, rather different to normal engineer equipment. Any unit, other than a Tunnelling Squadron, wishing to undertake work of more than minor scope will, therefore, require a certain number of trained mining personnel and some special tunnelling equipment.

The sections of this paper have been arranged, as far as possible, so as to place the various "operations" in the correct sequence. For this reason survey has been split up. First there is "outside" survey, which occurs at the beginning and is only dealt with briefly as it is a subject on its own and not peculiar to tunnelling. "Internal" survey, which occurs near the end of the paper, is very much a miner's subject and is, therefore, dealt with in more detail.

Historical

Before starting to describe the present day methods of rock tunnelling it may be of interest to consider, very briefly, some of its historical aspects. Man has tunnelled from practically the beginning of time and no doubt the stone age cave dwellers enlarged their homes by some primitive rock tunnelling. The stone age ended with the discovery of metal and tunnelling was carried out to obtain the ores and to drain the mines including the tin mines of Cornwall first operating in the days of the Phoenicians. Ancient Rome had her tunnelled aqueducts long before the Christian Era and some of these Roman tunnels and cisterns are still in use today. Underground survey was a high art when the Nabateans hewed out their rock city of Petra 600 years before Christ and, although they were working in fairly soft sandstone, the great rectangular chambers inside the mountains of Moab are excellent examples of "setting out" underground works.

The first text book on tunnelling appears to have been produced by a German, Georg Bauer, in 1556. Writing under the Latinized form of his name, Georg Agricola, he produced "De Re Metallica". Originally written in Latin it was translated into the more popular languages and for 350 years was the only handbook on mining, tunnelling and metallurgy. It was illustrated by woodcuts.

In those days the work of "blasting" was done by "fire-setting", being carried out by building a fire against the face and then quenching the heated rock with a mixture of vinegar and water. This broke up the rock, which was then prized out with bars. The "muck" was carried away in wheelbarrows or four-wheeled trucks running on planks, and then hauled up the shaft either by labourers or, in the "up-to-date" mines, by a water wheel.

These very early tunnels were mainly for mining, transport tunnels making their appearance with the coming of the canals. In France the first was the 515 ft Malpas tunnel built in 1678–81, whilst in 1803 the Tronquoy tunnel on the St Quentin Canal was the earliest one to be timbered and arched with stone throughout.

In England there were about forty-five tunnels on the early canals, the Marsden tunnel being 3 miles long, but with the coming of railways more and more were driven.

America did not start driving large tunnels until about 1820, but once started she seemed to forge ahead with mining techniques and today most of the mining methods come from across the Atlantic. From a historical point of view probably the most interesting American tunnel was the Hoosac, connecting Boston and Albany. It was $4\frac{3}{4}$ miles long and built between 1854–76; having been started by a private company and, after many hold ups, completed by the State. The point about this tunnel is that it was here that dynamite and power drills were first tried out in place of gunpowder and hand drilling.

Selection of the Tunnel Line

In the construction of underground chambers for use as stores, shelters, factories etc, the choice of site will depend mainly on factors far removed from tunnelling. These works will be sited so as to be most convenient to the "geography" above ground, such as roads, railways, towns or existing factories. The ground formation, however, will have to be considered as it is no use trying to open up large underground chambers in bad ground or "rotten rock". It is also more convenient to approach an underground installation by an "adit" or slope rather than down a lift shaft. The ideal condition for such an underground installation is a hillside of hard rock.

With a tunnel, "above ground" considerations usually fix the "portals" or entrances. For example water or sewage has to be transported underground from A to B, but although A and B are fixed the route taken between them will depend a great deal on geological conditions. Possibly a railway has to pass through a stretch of hilly country, here again the ends are fixed but the route will depend mainly on conditions below ground.

In the selection of a "tunnel line" a reconnaissance is carried out both on the crust formation of the ground and its geological formation, the selection of the final route depending on both of these together with such factors as:—

1. Laying out curves and gradients in the case of railways and roads.
2. Gradients in the case of water or sewage.
3. Rights of way or easement rights.
4. Other underground works or services.
5. Heavy installations on the surface.

All these points will have to be taken into account together with problems of construction such as the siting of working shafts or approach "adits". The economics and labour effort required for each possible route will then be considered and from all this data a final "tunnel line" decided. This "line" will probably be in a series of "straights" and it is very unlikely that it will be the direct line from "A" to "B", except of course in very short tunnels.

Geological Investigation

Ground reconnaissance, being common to all engineering projects, will not be dealt with in this paper. However, these days such a "reconnaissance" for a civil engineering project, normally called "site investigation", invariably includes a certain amount of sub-soil investigation, usually carried out by sinking boreholes. There is a very true saying in the profession that you pay for boreholes whether you sink them or not. In tunnelling these boreholes take on an even greater importance and usually have to be sunk to much greater depths.

Prior to the sinking of boreholes a certain amount of information will have been obtained from geological maps of the area which exist, in varying degrees of accuracy, for most of the world and from which it is possible to obtain a general idea of the types of rock likely to be met. Any existing mines, quarries or tunnels will have also been examined. However, these will only give a general picture and it is from boreholeing, or the sinking of "trial shafts", that the more accurate information regarding the exact limits of strata, local faults, water etc. is obtained.

The sinking of "trial shafts" is self explanatory as is surface boring. The latter is usually carried out by a "hand auger", samples of the sub-soil being brought up in the "thread", or if in rock "split tubes" are driven down by a sledge hammer or "monkey" and samples recovered from the tube.

If any depth of drilling is required a specialist firm is usually employed who are likely to use one of two main methods:—

1. *Wash Drilling*

The principle of this method is that a hole is sunk, either by rotary drilling or by hammering, and samples of the rock are washed to the surface by water. This method is cheaper than "core drilling", but has some serious disadvantages:—

(*a*) Samples are not brought up in their original state and their identification depends on the experience of the drilling foreman. Here the "human element" can quite easily fail and fragments washed to the surface can be adjudged as coming from a soft strata when in fact they come from hard rock, or vice versa.

(*b*) Water may wash particles of earth from the sides of the borehole down to the bottom, whence they are pumped up to be examined. Thus samples coming from a few feet below the surface may be considered as coming from much further down.

(*c*) Using water for washing up particles makes it impossible to judge when one is passing through water bearing strata.

The writer knows of one site where "wash drilling" was carried out and ground that was reported as being hard rock was in fact "running sand" followed by shale containing a large amount of water. Here faulty "site investigation" caused a great deal of expense. Had the true nature of the ground been known the shaft would have either been moved to another site or sunk by a method more suited to overcoming running sand and excessive flooding.

2. *Core Drilling*

This is the only true way to get an undisturbed sample of bedrock and although it is more expensive than "wash drilling" its absolute accuracy may well pay for its added cost.

The rig consists of an annular cutting head on to which are attached "core barrels" as drilling proceeds. The actual cutting can be by diamond, in which case the cutting head has a number of diamonds set round it, or by a soft steel cutting head with a slot on one side down which steel shot are fed and as the head rotates they cut into the rock. The chief troubles with the "shot" method are that in very soft rock they may become embedded and stop the cutting action and that owing to their gravity feed drilling cannot be carried out at angles flatter than 45 deg. The more expensive diamond drill overcomes these disadvantages and is often used for drilling horizontally ahead of the tunnel "face". However, the "shot drills", apart from being cheaper, are able to drill very much larger cores.

In both cases water is used to lubricate the cutting and to carry away the sludge which travels up the hole outside the pipes. The amount used is, however, not great and does not interfere with estimating the amount of water actually in the ground, which is done by pumping. After advancing the length of the "core barrel", usually about six feet, the whole string of tools is withdrawn and the core removed. These cores, which are usually kept in long wooden boxes, are undisturbed samples of the ground through which drilling has taken place.

Design

The finished size of a tunnel is usually controlled by the use to which it is to be put. The exception to this is where, although only a very small cross section is required, a minimum dimension of about seven by seven feet has to be tunnelled in order to enable miners to work economically. When the older, brick lined, London sewers were first built they were very much larger than functionally required at the time owing to the fact that miners and bricklayers had to have room in which to work. Now, of course, they are able to handle the greatly increased flow of sewage, a fact unforeseen by the original designers.

The shape of a tunnel depends on both its use and the ground penetrated and often the actual "driving" is carried out in a different profile to that finally required. For example as a "floor" is needed during construction a large round tunnel may well be driven semicircular and enlarged later (see Fig 1), or a small tunnel be driven as a "horseshoe" thus providing both a floor and a convenient shape for ribbing. (See Fig 2.)

Ribbing and lining again depend on use and ground. In very hard igneous rock it is probable that no ribbing is necessary and if the tunnel is for sewage or non-purified water, then quite likely no lining will be required either. If however, drinking water is passing through or if a good "fluid flow" is required then the tunnel should be lined. Any tunnel which has traffic passing through must be lined or inspected daily and scaled, as even the best of rock is liable to slake on weathering. In poorer rock, although it can be tunnelled without supports, faster weathering occurs and if the rock is going to be exposed to the air for any time before being lined some sort of ribs and "banker bars" will be required. As the rock gets worse supports will have to go in as mining progresses. Several shapes can be used when ribs are required; though the nearer the shape is to that of the finished tunnel the less "overbreak" there will be to pack or "extra cutting" to be carried out. Concrete is now the standard lining for rock tunnels and all metal ribs, metal "banker bars" and rock packing can be left in position. Timber, of course, should not be concreted in and it is for this reason that, although it can be used for temporary roof supports, it should be replaced by metal as soon as possible and long before any settling of the roof has made its removal dangerous.

Outside Survey

Absolute accuracy in all tunnel survey, whether "outside" or "inside", is of the highest importance. In other types of engineering work there is usually a chance to check the survey as work progresses; in tunnelling there is no way to check the results until tunnels are "holed through", and then it is too late to make corrections.

The "outside" survey, or "running the ground line", consists of putting a triangulation over the area so as to establish a series of points on the surface over the line of the tunnel. It also provides enough survey stations to enable "lines" and "levels" to be taken inside the "headings" and to "tie up" accurately all "portals" or shafts connected with the tunnel system.

The normal procedure is:—

1. The "tunnel line" is run across country fairly quickly by normal survey methods and the intersection points and various "portals" or shafts pegged. This first survey is usually sufficient to enable work to start on the various

sites, and by the time these have been opened up and excavation is starting the next two phases of the "outside survey" should be completed and accurate "inside" surveying possible.

2. The first survey is checked and rechecked until the surveyors are absolutely sure of all the points.

3. After the "line" has been checked through permanent concrete monuments are established. Embedded in them will be brass or copper bolts or plates on to which theodolites and "targets" can be clamped. These are in fact usually similar to normal survey triangulation stations.

For the "outside survey" the normal method of triangulation can be used, although one or two large tunnels in this country have had this survey carried out by a new method of triangulation.

Briefly, this consists of taking sights from each station on to every other visible station. This means that when it is required to make a "fix" instead of the normal two, or possibly three, lines intersecting there are "rays" coming in from every other station in view. By co-ordinates all these lines or "rays" are drawn out to full scale on a sheet of paper and any one coming off the paper is obviously inaccurate and is scrapped. The final point is then estimated from all the remaining "rays", allowance being made for the fact that the longer the site the greater the possible error.

Planning

Once details have been settled regarding a tunnel's "line", shape and lining the method of construction has to be planned.

In a small tunnel it is likely that driving will take place from the two ends, the "headings" thus formed meeting approximately in the middle of the "tunnel line". However, with a larger project more working faces are required and these can generally be obtained by sinking shafts, driving in "adits" and opening up the ground in places where the tunnel is reasonably near to the surface. (See Fig 3.)

These extra faces:—

1. Provide more working space thus speeding up work.
2. Produce natural ventilation.
3. Enable high and low pressure air, water, power, etc to be tapped in at points along the tunnel line, thus cutting down long mains.
4. Cut down long "muck hauls".
5. Act as survey check points.
6. Speed up the placing of a concrete lining.

The sinking of a shaft or the driving of an adit pushes up "overheads", consequently the cost of these must be carefully balanced against the saving of time and money by the advantages enumerated above.

Leaving out the financial aspect, shafts and adits should be sighted on the following considerations:—

1. The main tunnel line should be fairly near to the surface.
2. The shaft mouth or "adit portal" should be accessible by road and there should be enough space around it for a working site. (See next paragraph.)
3. Water and power should be available.
4. Tips for the disposal of "muck" are necessary. (See next paragraph.)
5. Working faces should split the tunnel up into approximately equal lengths so that they join up at about the same time.

6. If possible where the tunnel changes direction in order to assist survey.
7. They should "mask" difficult sections of work. (See Fig 4.)

Starting Up Sites

There are certain requirements for a good site, and if a site has been well located these requirements will be on hand. However, it is not always possible to locate sites in ideal positions especially in the case of the "portals".

A working site requires

1. An access road which will be capable of standing up to a great deal of heavy traffic, especially if ribs are being used and a concrete lining placed.
2. A reasonable area for stores, compressor house, charging shed, cabins, etc.
3. A tip area on the site or near by. The amount of "muck" coming out of a relatively small heading is quite large and it is essential to be able to dispose of it fairly quickly if any real progress is to be made. When planning a tip the "bulking" of "muck" must be considered. (See paragraph on Mucking.)
4. Adequate water, both for drilling and concrete, is necessary. Once a heading is started tunnel drainage water can often be used for drilling, but concrete requires clean water.
5. Power should be available, either from the "grid" or from a temporary power station built to supply the tunnelling project.
6. In inhabited localities sites should be located as far away from dwellings as is possible. Once "24 hr work" is started the noise of compressors, blowers, skips, etc, during the night causes a lot of inconvenience to the local population.

Once sites have been located they should be "laid out" to make the best use of available space with the compressor house, the battery charging shed, the fitters' cabin, etc., sighted as near to the tunnel entrance as is convenient. The "muck tip" should not be too far away and, if possible, slightly below the level of the entrance so that full skips go downhill and empty ones up. The site for a batching plant needs access by road, gravity feeding and should be able to deliver finished mixes direct into skips whilst the storage area also requires a road leading into it and the light tunnel railway leading out. A crane is invaluable in this area and should be able to serve both lorries and skips. Of course sites often have to be laid out according to the ground, but, where possible, the above considerations should be applied. A typical site layout is shown in Fig 5.

As is common with most engineering sites work on the approach road should be started as soon as possible and it should be well made as any skimping will mean the constant employment of maintenance gangs later on. Though the roads are usually "temporary work" they often have to last for several years and carry a large amount of heavy traffic.

Drainage is another matter of great importance. Once the tunnel is started a great deal of hardcore becomes available for filling bad areas, etc., but in the early months a lot of work is carried out before any tunnelling starts and if this happens to coincide with wet weather progress will suffer on a badly drained site.

The normal time-table for starting up such a site is:—

1. The approach road is made on to the site and up to the shaft head or "portal".

2. A small storage area is cleared and one or two cabins erected.
3. A mobile compressor set is obtained.
4. Work starts on the relatively slow process of "breaking in".
5. Compressors, blowers, power, water, etc, are installed and the storage area enlarged. This work should be completed just as the "breaking in" is completed and the tunnel ready for the main driving.

It may well be felt that all the points raised in this last section are obvious and should be second nature to any engineer. They may be, once one knows about them, but often details are forgotten and sites just grow. The first requirement of efficient tunnelling is the initial planning, both in layout and the time-table, of the "portal" and shaft areas.

Planning a Heading

The second requirement of efficient tunnelling is the planning of the "headings", or working faces, with regard to the methods of attack so that equipment and installations can be ordered. This planning entails making the following decisions in respect of each "heading":—

1. The type of drilling equipment required.
2. The type of "mucking" equipment required.
3. The amount of air required, and thus the number and type of compressors.
4. Any special equipment that may be needed.
5. Requirements for roof supports, etc.

In the case of a uniform tunnel each "heading" will be similar, though slightly different methods may be used at various faces either if the type of ground varies or if experiments are being carried out to see which proves the most efficient. In the case of a tunnel of varying section different methods of tunnelling may be used on each "heading".

Basically all rock tunnelling consists of—"drill, fire and muck" with support of the roof where necessary. The method of carrying out these operations varies according to the size of the tunnel and the type of rock. Though the geological survey gives a fairly accurate forecast of what types of rock will be met, there is always the possibility of running into unsuspected bad patches and this may necessitate a slight change of equipment once the job has started. These changes, however, will not affect the main methods of attack nor require alterations to the heavy plant and in all probability they will be confined to altering drills and steels and varying the drilling patterns and the amounts of explosive.

The "Break In"

Before normal tunnelling can commence a "break in" has to be effected either through the top soil and loose surface material to form a "portal", or from the foot of a shaft. The latter is usually fairly simple as one is already operating clear of the surface in more compact ground and with the shaft lining acting as a shield. I shall, therefore, only consider the "break in" to form a "portal". Every "break in" is an individual problem and has to be handled slowly and carefully and to suit local conditions. That is why, as already stated, it is advisable to get ahead with the "break in" before the site is geared up to operate full scale tunnelling. There are, however, a number of standard methods by which "break ins" can be carried out.

It will be realized that unless one is tunnelling into a fairly steep face of good rock it will first of all be necessary to get through surface material and unless this is suitable "contained" it may keep falling and the "portal" "moving back" (see Fig 6). Also, whilst "going in" some sort of shield is required to afford protection against these falls (see Fig 7). Even with good rock internal blasting may loosen boulders up above the entrance and it is advisable to have some sort of protection against them, a simple method being shown in Fig 8. Four basic methods of "breaking in" are considered and consist of:—

1. *Portal Strutting*

This is shown in Fig 9 and merely consists of timber strutting erected both to afford protection against falling material and to "hold" the ground. As this would eventually have to be replaced by permanent lining it should not be used where movement of the ground is likely to make the replacement of the timber difficult and dangerous.

2. *Concrete Shield*

This is shown in Fig 10 and consists of creating a condition similar to that existing at the bottom of a concrete lined shaft where the heading is driven through the concrete which is suitably "boxed out".

3. *False tunnel*

For particularly bad surface ground it might be necessary to "work in" with a false tunnel as shown in Fig 11. This is built up with ribs and "banker bars" covered with concrete and extends into the face both "holding" the ground above and acting as a shield. This method is an alternative to portal strutting where it would be difficult and dangerous to replace the timber work.

4. *Pilot tunnel*

This is used where a patch of bad rock lies on the tunnel line. A pilot is driven through and enlarged inside thus enabling tunnelling to proceed whilst the "bad patch" is dealt with slowly and carefully. This method can also be used when bad rock is met underground, but it has a number of disadvantages the main one being that it restricts the flow of men and materials to and from the working face.

Once the "break in" is effected pure tunnelling can start and it is, obviously, the object of every tunnel engineer to start the "full speed attack on the face" as soon as possible.

Methods of "Attack"

There are a number of basic ways of working tunnels of varying sizes starting with the smallest convenient "heading" which is about seven by seven feet. As already explained it is not economical to try and work in a smaller area, except perhaps for extremely short lengths.

1. *Full face attack* (see Fig 13)

Here a full face is drilled by some sort of drilling rig or airlegs (see Drilling Section), the whole face is then fired and "mucked". If the "heading" is a little larger, instead of waiting for the "mucking" to be completed before starting to drill again, drilling with airlegs may start on the "muck pile" (see Fig 14). Thus as the "muck pile" diminishes the drillers work down the face. The heading would have to be at least ten feet high before this latter refinement would be practicable.

2. *Larger tunnels*

The "full face" attack can still be used on these, but some sort of drilling platform or "jumbo" (see Drilling) is necessary. The other method of working a large tunnel is to start off by driving a small heading or drift and then enlarge it to the required size.

3. *Heading and bench* (see Fig 16)

This method is American and was originally used on small tunnels, but it is now normally confined to larger ones.

The top "heading" is driven in, usually the length of one or two "rounds". If there is headroom for steel changing, the bottom "bench" can be drilled vertically downwards whilst "mucking" is being carried out, but if there is not the head room then it is drilled horizontally after "mucking". At the same time the top "heading" is drilled again, and both are charged together. The "bench" is fired an instant before the top "heading" and most of the "muck" from the latter is then thrown back on to the floor of the tunnel. Drilling and "mucking" then start together. This system has the advantage of simultaneous drilling and "mucking" and also requires less explosive than the "full face" method.

4. *Top heading* (Fig 15)

This is a modification of the last method for use in bad ground. The "heading" is driven well in and the roof supported. If there is only a short length of bad ground, mucking is done by hand. Otherwise it is done by a small "mucker" and a "cantilever car" (see Fig 17). The "bench" is then excavated in short lengths, replacing the short roof supports by long struts, one at a time.

"Drifts"

A "drift" is a small tunnel, usually about ten by ten feet, which is driven through the length of the main tunnel and then enlarged to the required section. Amongst the advantages of using a "drift" are the facts that it acts as a pilot tunnel, it "explores" the ground the main tunnel is going to meet, it may be a safer method of coping with bad ground and it does enable some tunnelling to proceed whilst heavy plant is being assembled for the main tunnel. On the other hand it does savour of "two bites at the cherry".

1. *Centre "drift"* (Fig 18)

Here the "drift" is driven through the centre of the tunnel section. To enlarge it holes are driven radially, although such drilling cannot start until the centre "drift" is right through otherwise it would obstruct "muck trains" coming from the face. Once the drift is through radial drilling, firing and "mucking" can go on practically continuously. This method provides very good natural ventilation and is economical in explosive.

If bad ground is encountered the centre drift can be enlarged by the "heading and bench" method until good ground is reached again (see Fig 19).

In rock tunnelling "bad ground" applies to any ground which requires any sort of continuous roof supports. The "centre drift" method is not suitable if the "bad ground" is more than just the occasional patch in which case a "side drift" would be used.

2. *Side drift* (Fig 20).

Two "drifts" are advanced along the sides of the tunnel and "plumb posts" are set up and tied back into the outside walls by "wall plates" or "beijls" (see Supports). "Breakups" are then made into the arch and timbering erected. When this meets in the centre a "core" is left which can be excavated quite safely, though the use of explosives will be limited for fear of damaging the arch. This "core" acts as a working platform for erecting the timber arch and on some jobs, especially large underground chambers, the concrete lining is placed before the "core" is removed.

3. *Pilot tunnel drift*

A final method is that of driving a pilot tunnel parallel to the main tunnel and about seventy to eighty feet away from it. A centre "drift" is also driven right through the main tunnel and about every quarter mile the pilot and the "drift" are linked up. Although this method requires two tunnels to be driven, one of which is of no later use, it does enable the enlarging operation to be carried on at a number of points. Furthermore, any bad patches do not hold up all work, but can be by-passed by "muck trains" in the pilot tunnel. This method also of course provides excellent natural ventilation.

Drills

Drills and drilling are a very important part of rock tunnelling and to a great extent the rate of progress depends on this phase of the work. Not only is the progress affected by the speed with which holes can be drilled, but how they are drilled. A "tunnel boss" or "leading miner" will mark out the centre and the shape of the face and will say what sort of drilling "pattern" he wants, but the exact position of holes and the direction in which they go is usually left to the drillers. Good drillers will cut down "overbreak" to a minimum, "overbreak" being any ground excavated outside the limit of the tunnel section. Not only does this reduce the amount of muck to be hauled, but where ribs are being used, it cuts down the amount of packing which has to go outside these ribs to hold the roof. Good drillers are just as important as good drills.

There are, of course, very many different types of drills, but only the two main categories will be considered in this paper. First there is the drifter which is the standard rock drill. It is an air driven machine working on pressures from 90 to 110 lb per sq-in. The drill operates in a series of hammer blows and between blows the "steel" is rotated part of a turn. They can operate either wet or dry and to prevent silicosis in tunnel work the law states that drilling must be wet unless there is a very efficient system for clearing dust. As such dust clearance is complicated and expensive only wet drilling will be considered. Normal drifters weigh from 117 to 240 lb and have cylinder bores varying from $2\frac{5}{8}$ to $3\frac{3}{4}$-in. They are too heavy to hold by hand for any length of time and have to be mounted on some sort of leg or carriage. The second and smaller category is the Jackhammer which is mainly used for such small jobs as trimming, drilling holes for dowel pins, opening up portals, breaking up boulders etc. It is similar to a drifter though smaller and can be hand operated. The steels may not rotate and it is permissible, for very small jobs, to operate them dry. All future references to drills will refer to the drifter.

AIR

This is supplied by the compressors and is also used to drive "muckers" and pumps. It is led along the tunnel in an "air main", usually 6-in steel pipes, and into an air manifold. This manifold contains a number of taps and nozzles to which the canvas air "bags" can be fixed. These are "bags" lead to the drills, passing through an oiling bottle on the way. As the face advances the air main is lengthened and the manifold moved forward so as to be kept within fifty or sixty feet of the face. During firing all the drills and canvas "bags" are moved back and the manifold should have some sort of protecting screen put over it. On an average drifters use between 170 and 220 cu ft of air per minute, though of course this figure is greater at high altitudes.

WATER

The water is fed through the centre of the drilling steels and is used to keep down the dust and to lubricate the bit. If the water pressure gets too low, in soft rock the bit will clog. A good water pressure at which to work is 10 lb below compressed air pressure which is normally about 90 to 110 lb per sq-in. Tunnel drainage water can be used for drilling, but it should first of all be passed through a settling tank. If this is not done all the suspended matter in it will clog the drills.

DRILL SUPPORTS

As previously stated the heavy "drifter" drills require a support and this support must be able to feed the drill forward as drilling proceeds. Starting with small "headings" the main method of supporting drills are:—

1. *Airlegs*

These consist of a telescopic leg which can have its length adjusted by operating the air valve on the outer cylinder. The correct position for using this leg is shown in Fig 21. Here one man can operate the drill without taking any of the weight and as he increases the length of the leg the drill is fed forward. These airlegs can be used in small "headings", drilling from the muck pile and from a drilling platform. Their advantage lies in the fact that, unlike a large drill carriage, they can be moved about very easily.

2. *Bar mountings*

Used in small "headings" where the width is less than the height, these consist of heavy lengths of pipe with a jack at one end. They are set horizontally across the tunnel and drills are clamped to them (see Fig 22) the clamp fitting being such that the drill can be fed forward. Great care must of course be taken to ensure that the bars are rigid.

3. *Column and bar mountings*

Similar to "bar", these are used when the tunnel height is less than the width and are in fact a combination of both "column" and "bar" (see Fig 23). The pipes are from $3\frac{1}{2}$ to $4\frac{1}{2}$-in diameter and again drills are mounted on to a slide or screw carriage, the carriage being clamped to the bar. Drilling patterns should be planned so that these bars, once set up, have to be moved as little as possible.

4. *Platforms*

When airlegs are used on a large face some sort of drilling platform or carriage is necessary. A platform should be capable of being dismantled fairly easily and stored at the side of the tunnel. Two types of platforms are shown in Fig 24.

Drilling Carriages

If a platform cannot be dismantled it will have to be rolled back from the face on wheels and becomes a "drilling carriage". The great problem with regard to these is that of getting "muck trains" past them when they are pulled back. In a small "heading" drill carriages are not required, whilst in very large "headings" muck trains can get past a "platform" or the platform can be high enough to let the trains pass through it underneath. The difficult condition is in medium "headings" of about twelve feet diameter. Here some sort of platform is required, but space is very limited and when drilling is not taking place the approach to the face must be kept clear for "mucking". In this size of "heading" platforms are usually considered more suitable than carriages. There is, however, one "carriage" that can be used in these circumstances which is the Sullivan Rig. This consists of a rail mounted body about the size of a tunnel loco mounting three arms which can be adjusted to any position by oil pressure. Automatic racks are fitted to these arms and they have a chain drive, driven by air, which slowly feeds a drill forward. When not in use the arms are laid flat and the rig can be shunted on to a "lay by".

They have, however, four main disadvantages. They are cumbersome to run to and from the face, they occupy a "lay by", thus preventing its use for shunting skips, they do not always hold the drill steady and they take time to move from one "set" of holes to another.

The large drill carriage, or "jumbo", moving forward on rails can be used as a platform for airlegs, or "bars" and "columns" can be fixed to it on to which are clamped sliding drills. There are many types of "jumbos", usually each one is built to suit a particular job. They have to enable the whole face to be drilled, be mobile and enable "muck" trains to get past them. They can be used on smaller headings if there is some means of getting them clear of the tunnel track, for example if used with a pilot tunnel.

Steels and Bits

There are two general types of steels and bits, the first being the "forged" bit where the steel and the bit are in one, whilst the second is the detachable bit. In both cases the steels are the same being usually ⅞ or 1-in with a hole running down the centre for water.

1. *Forged bits*

These are forged on to the end of the drill steel and usually have tungsten carbide tips. In medium rock these steels and bits should drill about 1,000 ft before they need regrinding.

2. *Detachable bits*

These screw or wedge on to the end of the steel and may have tungsten carbide tips, but as they are easily lost it is often more economical to use the "throw away" bits. These are ordinary steel bits which cost about 1*s* each compared with the £4–£5 for a tungsten carbide bit. In very hard rock the "throw away" bit would not be very effective, but in medium rock they are quite adequate and in shale can drill anything up to 100 ft per bit. Sometimes they can be "swaged" and used again.

There are several "shapes" for bits the conventional ones being a cross or a four-point double taper (see Figs 25, and 26 which also show the various cross sections used in "steels"). Probably they "Z" bit is the most useful as it is the least likely to clog in shales.

Size of Hole

Providing the ground will stand the explosion it is in the interest of speed to drill a "round of holes" as deep as practicable thus getting greater progress in one cycle (i.e. drilling, firing, mucking). A usual depth is 10 ft, which will "pull" about 9 ft and which will be drilled by three or four steels each one longer than the last, thus avoiding starting off the hole with a 10-ft steel which may bend and break. Each successive change of steel requires a smaller width of cutting bit so that the new steel can follow down the hole to its cutting position without binding. The last, or deepest cut should be $\frac{1}{16}$-in greater than the diameter of the powder cartridge. Too large a change is uneconomical, for the smaller the hole the faster it can be drilled.

Drilling Patterns

Efficient blasting procedure depends on many factors with the volume of ground broken varying with the texture of the rock, the depth of the hole, the quantity and rapidity of the explosive and the amount of stemming. Holes correctly charged and stemmed will generally break out as shown in Fig 27. As the explosive acts normal to the axis of the hole the inclined or "cut" hole is the most efficient and there is less chance of the stemming being blown out. However, because of the restricted area of a tunnel and the necessity of controlling overbreak it is impossible to point the holes to obtain the theoretical maximum efficiency of the explosives. To counteract this disadvantage the practice in tunnelling is to make a "burn cut" in the centre of the face in which the holes are about twelve inches deeper than the surrounding ones and are more heavily loaded to throw the muck out of the face. This "cut" provides a space into which the rest of the ground can expand when it breaks. There are many different drilling patterns with the "cuts" at various parts of the face, but in this country the centre "cut" is usual and the rest of the muck is brought out in a series of concentric rings each fired a fraction after each other. This is described in more detail later.

Maintenance of Drills

Drilling machinery requires good maintenance and on a large project there is usually a central drilling workshop containing machines and furnaces for resharpening, tempering and threading shanks for detachable bits and, in some cases, steels for detachable bits are manufactured from hollow steel bars. Each site should have its fitter's cabin where, between drillings, all machines are stripped down, checked and oiled, whilst at the face during drilling there should be a "spanner man" who carries out running repairs on drills, air "bags" etc. He also should be able to clear clogged steels as when the centre water hole becomes sealed and is left to dry the sediment gets very hard and extremely difficult to move. Quite often "drilling records" are kept showing time for drilling and footage per machine and in some cases special test records of footage per bit are taken to compare how the various types of bit stand up to the existing conditions.

Blasting

It will be appreciated that tunnel blasting is very much a specialized art, the object of which is to blow out an exact amount of rock and consequently to move either too little or too much is bad economics. One of the main differences between service demolitions and tunnel blasting is the use of the short delay detonators in addition to the normal instantaneous or "No O" electric detonator. These delays are for ½ sec, 1 sec and then by seconds up to 8. A face is charged up with a detonator in each hole and these are all connected up to the firing circuit. When the exploder is pressed all the detonators start "burning" together but fire at different times according to their delay, thus the charge goes off in a series of "shots". This is essential to produce the effect described in the section on drilling, that of pulling out the "burn cut" followed by a series of concentric rings. Fig 28 shows a typical face with the amount of explosive and type of delay used in each hole. This will of course vary according to the ground conditions and the "pet theories" of the "tunnel boss" marking it out, but it is the basis from which most "patterns" are designed. It will be seen that two uncharged holes are included in the "burn" in order to give the three charged ones, firing first on "instantaneous", room to explode.

The explosives are looked after by the "powder monkey" who also makes up primers by inserting detonators into sticks of gelignite. He has a supply of these ready before "charging up" begins and usually takes them up to the face in a wooden box divided off into compartments, one compartment for each type of delay. In addition he makes up "clay cartridges" for stemming, though sometimes wet cement bags are used.

The whole shift will carry out the actual charging although the pattern will be decided upon and the process supervised by the "tunnel boss". With miners working on bonus both speed and accuracy are sought after. Accurate blasting will save them either having to carry out too much trimming or being faced with unnecessary "mucking" and packing.

After drilling, the holes are "blown out" with an air pipe and the electric lights are taken back from the face, charging being done by a lantern. Unlike service procedure the primers are put in first and the gelignite cartridges follow them and then stemming is pushed in and tamped with a wooden pole. The detonator leads hang out and in a wet tunnel, where there is any electricity, the ends of these leads should be covered by small rubber caps. When "charging up" is completed the shift moves back and the "tunnel boss" or "leading miner" removes the rubber caps, joins up the detonator leads into a circuit and connects it to the firing cable. He then withdraws to a safe distance, tests the circuit and fires. There is now a wait until the fumes have cleared and for this reason, whenever possible, a "shift" fires just before coming off duty so that by the time the new shift gets in the fumes have cleared. The ideal work sequence for one shift is "muck", roof support, rail laying, etc, drill, charge and fire. After the fumes have been cleared the "tunnel boss" and "leading miner" go in first to test the roof with scaling bars and one of the first tasks of a "shift" after firing is to "scale" the roof bringing down all loose pieces.

The "tunnel boss" and "leading miner" are also the persons who go in, after a due pause, in the case of a misfire. The normal safety precautions should, of course, be applied concerning the handling and storing of explosives. These are sometimes rather difficult to apply with a civilian organization as the average miner is a hard working, hard drinking, happy go lucky type who regards all, but the most obvious safety precautions as a waste of time and likely to affect his bonus. A habit I never cared for was that of leaving the handle with the exploder whilst men charged and connected up the face and my "foolish habit" of having the handle in my pocket when at the face was tolerated with amusement, by the miners I worked with, as one of the idiosyncrasies of Army officers. One safety precaution that miners do, however, accept without any question is that of always wearing a helmet. I think most of them have experienced enough "falls" of varying degrees to realize the need for this rule.

A careful record should be kept of all explosives used as, apart from being a normal security measure required I believe by law, it also shows how the "explosive to muck" is varying.

Ventilation

Nearly all tunnels require artificial ventilation during construction and it is in the interests of speed and economy to be able to clear the face of explosive fumes as quickly as possible after firing. Air is normally blown through ducting which may be anything up to eighteen inches in diameter and to avoid damage this is usually slung along the roof. There are three main principles used in ventilation:—

1. Bad air is sucked away at the face. Although this pulls away explosive fumes it does mean that the fresh air comes in at the portals and has to go right up the heading before reaching the men working at the face.

2. Fresh air is blown in at the face. This gets the freshest air to the men working, but means that explosive fumes are blown the full length of the heading.

3. A combination of both methods can be used where fresh air is blown in at the face, but immediately after firing the system is changed to suction for about thirty minutes and the explosive fumes are sucked clear. This is done either by having a reversible blower or a "one way" blower with a series of valves (see Fig 29).

"Mucking"

When rock is broken it "bulks" about 50 per cent, consequently in planning "mucking", hauling and tipping operations due allowance must be made for dealing with one and a half times as much "muck" as the volume of the tunnel.

"Mucking" can vary from hand operations up to using large air driven excavators at the face of a large tunnel.

1. *Hand mucking*

Though this has almost entirely been replaced by machines it is still carried out in small confined spaces or during the "break in" when small amounts have to be handled carefully. In some cases "muck" can be "handled" straight into skips as shown in Fig 30 and this is known as "trapping". Alternatively a belt conveyer may be used to bring muck out from a small heading and tip it into the waiting skips.

2. *Eimco mechanical "mucker"*

The best known of the mechanical "muckers" are those manufactured by Eimco and although other firms make similar machines in tunnelling language the word "Eimco" is used very much as "Barber Green" is with regard to the laying of tarmac and bituminous surfaces.

These machines are air powered and travel on the rails in the same way as the skips. The whole top of the machine can be rotated by hand to the right or left, but automatically centres itself as the bucket tips over backwards to deposit its load in the skip hooked on behind it. (See Fig 31.)

The smallest is the "12B" which can be used in a 7 × 7 ft "heading" or else two can be used side by side in larger tunnels. For larger "headings" there are the "21" and the "40".

3. *Conway "mucker"*

This "mucker" can be air or electrically driven and consists of a "dipper" hinged to the front end of an "apron" which in turn is hinged to the main frame. Both the "dipper" and the "apron" can be raised or lowered whilst the latter can be swung to either side. The machine is driven on to the muck pile, then by raising the "dipper" and the "apron" the muck is slid on to a conveyor belt which deposits it into the skips. Fig 32 will make this operation clear whilst Fig 33 shows how the "Conway mucker" can be converted into a "slusher".

4. *"Slushers"*

The "slusher" operates on the "drag line" principle, a scraper being hauled forward and then dragged back through the muck pile and up a slide, finally dumping its load on to a conveyor belt. In the "Conway slusher" the scraper is hauled forward by a boom, but on very large "slushers" some sort of holding device is driven into the face after firing and a snatch block attached. The "scraper" is then hauled forward by a winch on the "slusher" hauling a cable through this snatch block.

5. *Shovels*

In very large headings air-powered shovels can be used. These are similar to the "face shovels" used in earth moving above ground and can be either crawler mounted or rail mounted.

Slide Rails

In the case of rail mounted "Eimcos" it is essential that they get right up to the face and this can be done by pushing two "slide rails" into the muck pile and driving the "mucker" on to them. These rails are usually lengths of ordinary rail, either inverted or on their side, clamped to the track as shown in Fig 34. After the "muck" has been cleared slide rails are replaced by ordinary track.

Hauling

It is essential that hauling keeps pace with "mucking" and it can be considered as three operations:—

1. Getting full skips clear of the "mucker" and supplying empty ones.
2. Running trains between the "face" and the "portal" or shaft, and
3. Tipping.

The basic problem in the first operation is to bring empty skips up one side of the "heading", get them into a position where they can be filled by the "mucking " machinery and then get them away to form up a train. Normally the "mucker" operates in the centre and a layout as shown in Fig 35 is required. Skips would probably be hand pushed or "poneyed" to and from the "mucker". To save time this distance for "poneying" should be small consequently the "switch" must follow up as close to the face as possible the whole time. This is carried out by laying a double track to the face and running the "mucker" on the two centre rails, a "California switch" then lays on top of the rails to transfer skips from either track into the centre, and can be slid forward as required (see Fig 36). This method is the most common in medium-sized tunnels, although there are many other ways of carrying out this operation including hauling empty skips up to the roof to let the full ones out.

A continuous supply of empty skips must reach the face and full skips got away as there is invariably very little "siding" space in a "heading". This necessitates trains moving up and down the whole time and the longer the heading the more "trains" are required and consequently more crossing places. (Tunnel track is nearly always a single line with "laybys" at intervals for use as crossing points). If the muck is being taken to the surface up a shaft the track layout at the foot of the shaft has to be carefully designed to fit into a confined space and enable full skips to be got into the cages whilst empty ones are brought out. Some storage space is also necessary as one cage will not be able to accommodate a whole train at a time, also there may be hold-ups.

A similar layout will be required at the top of a shaft or outside a "portal", but usually much more space is available. Outside the tunnel diesel locos usually take over from the electric tunnel locos if there is any distance to the tip site, thus there must be a "run around" to enable this switch to take place. If the "muck" is being taken away by lorry tipping is fairly simple and usually a hopper or some sort of ramp enables the lorries to be filled. If, however, the "muck" is being dumped from the skips on to a tip a "tip gang" will be required who will empty skips during "mucking" and spread the "muck" and slew rails the rest of the time. Wet weather can play havoc with tips especially regarding the track which soon bogs down and causes derailments. If possible it is always a wise precaution to have enough skips and siding space to enable a complete "mucking" to go ahead unhindered, even if the tip is out of action and it is impossible to get skips emptied at the time.

Finally a brief word on locomotives. Unless a tunnel is very well ventilated diesel locos cannot be used inside whilst electric locos usually have not got the power to tackle the steeper gradients found on tips nor do they stand up to the weather so well. The normal arrangement is, therefore, that electric locos work underground and diesel on the surface and in the case of a "portal", as already stated, a "change over" point is necessary. The electric locos run off large batteries which have to be charged and with a "portal" a charging shed is normally built whilst at the bottom of a shaft a charging bay is tunnelled out.

Supporting the Roof

In rock tunnelling there is no practical method of estimating the ground pressure that must be resisted by "timbering", thus analytical design of roof and wall supports is not possible. Incidentally "timbering" is a mining expression referring to all kinds of supports for roof and walls be they timber, steel sections, ribs, concrete rings or any other type.

In very deep tunnels rock under stress may be encountered and there is the tendency for the walls to be "squeezed" into the tunnel. Often this type of ground is not recognized until after the excavation has passed, in which case extra "timbering" has to be placed. At depths less than 500 ft this "squeezing" is not likely to be encountered and the greatest load coming on to the timbering will be the weight of the "core" between the tunnel roof and the natural arch of the rock (see Fig 37). The full weight of this "core" will only be experienced where "rotten rock" or the lay of the strata prevents this "core" being held in position by the rest of the ground. As will be seen from Fig 38 a dipping strata is much safer than a horizontal one. Problems concerning the "squeezing" of rock are somewhat beyond the scope of this paper thus roof supports will be considered as serving two main purposes:—

1. As an "umbrella" to protect the miners from falling pieces of rock loosened by blasting or weathering.

2. To support larger masses of rock whose natural support has been removed by the excavation of the tunnel.

In both cases the prevention of falls reduces "overbreak" and, as already stated, the less the "overbreak" the more economical the tunnelling. In the latter case the important thing is to prevent initial movement of the rock and, if blasting has unfortunately broken out the ground larger than the tunnel section, then the space between the ribs and the rock must be tightly packed to prevent any such movement (see Fig 39). This would be done by actual timber packing which can be placed quickly by the miners and enable them to push ahead. Later on, but before weathering has put too much weight on this timber, a "back gang" would replace the timber by concrete and steel packing. This operation must not be left too late otherwise the removal of the timber will be a dangerous operation. The reason for replacing timber by concrete and steel is that any tunnel requiring support will eventually be "lined" and linings are practically always of concrete. A concrete lining can be placed over any steel work or concrete packing or segments, but as already stated must not be placed over timber. The placing of concrete linings is a subject on its own and I do not propose to deal with it in this paper except to say that as a rough guide the lining should be 1-in thick for every foot of diameter, with the minimum thickness not less than 8-in in soft ground and 6-in. in rock.

Types of Support

In igneous rock normally no support will be required but, as mentioned in "Design", if drinking water is passing through there should be a thin concrete lining and in a tunnel being used for traffic either there should be a lining or concrete spray, to prevent weathering, or else it should be "walked" once a day to "scale off" any loose pieces as even the hardest rocks will weather. Hard rocks may also contain bad patches which have to be "held". This can be done by means of "beijls" (pronounced bails) details of which are shown in Fig 40. Once bad patches get too large they must be treated by the normal methods of supports as used with poorer rock.

Timber is a common form of tunnel support as temporary ribbing, but of course it has to be removed on any permanent tunnel and it is for this reason that steel ribs are to be desired if they can be erected quickly as tunnelling proceeds. Although not as adjustable as timber they can be left in place.

Behind the ribs is placed "lagging" which again can be timber or steel and is spiked or wedged in position. It may be open spaced so as to "catch" only the bad patches of rock or in "rotten ground" it may be "close spaced". Steel ribs usually have corrugated steel "banker bars" as lagging.

In bad rock, such as soft shale, or during a "break in" segments may be used. These may be of concrete which, after placing, have grout packed behind them, or of cast iron, suitably caulked in wet rock.

Normally rock will stand long enough to allow drilling and firing to be carried out and the type and condition of the rock will govern the distance at which the "timbering" must "follow the face". In very bad rock, however, it may not be safe to drill underneath an unsupported roof, in which case roof supports must be carried right to the face before drilling starts. The difficulty in this case is that some of the ribbing will always be knocked out when the charge is fired, but this cannot be avoided.

Inside Survey

"Outside survey" enables a tunnel to be started and produces bench marks on each site together with fixed pillars on the "tunnel line" which form the base lines. In "portals" and "adits" these lines can be carried forward into the heading by theodolite, but in the case of shafts the base or "tunnel line" will have to be transferred to the foot of the shaft by means of two plumb lines.

Getting the "base line" down a shaft is probably the most difficult problem in tunnel survey, especially as the length of this "base line" is limited by the diameter of the shaft. The plumb lines are usually of piano wire with 20 to 30 lb weights on the end and naturally sited as far apart as the shaft will permit. They are wound down from a bobbin, over a pulley which has a fine lateral adjustment, and through a "light box" below which the plumb bob is damped (see Fig 41). By these methods the "tunnel line" from the surface is transferred to the foot of the shaft whilst the level is "dropped down" by means of a steel tape.

Once inside the "heading", either down a shaft or into a "portal", the line and level have to be carried forward and this is done by means of roof or floor stations. There are various types of these stations, but basically they consist of a steel plate or rail fixed securely into the roof or set in a large block of concrete on the floor. To carry the line forward the instrument is set up, with the aid of a short plumb bob, exactly on line underneath the last station. It is sited on the last but one station and then by "transit" the line is carried forward and with the aid of a plumb bob a mark etched on the steel plate of the new station. When siting on to a plumb line in a tunnel a powerful and diffused light has to be placed behind it. This light usually consists of several bulbs in a box the front of which is ground glass or tracing paper. Levels are taken forward on the normal system, the steel plate or rail acting as a bench mark.

It will be appreciated that tunnel survey has to be extremely accurate and it is the boast of any true miner that his "headings meet on a dime". The spacing of survey stations to achieve this accuracy naturally depends on local conditions although as an average, on straight sections, they are placed at about every 500 ft. Between these accurate roof or floor stations the engineer sets out other stations to enable the "tunnel boss" to mark out the face for firing or to set ribs. These do not require such great accuracy and are usually spaced at about 100 ft intervals. They must be designed so that the "tunnel boss" or "leading miner" can fix them up quickly whenever he wants to get his line and level. Three popular types are:—

1. *Candle pots*

This is the most common method and consists of small iron pots, hung down from the roof on a length of chain, into which a candle can be placed (See Fig 42). The engineer levels them in from his main survey stations so that the flame of the candle is on the tunnel axis. The pots are either fixed to a plug in the roof, or else they are hung on a hook from the ribs. When they are not in use the "fixed" type are looped up over a rib or a dowel pin, whilst the "hook on" type are removed from their hooks. It is, however, important to arrange the height of these hooks so that each candle pot has the same length of chain. If different lengths of chain go to different hooks, then mistakes are bound to occur.

2. *Inverted boning rods*

These are boning rods which are hung upside down on adjustable hooks and which have siting holes in them (see Fig 43). Here again the rods are sited by the engineer after which the adjustable screws are locked. The boning rods are interchangeable and when the miners require to find their "tunnel line" they hang rods on to hooks. The main disadvantage of this method is that the boning rods take time and labour to make and easily get broken. It must be remembered that a tunnel is a dark and cramped place with a great deal of men and materials passing to and fro and often several inches of water underfoot, and anything that is not robust soon gets broken or lost.

3. *String*

Finally a simple and popular method is to use a string which is stretched at axis level from plugs in the walls or from the ribs together with a plumb bob hung down on the centre line. After the engineer has set them they are located by nails or saw cuts in the ribs.

In all these methods, to get his line the "tunnel boss" fits up two "siting devices", has a man on each to hold a match at the "axis point" and then lines in a stub of candle at the face. As the face moves forward the engineer has to keep setting up both permanent and temporary stations and a "tunnel gang" working on bonus are not prepared to hang back whilst the survey catches them up, on the other hand they are not prepared to stop working to let the surveyors set up their instruments; consequently a tunnel surveyor soon learns to carry out accurate survey with the roar of drilling in his ears or with strings of skips clattering passed him. He also learns to work on weekends as it is only then that he gets the opportunity to carry out a careful check of his work.

It is not proposed to deal with laying out tunnel curves in this paper except to say that the simplest method for giving points to miners is that of "offsets from tangents".

Conclusion

As already stated it is not proposed to deal with the placing of tunnel linings which is a subject on its own, so with "inside survey" we leave our hard rock miners, very much a race on their own, working their "headings" and earning their bonuses most of which may go down their throats. The "conclusion" in this case indicates the end of the paper rather than any carefully argued finding. However it is hoped that the reader will draw his own conclusion that rock tunnelling is a most interesting branch of engineering which, although rather specialized, becomes more and more fascinating as one learns more about it.

TUNNEL SHAPES

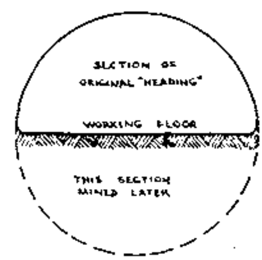


FIG 1 CIRCULAR TUNNEL DRIVEN AS A SEMI-CIRCLE

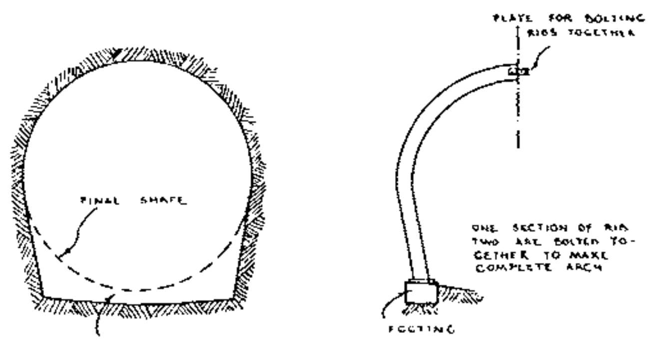


FIG 2 "HORSESHOE"

OBTAINING WORKING FACES

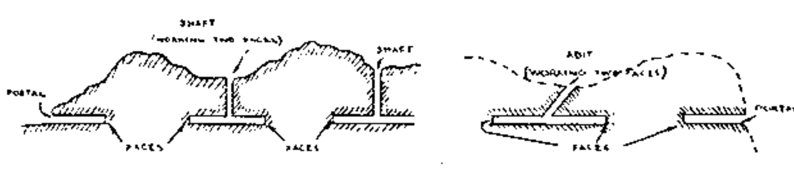


FIG. 3 USING SHAFTS ADITS & PORTALS TO INCREASE WORKING FACES

MASKING BAD GROUND

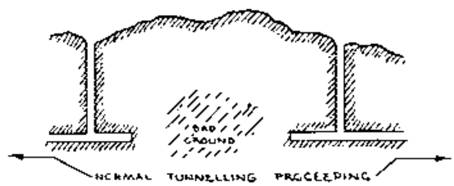


FIG 4 THE BAD GROUND WILL BE TUNNELLED BY SLOWER METHODS

SITE PLANNING

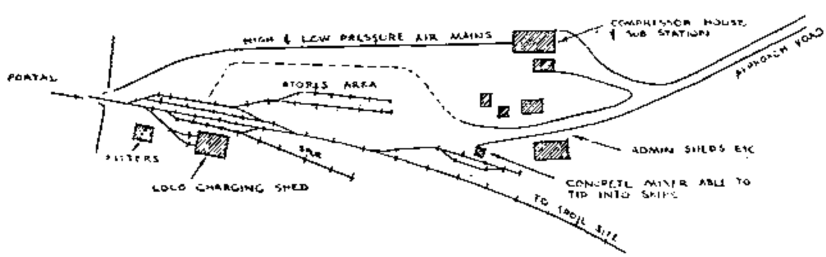


FIG. 5 TYPICAL LAYOUT FOR "PORTAL AREA"

THE "BREAK-IN"

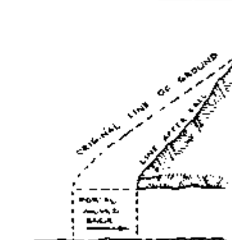


FIG 6 FALL OF SURFACE MATERIAL PUSHING BACK "PORTAL"

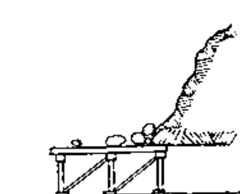


FIG 7 SHIELD AGAINST FALLING MATERIAL

THE BREAK-IN CONTD.

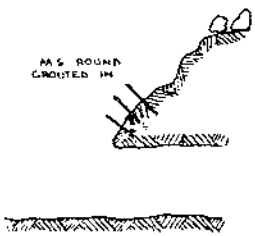


FIG 8 PROTECTION AGAINST LOOSE BOULDERS

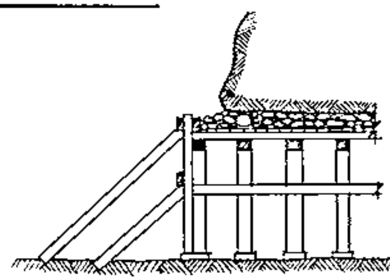


FIG 9 PORTAL STRUTTING

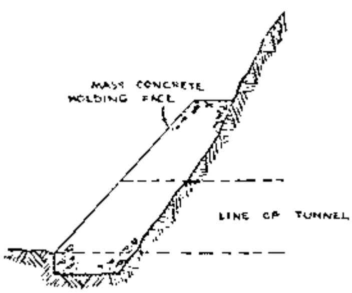


FIG 10 CONCRETE SHIELD

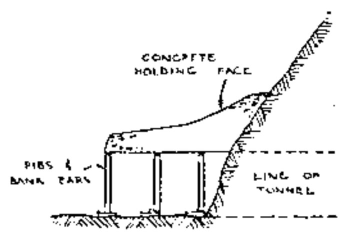


FIG 11 FALSE TUNNEL

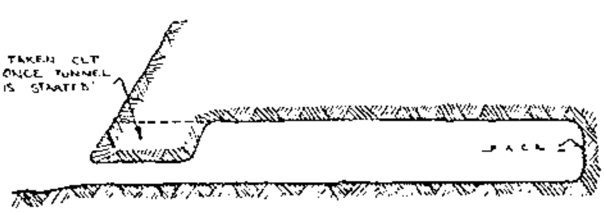


FIG 12

PILOT TUNNEL DRIVEN THROUGH BAD TOP ROCK

METHODS OF WORKING A HEADING

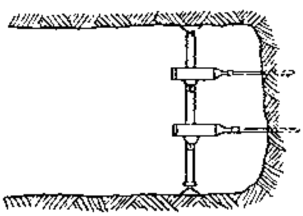


FIG. 13 "FULL FACE" ATTACK

FIG. 14 DRILLING OFF "MUCK PILE."

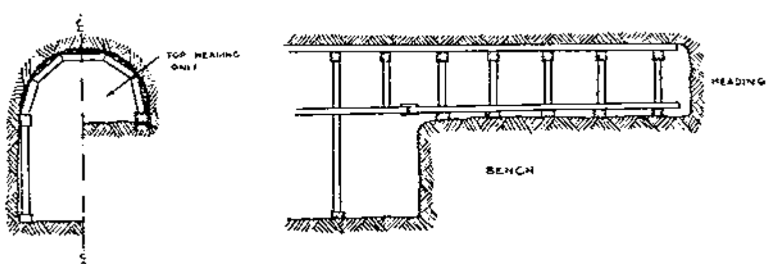


FIG 15 "TOP HEADING" FOR USE IN BAD GROUND

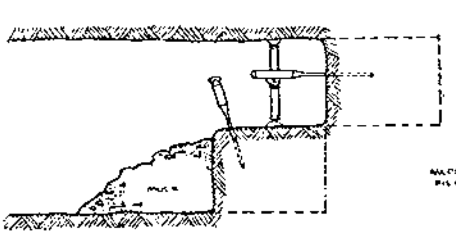


FIG 16 HEADING & BENCH

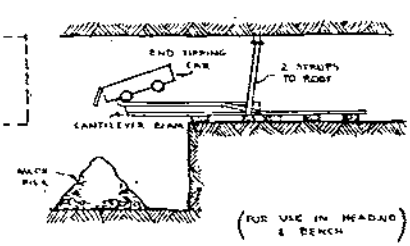


FIG 17 CANTILEVER CAR

DRIFTS

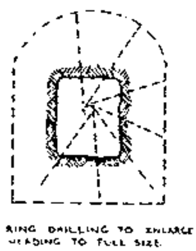


FIG 18 CENTRE DRIFT

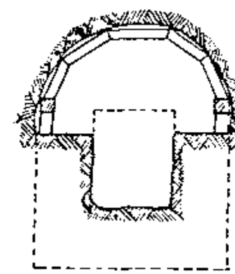


FIG 19 ENLARGING CENTRE DRIFT IN BAD GROUND BY 'HEADING & BENCH'

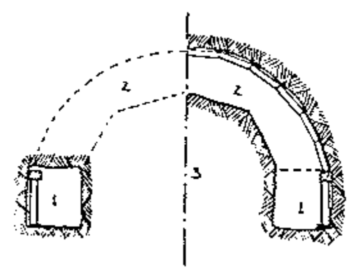


FIG 20 SIDE DRIFT TUNNELLING SHEWING SEQUENCE OF EXCAVATION

DRILL SUPPORTS

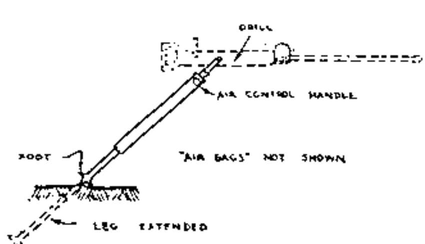


FIG 21 AIRLEGS

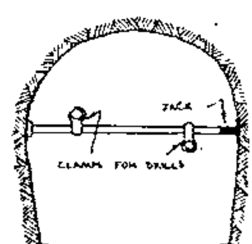


FIG 22 BAR MOUNTING

DRILL SUPPORTS CONTD.

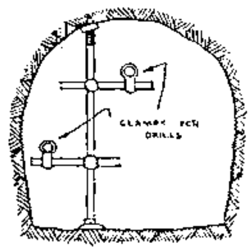


FIG 23 COLUMN AND BAR MOUNTING

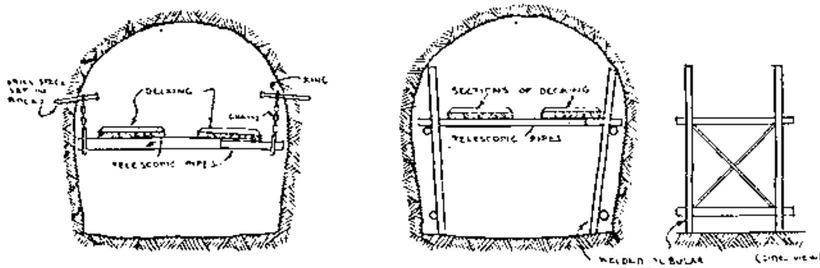


FIG 24 TWO TYPES OF DRILLING PLATFORMS

DRILLS AND BITS

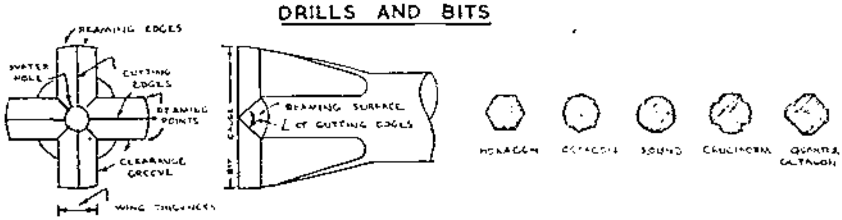


FIG 25 NOMENCLATURE OF DRILL BITS AND SHAPES OF STEELS

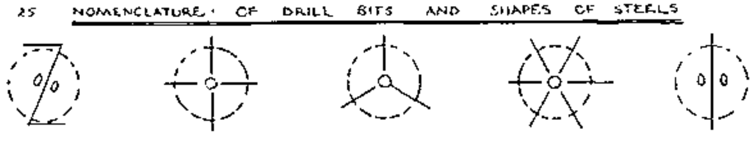


FIG. 26 VARIOUS SHAPES USED FOR BITS

(ONLY CUTTING EDGES & WATER HOLES SHOWN)

DRILLING AND BLASTING

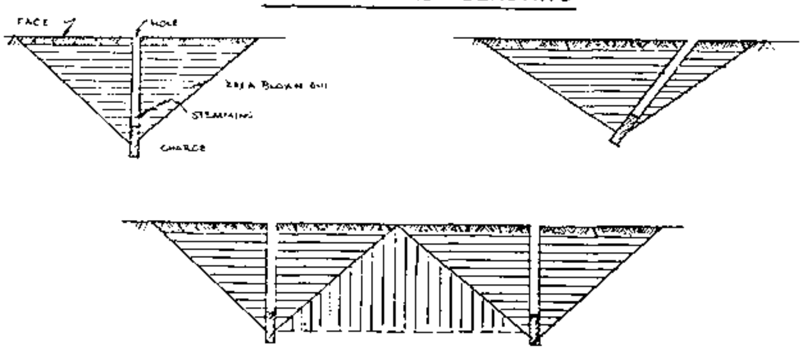
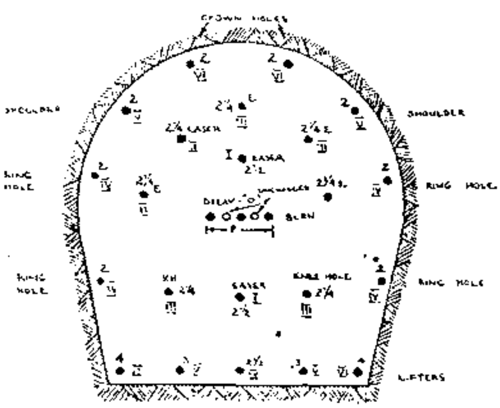


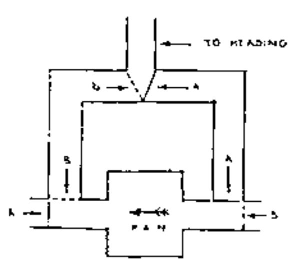
FIG 27 THEORY OF DRILLING & BLASTING



ROMAN NUMERALS = DETONATOR DELAY No.
OTHER NUMERALS = LBS OF EXPLOSIVE

IF CHARGE IS TO BE REDUCED
a) LEAVE "LIFTERS" THE SAME
b) REDUCE MOST ON OUTSIDE RING
c) REDUCE A SMALL AMOUNT ON INSIDE RING
d) VARYING "BURN" WILL ALTER FRAGMENTATION

FIG 28 TYPICAL DRILLING & CHARGING PATTERN
(USING 62¼ lb of EXPLOSIVE & A 5-HOLE BURN CUT)



POSITION A FOR BLOWING
POSITION B FOR SUCKING

FIG 29 NON-REVERSIBLE FAN BEING USED FOR BLOWING & SUCKING

MUCKING

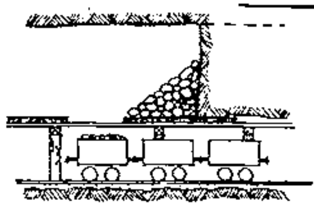


FIG 30 HAND TRAPPING

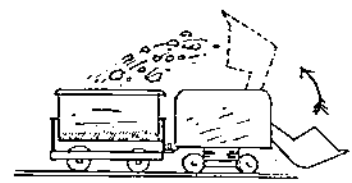


FIG. 31 "EMCO" MUCKER

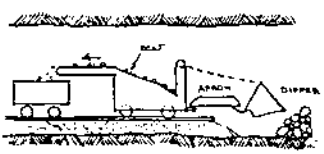


FIG 32 "CONWAY" MUCKER

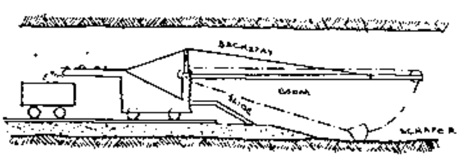


FIG 33 "CONWAY" MUCKER CONVERTED TO BOOM SLUSHER

SLIDE RAILS

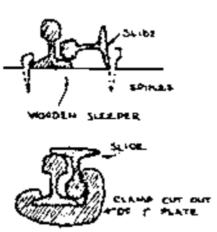


FIG 34 SLIDE RAILS
(TWO METHODS OF CLAMPING TO TUNNEL TRACK)

HAULAGE

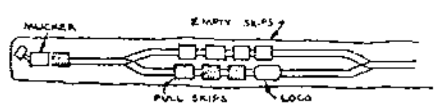


FIG 35 SHUNTING SKIPS TO "MUCKER"

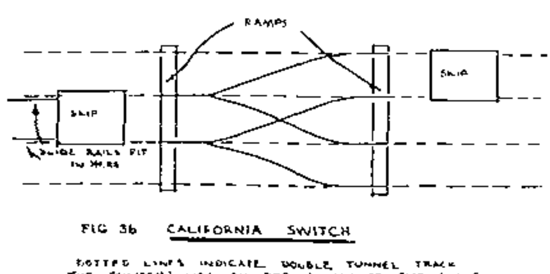


FIG 36 CALIFORNIA SWITCH

DOTTED LINES INDICATE DOUBLE TUNNEL TRACK
THE "SWITCH" LIES ON TOP & CAN BE SLID ALONG

SUPPORTING THE ROOF

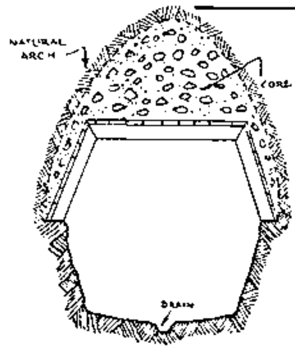


FIG. 37 NATURAL ARCH

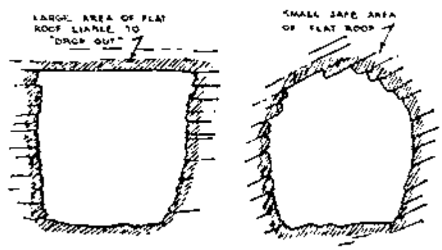


FIG. 38 HORIZONTAL & DIPPING STRATA

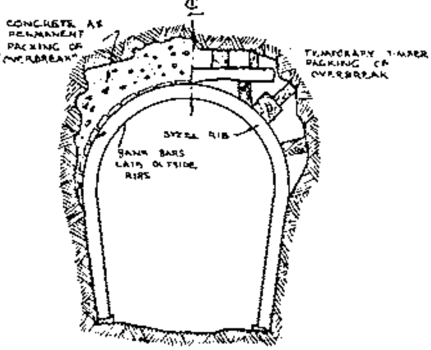


FIG. 39 PACKING BETWEEN ROOF & RIBS

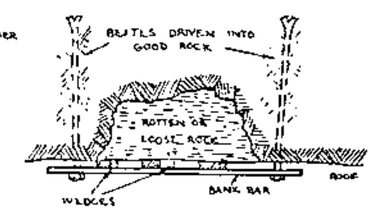


FIG 40 "BEITLS"

INSIDE SURVEY

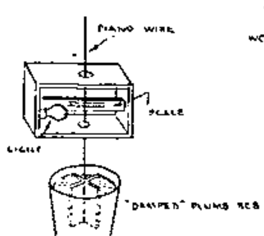


FIG 41 LIGHT BOX

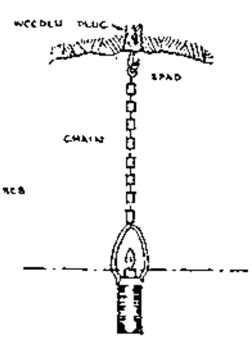


FIG 42 CANDLE POT

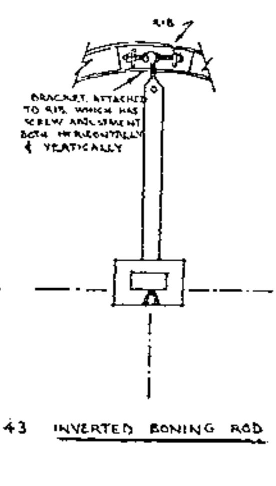


FIG 43 INVERTED BONING ROD

The Lines of Torres Vedras

By General Sir James Marshall-Cornwall, KBE, CBE, DSO, MC

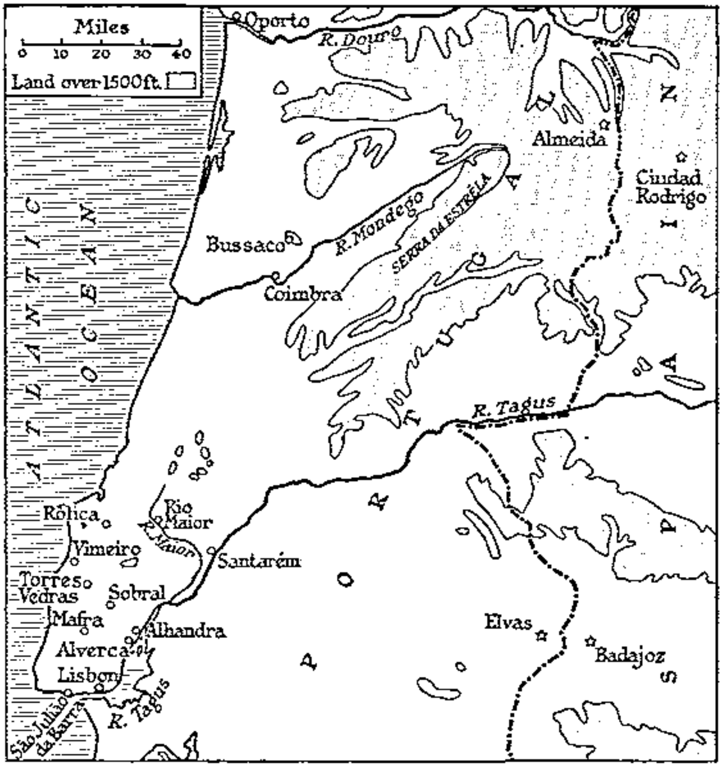
This article originally appeared in *The Geographical Magazine*, September 1961 and is published by the kind permission of the author and the editor.

General Sir James Marshall-Cornwall, has most kindly presented to the RE Museum, Chatham, a complete map of the Line of Torres Vedras, prepared by Colonel Francisco Baptista the Portuguese Engineer Officer in charge of maintaining the fortifications.

On 27 September 1810 (as I described in the July number of *The Geographical Magazine*), the Anglo-Portuguese Army under Viscount Wellington (as he then was) gained a resounding tactical victory at Bussaco over a numerically superior French Army, led by that experienced warrior, André Masséna, Duke of Rivoli and Prince of Essling. Masséna had started his career as a cabin-boy and then became a smuggler in the Alpes Maritimes; after retiring as a company-sergeant-major from the French Royal Army, he blossomed out in the Revolution as the most efficient and trusted of Napoleon's Marshals.

In spite of his costly failure to drive the British and Portuguese off the steep Bussaco ridge, Masséna succeeded in marching his whole army two days later round Wellington's left flank, north of the Bussaco position, thus forcing him to retire southward on Lisbon. As Masséna sat down at Coimbra on 4 October to write his dispatch to Napoleon on the Bussaco battle, he had some reason to think that he now had the ball at his feet. By his skilful manoeuvre after the battle he had converted a tactical defeat into a strategic victory; within a few weeks his army of 63,000 would undoubtedly drive the 35,000 British into the sea, and he would be in possession of Lisbon and all Portugal. But the crafty Masséna, although he did not then know it, had met his match.

A year previously when Wellington, after his victory at Talavera, had been obliged to retire into Portugal before superior French forces, he realized that it was essential to safeguard the embarkation of his expeditionary force if the French were ever to concentrate overwhelming strength against him. At that time Napoleon had something like 250,000 men in the Peninsula, while the British force of 35,000 was the only field army which England possessed. Wellington reckoned that he would be compelled to evacuate the country if Napoleon could ever concentrate 100,000 men against him. He was determined not to risk a hurried embarkation, as had been forced on Sir John Moore at Corunna the previous January. The port of Lisbon, although a magnificent harbour, would be a bad point of embarkation, as it is situated fifteen miles up the Tagus from the open sea, and the enemy might be able to seize both banks of the estuary. So after consulting his fussy colleague, Admiral Berkeley, Wellington selected as his emergency embarkation point the little port of São Julião da Barra, just outside the Tagus bar. But a much



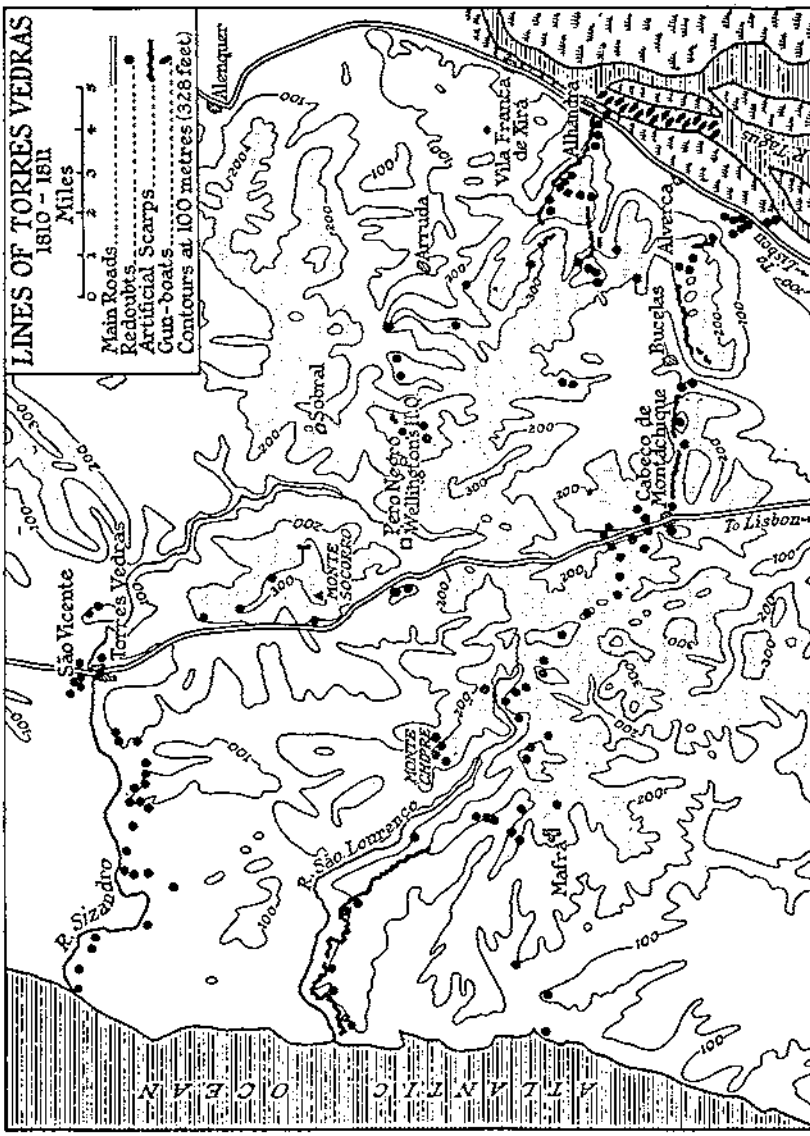
A. L. Thornton

wider and deeper covering zone was to be provided by creating two strong outer lines of defence, giving ample elbow-room for manoeuvre and counter-attack.

Wellington, with his genius for choosing a good tactical position, had in October 1809 made a thorough reconnaissance of the tangled mass of steep foot-hills and valleys that fill the Lisbon peninsula between the River Tagus and the sea. Inland, to the east of Lisbon, the Tagus opens out into a wide lagoon, making the capital unapproachable from that side except by boat. To the west lies the Atlantic, where the Royal Navy had held unchallenged supremacy since Trafalgar. All that remained to be done was to render the northern land-front impregnable for a distance of some thirty miles. Having laid down the point of vital tactical importance, and having secured the promise of adequate reinforcements from the Royal Navy in cannon, gun-boats and signalling equipment, Wellington handed over the detailed work of fortification to his Chief Engineer, Lieutenant-Colonel Richard Fletcher,[1] Royal Engineers.

Fletcher responded nobly to the task. With his small staff of sapper officers, British and Portuguese, and a locally enlisted labour force of 10,000 he succeeded within the next twelve months in creating the most effective system of field fortification known to military history. Philip Guedalla has

[1] Lieut-Colonel Sir Richard Fletcher, Bart, KCH, killed in action at the storming of San Sebastian, 31 August 1813.


LINES OF TORRES VEDRAS
1810 - 1811
Miles
0 1 2 3 4 5
Main Roads
Redoubts
Artificial Scarps
Gun-boats
Contours at 100 metres (328 feet)
Alenquer
Sobral
Arruda
Vila Franca de Xira
Alhandra
R. Tagus
Alverca
To Lisbon
Bucelas
Cabeço de Montachique
Pero Negro
Wellington's H.Q.
Monte Socorro
Torres Vedras
São Vicente
To Lisbon
R. Sizandro
Monte Chipre
R. São Lourenço
Mafra
Atlantic Ocean

A. J. Thornton

described it as "that inspired introduction of the broad facts of geography into the art of war".

The defensive system consisted of a triple line of strongly built masonry redoubts. Starting from the coast, the first line ran eastwards from the mouth of the Rio Sizandro to the village of Torres Vedras, where a strong *point d'appui* was constructed, covering an important defile through which passes the main road to Lisbon from the north. Thence the line of works ran in a general south-easterly direction along a well-marked ridge, passing west of Sobral and Arruda and reaching the right bank of the Tagus south-west of Allhandra, through which the main highway runs from the north-east. The total length of this line was twenty-eight miles. The second and main line of defence ran approximately five miles behind the front line, and was somewhat shorter, having a length of twenty-two miles. The sector nearest the coast, as with the front line, was covered by a dammed-up stream, the São Lourenço and the line of works then went south-east along a very steeply scarped ridge, north and east of Mafra. The centre sector of the line, between Monte Chipre and the Cabeço de Montachique, was particularly steep and rugged, covering a group of rocky peaks which rise to a height of 1400 feet above the sea. From Montachique the line continued along another steep escarpment south of Bucelas and reached the Tagus south-west of Alverca.

The third and last line was a beach-head perimeter, only three miles in extent, to cover the eventual embarkation at São Julião da Barra, on the northern shore of the Tagus estuary.

Last September I had the good fortune to drive all round the Torres Vedras Lines under the able and friendly guidance of Colonel Francisco Baptista, the Portuguese Engineer Colonel responsible for their maintenance. "The Lines" were not a continuous linear rampart like Hadrian's Wall, Offa's Dyke or the Danevirke. They consisted of chains of mutually supporting redoubts, 152 in all, crowning every dominant tactical feature on the selected line, and enfilading all approach roads and defiles. Every device of the military engineer's art was employed to supplement the natural obstacles offered by the terrain: rivers were dammed, converting them into lagoons and marshes; roads were blocked with abatis and *chevaux de frise*; bridges and culverts were prepared for demolition; forward slopes were artificially scarped, and the field of fire was cleared of all houses and natural cover. The Tagus estuary was patrolled by a flotilla of gun-boats manned by the Royal Navy, which was also responsible for equipping and manning a semaphore signalling system, with nine main signal stations erected on prominent points.

The redoubts were solidly built masonry forts, star-shaped or polygonal in trace, each defended by a dry ditch and counter-scarp. All but the smallest were armed with cannon, of which some 450 to 500 were employed, manned by British and Portuguese gunners. But no first-line infantry were locked up in the redoubts, *à la Ligne Maginot*, for their garrisons consisted of the Portuguese Militia and Ordenança (Home Guard) of whom Wellington had some 30,000 at his disposal, thus setting free his field army of 35,000 British and 25,000 Portuguese regular troops for manoeuvre and counter-attack. He had in addition a contingent of 8,000 Spaniards.

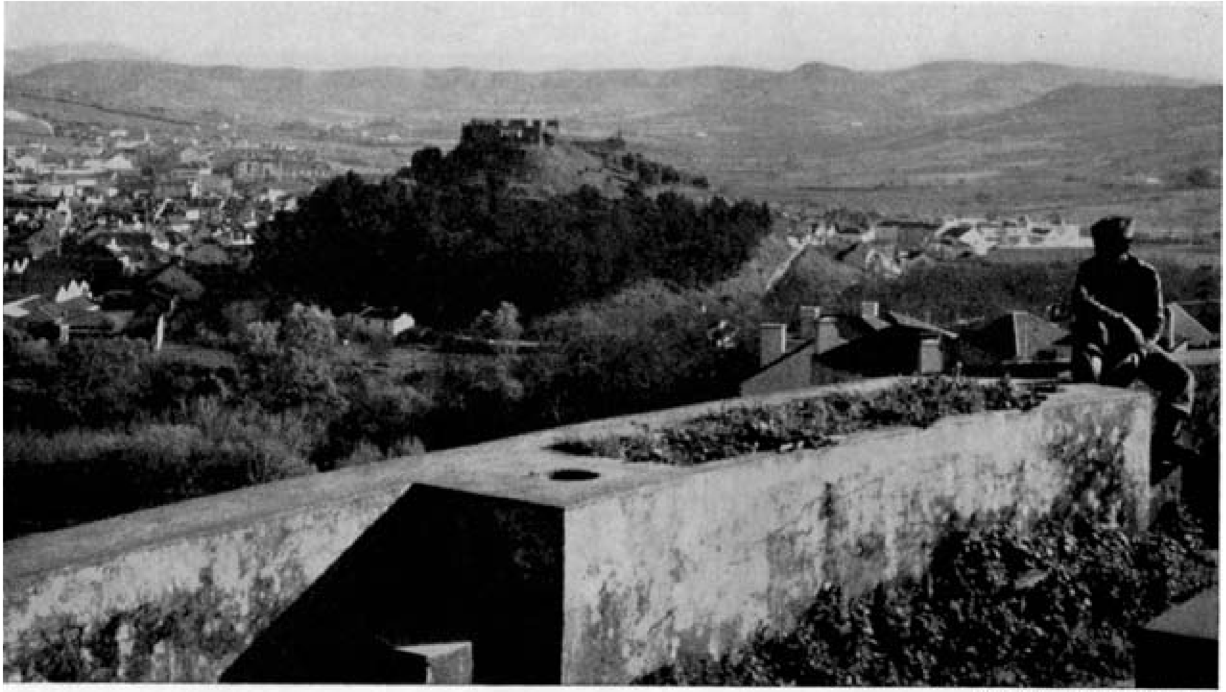
When I made my visit to the Lines, just a century and a half after their original construction, I was greatly struck by the solid condition of the masonry redoubts, having previously imagined that the Lines were only a system of earthworks. Most of the redoubts crown the hill-tops and have thus escaped the plough of the cultivator, though in some places the masonry escarps have been robbed for building-material. I was, however, delighted to find that the Portuguese Government is restoring to its original condition the great triple redoubt of São Vicente, which crowns the hill just north-west of the village of Torres Vedras. This fort, one of the strongest works of the Lines, is to be maintained as a historic monument; when the work of restoration is complete, it will form a permanent and impressive memorial to Luso-Britannic comradeship and cooperation. The restoration work is being carried out by the Corps of Military Engineers under the supervision of Colonel Baptista. Certainly no more competent supervisor could have been chosen, and I was amazed at his detailed knowledge about every one of the 152 redoubts under his charge. In the ten hours which I spent in his congenial company I learnt more about the art of field fortification than I did during my years as a Woolwich cadet.

The strategic consequences of the Lines were enormous, for they not only decided the issue of the 1810 campaign in Portugal, but they formed the turning-point of the whole Peninsular War. They certainly well repaid the time, labour and money expended in their construction.

Within a fortnight after the withdrawal from the Bussaco position at the end of September 1810, six British divisions had retired within the shelter of the Lines. The retreat had been conducted in an orderly manner, covered efficiently by the British cavalry rearguards. On 11 October the French cavalry patrols under Montbrun bumped into the outer defensive line all along the front, from the mouth of the Rio Sizandro to the Tagus estuary at Alhandra, and reported that they could advance no further. On the following day Junot's VIII Corps, which had not been engaged at Bussaco but had been delayed in its march by incessant rain, attacked Craufurd's Light Division, which was still outside the Lines between Sobral and Arruda. The peppery Robert Craufurd launched a somewhat unnecessary counter-attack in his usual impetuous way, and outpost bickering continued for two more days on this sector, until Wellington pulled the Light Division in behind the Lines. Wellington established his own headquarters at Pero Negro in the centre of the front line near Sobral, close to Monte Socorro, a magnificent observation post 1,292 feet high, from which he could scan the whole countryside.

On October 14 Masséna came up and made a personal reconnaissance of the Lines. He was completely astounded, not only by the powerful fortifications confronting him, of which, strange to say, he had had no previous intelligence, but also by a maze of rugged hill-country which barred his path to Lisbon. Turning to the two renegade Portuguese officers on his staff, General Pamplona and the Marquis of Alorna, he reproached them bitterly for having deceived him with the promise of an easy promenade from Coimbra to Lisbon. The two Portuguese officers excused themselves by saying that they could hardly be blamed for not knowing about the fortifications which Wellington had thrown up in the last few months. "The devil," the Marshal retorted angrily, "Wellington didn't make these mountains!"

Masséna might with more justice have upbraided his leading corps commander for not warning him about the local topography, for two years previously Junot had been sitting in Lisbon for eight months until Sir Arthur Wellesley (as he then was) had bundled his troops back through that very country after the victories of Roliça and Vimeiro. Junot indeed, remembering Wellesley's swift advance on Lisbon via Torres Vedras and Mafra in the



By kind permission of Michael Teague

Photo 1. Torres Vedras from São Vincente, a key point in the Lines which Wellington constructed in 1810.

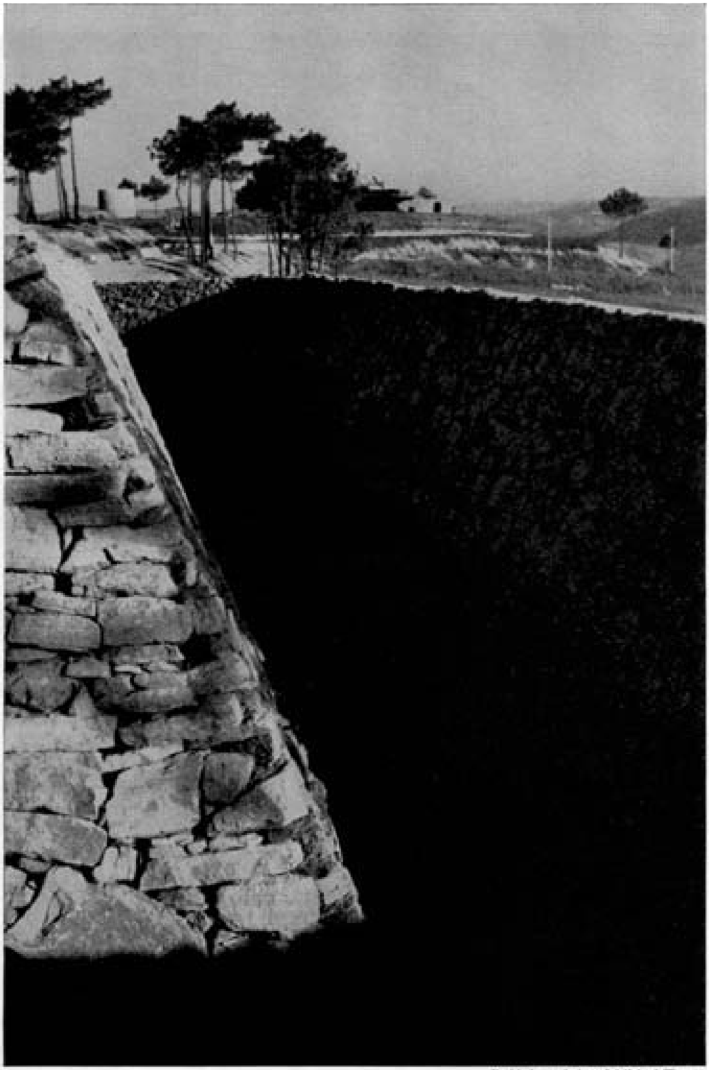
The Lines Of Torres Vedras 1

By kind permission of Michael Teague

Photos 2 and 3. Crowning the hill at São Vicente is part of a windmill which existed before the Lines were built, and which Wellington's engineers included in the reboubt as an observation post. The timber shuttering will be removed when the restoration of the masonry revetments is finished.

The Lines Of Torres Vedras 2 & 3

The Lines Of Torres Vedras



By kind permission of Michael Teague

Photo 4. São Vincente's masonry rampart with its formidable dry ditch. Each main fort was defended by a battery of guns, mostly nine-pounders and twelve-pounders, with a few heavier pieces supplied by the Royal Navy.

hot August days of 1808, advised Masséna to attack the British lines immediately. But Masséna was not to be drawn. His experienced eye at once realized the enormous strength of the position in front of him—a position which was impossible to turn, as he had, somewhat tardily, turned the Serra do Bussaco. And he also remembered the bloody losses which his two veteran corps had suffered at the hands of a numerically inferior Anglo-Portuguese force on the unfortified Bussaco ridge. Masséna was now faced with a far harder task. The slopes at Bussaco, though steep, had been dry, and considerable cover was afforded by boulders and brushwood. But in front of the Lines every watercourse had become a torrent with the autumn rains, and each one had been dammed, so that whole sectors of the position were covered by inundations, while elsewhere every house and wall and bush which might have afforded cover had been cleared away. So Masséna did the only thing he could do—he sat down and waited, for his only chance of victory was to tempt Wellington to leave the shelter of the Lines and attack him. But that was just what Wellington would not do; looking down at the French encampments from his lofty command post above Sobral, he is recorded as having said: "I could lick those fellows any day, but it would cost me 10,000 men, and, as this is the last army England has, we must take care of it.'

Masséna's "Army of Portugal" was stalemated, and indeed, as its lines of communication with Spain and France were cut by the Portuguese guerrillas, it was slowly starving. The only course left open to him was to imitate Wellington's tactics. On 10 November, just a month after his advanced guard had been halted by the Lines, Masséna ordered a general withdrawal to the line Rio Maior-Santarém, some thirty miles to the north-east. He was fortunate in effecting his retreat under cover of a thick fog. Heavy rains flooded the Rio Maior valley which protected his new front, while his southern flank rested on the swollen Tagus. Wellington's divisions followed up slowly, but the water-logged state of the country made military operations impossible and both sides went into winter quarters.

The Anglo-Portuguese Army was in an infinitely better situation than the French, as it had a secure supply line back to its base at Lisbon. Not only was Masséna's army entirely cut off from the French columns operating in Spain, and thus forced to live on the country, but the Portuguese countryside had been stripped bare of supplies and forage by Wellington's orders. The French therefore spent a miserable winter and the troops were half-starved and ill clad; their discipline deteriorated to such an extent that any further thought of offensive operations was out of the question. Masséna with dogged tenacity continued to hold on, hoping that Napoleon would send him reinforcements. Finally, in February 1811, his corps commanders convinced him of the hopelessness of remaining in Portugal. Early in March the retreat began, first northward towards Coimbra, and then north-eastward through the difficult country south of the Mondego River, Wellington followed him cautiously but relentlessly.

The French retreat was not without its livelier incidents. The rearguard consisted of the VI Corps under Marshal Ney, who was hardly on speaking terms with his chief, Marshal Masséna. On March 13 at Fonte Coberta, ten miles south of Coimbra, Ney withdrew his two rear divisions without informing his army commander Masséna and his staff were dining unsuspectingly by the bank of a stream when they were suddenly surprised and narrowly escaped capture by a cavalry patrol of the King's German

Legion. A few days later, after a further act of insubordination on the part of Ney, Masséna removed him from command of his corps and sent him back in disgrace to Spain.

When the French Army Headquarters got entangled in the rough country of the Serra da Estrêla, misfortune also happened to "Madame X", the attractive little lady who had accompanied Marshal Masséna throughout the campaign, disguised as a captain of dragoons. While scrambling along a mountain path her horse fell and threw her badly among the granite boulders, so that she was severely cut and bruised. Consequently, "*cette femme courageuse*", as Masséna's A.D.C. calls her, who had so gaily ridden into Portugal, had to make an undignified exit on the shoulders of stalwart French grenadiers.

At the beginning of April Masséna quitted Portugal for ever, with 40,000 ragged and starving Frenchmen in very different plight from the splendid array of 67,000 fresh troops which had invaded the country seven months previously.

The Lines of Torres Vedras had fully justified their construction.

Electrical and Mechanical Engineering in the Royal Engineers

By MAJOR J. MCDOWELL, RE

INTRODUCTION

THERE is little doubt that the interest of Royal Engineer officers in E & M as an avenue of technical qualification in the Corps has waned alarmingly since the last war. There are many who believe that REME handle the major E & M requirements of the Army and that with the civilianization of Works Services the Corps can, and should, hand over as much as possible of the electrical and mechanical engineering for which it is still responsible to REME to leave the RE free to undertake their chief role as field engineers in the battle. Indeed, many Sappers have little idea of the scope of E & M in the Corps.

This paper is an attempt to bring E & M into its proper perspective in the Corps of today for the benefit of those officers who might be interested in it.

The writer is an "unlettered" and, for most of his service, a GS Sapper and believes, therefore, that this article may be less biased than if it were written by an E & M specialist. For the same reason, he makes no apology for any controversial matters of fact or opinion it may contain. If it stimulates those of differing opinions, or greater knowledge of the subject, to contribute their views in these pages, this paper will have attained its aim of arousing more interest in the subject.

PERSPECTIVE

In order to bring E & M into its proper perspective, let it be borne in mind that Royal Engineers do not merely provide support in the field for the Corps battle. In descending order of magnitude, from a technical point of view, Royal Engineers must take their part in:

(*a*) Full scale atomic war with massive destruction in a matter of hours, followed by the battle for survival requiring the fullest technical skill of every surviving engineer and technician.

(*b*) Conventional or limited atomic war, fought as currently taught, in sharp engagements lasting weeks or perhaps months, creating relatively small areas of mass destruction, but producing wide engineering problems outside the immediate battlefield which the writer believes the Army cannot afford to ignore. If such operations do not rapidly develop into full scale atomic warfare, they must deteriorate into

(*c*) Stalemate conditions, as occurred in Korea, whilst political negotiations are conducted. These conditions also arise in semi-political situations, like the Canal Zone prior to the evacuation, Cyprus, the Suez venture, the Congo and Laos, Kuwait and now Berlin. In these circumstances, the writer believes that no military force possessing engineers can withhold its technical skill and resources from the inevitable engineering problems to be met which affect the military as well as the civil population.

(*d*) Finally, there are planned operations, conducted in a non-warlike atmosphere, arising from natural catastrophes such as floods and earthquakes, from civil disturbances or general strikes, and for scientific operations like Christmas Island.

If the reader accepts the foregoing, then clearly there are tasks for all branches of the Corps both field and technical and for E & M trained personnel whose major role is in the field of what is best termed "public utilities".

"Public utilities" in this sense can be defined as the provision for the Army of power, water and POL, and the installation and operation of their means of supply. This must include associated E & M services such as water purification, sewage disposal, refrigeration and air conditioning, and workshops for the manufacture and repair (in conjunction with REME) of engineer material.

During the shooting phases of operations, these are provided in the field by the "GS Sapper" with his field generators, pumping and purification equipment, workshop lorries and other portable machines. Even in this limited sphere of E & M most field sappers will agree that there is a constant requirement for development of equipment and techniques of operation. However, this paper is concerned mainly with the more advanced aspects of E & M for which additional specialist training is necessary.

Scope of Electrical and Mechanical Engineering

In the Corps

The scope for E & M trained RE officers in military engineering can be outlined under the following major headings:—

(*a*) Design and development of engineer plant and equipment both for RE and GS needs.

(*b*) As practical engineers, to design, install and commission E & M utilities and complexes.

(*c*) Restoration and/or operation of public utilities in these fields.

(*d*) Operation of workshops for manufacture of urgent GS or RE requirements.

(*e*) Operation of repair workshops for the maintenance of RE plant and equipment which is not in the province of REME.

(*f*) Development of economic and technically sound methods of plant and spares provision and preservation.

(*g*) As technical advisers in E & M to Royal Engineer Commanders at various levels.

(*h*) Instructing officers and other rank technicians.

Before going into details under the above headings, it is proposed to compare them with the scope of E & M undertaken by REME, by emphasizing those aspects which are not within the charter of that Corps.

RE vis à vis REME

REME do not:—

(*a*) Operate E & M utilities for the Army, neither do they directly design, install nor commission them.

(*b*) Operate production workshops for manufacture of urgent GS or RE requirements.

(*c*) Repair certain classes of RE equipment and plant, notably large transportable equipments as opposed to the truly portable range.

(*d*) Hold, or supply any military stores or equipment for other arms of the service.

(*e*) Act as E & M advisers to the Army within the definition given above.

But lest it be thought that the range of REME activities is not appreciated, it should be remembered that they have to carry the huge repair and maintenance load of the Army's electronics, armaments, armour, vehicles and GS stores as well as quite a proportion of purely RE plant.

In fact it has been stressed in recent studies that REME priority for repair in battle is in the order given above and that the workshop capacity likely to be available for GS vehicles, let alone engineer "funnies", is going to be small. It is fair comment to say that the repair facilities for RE Plant in general are not entirely satisfactory even now, in peacetime conditions.

It is, therefore, difficult to follow the logic of those in the Corps who would advocate the handing over of all E & M to REME.

Without undue exaggeration, one might envisage some of the results of such a policy. In an operation such as Christmas Island, the Sappers, after supporting the initial landings with their field equipment, would have built the accommodation and the roads and airfield, operating the plant and pavers under close REME supervision.

REME would have designed, installed, commissioned and operated the power stations, electricity supply network, water supply and purification, sewage works, air conditioning, cold storage, POL tank farm and pipelines, as well as the special requirements of the scientists concerned. As the mechanical experts it would seem right for them to have installed and operated the quarries and asphalt pre-mix plants.

In the tactical battle, one would envisage field squadrons supported by a Field Park Company, REME, with its Sapper Stores Troop. (Or could that aspect be undertaken by the RAOC Stores Section?)

To be fair to the protagonists of reduction of E & M commitments in our Corps, one must admit that the division of some responsibilities between the two technical Corps in the repair and maintenance field appears to leave room for improvement and this is discussed in more detail later.

It is now proposed to examine further the scope of E & M under the headings given previously. The range is wide and it is possible that there are many specialists in E & M who would hesitate to claim knowledge of all its activities. Certainly the writer cannot claim this, but nevertheless proposes to illustrate each section as far as he can and also to add a little piquancy by introducing a few controversial points of view.

Design and Development

The Corps, under the aegis of DREE and MEXE, is responsible for the design, or selection and modification of suitable civilian equipment and plant for use by Sappers generally. Obviously this includes the larger generators, pumping sets for POL and water, water purification equipment, refrigeration, air conditioning and cold storage plants, major civil engineering equipment and steam raising plant, etc.

It may not be generally realized that many of those items which the GS Sapper obtains from Ordnance, and which are repaired by REME, are also a design responsibility of the Corps.

For example, these include field lighting sets and generators below 50 kW, compressor trucks or trailers, C vehicles generally and certain electronic equipment such as mine detectors. Some of these, notably generators and many C vehicles, are used by arms other than the Royal Engineers.

In addition to plant with prime movers or other means of power conversion, there is design work to be done in pipelines and storage systems for water and fuel. There is a great field for research into the uses of gas turbines and packaged atomic plant, and in the general process of bringing more horse power into the hands of the Sapper in the field.

There seems to be a tendency nowadays towards equipping and training the Corps only for its role in the shooting war without much thought for the other aspects, particularly the aftermath or stalemate phases of an operation.

An example is in the proposal to standardize field generators on a high frequency (400 cycles per second instead of the present 50/60 cycle standard). This suits the electronic equipment now to be found increasingly in the forward areas and may show certain savings in prime mover weights (though the reverse in the alternators). However, it will bring in its train a massive re-equipment programme since every AC motor in service will have to be of a special type which is not, nor likely to be, manufactured for normal civilian use. But the most embarrassing aspect of this proposal is that none of this equipment will be compatible with any civil electricity supply network in any part of the world. (Our present generating standards are, of course, extremely flexible). Thus to "aid the civil power" the Corps would first have to ask for the equipment, whereas now we can both use or reinforce civilian installations.

Again, in the field of engineer plant, there is the continual cry for a "standard machine with a standard engine" which will do everything. But competent designers admit that in the wide and constantly developing field of earthmoving and mechanical handling, this ideal cannot be fulfilled. As a rule composite machines rarely perform any of their functions as well as the single purpose machine. They are often so complex in their ancillaries that the small saving in maintenance and spares leading from the use of the "standard" prime mover is lost in the peculiar requirements of the rest of the machine.

Finally, there is the problem of training technicians for the Corps. If they train merely in purely military equipments, they will need additional training to use civil equipment when it comes to aiding the Civil Power.

Obviously there must be compromise in these matters but a great deal of careful study should be given to any proposals to equip the Corps with special purpose machinery and devices in those fields where some civil versions already exist. Our designers should concentrate on those aspects where there is no civil equipment or requirement. It is probably true to say that weight and standardization problems are the major short-comings of civil machines which are otherwise suitable for military use. But it is equally true that civilian users would gladly accept improvements in these respects, provided they were reasonably economic. Instead of trying to compete, let our designers collaborate with the makers with these aims in view to the mutual benefit of everyone.

Even if the reader does not agree with these views, he must admit that the arguments merit consideration, and it is essential that those responsible for design take the balanced view.

The E & M trained officer, therefore, requires an academic as well as a practical background, with field experience both in the Sapper and the commercial or industrial sense to bring to bear on such problems so that he is neither confounded by boffins with brilliant but impractical ideas, nor deterred by inexperience from promoting sound improvements to the technical sinews of the Corps.

E & M Projects

Alongside his colleagues specializing in Civil Engineering, there is a need for potential E & M officers to be trained on large projects. Through experience gained from appointments with ESSE, they can secure the essential practical background required in the installation and commissioning of E & M utilities and services and, therefore, in repair and rehabilitation of them. Christmas Island necessitated qualified officers to handle the complete field range of public utilities. At this point, a word of praise for the Corps E & MOs would not come amiss for this project was very largely in their hands. They are an essential part of the E & M backing of the Corps, as are the Clerks of Works from whose ranks they are commissioned, and it is not possible to visualize the Corps performing its E & M duties without them.

In the Canal Zone, when the Egyptian Government abrogated their Treaty with the UK, the Corps lost the Egyptian and German technicians and labour who had, up to that time, formed the bulk of the staff of the WD utilities. All these had to be replaced at short notice by the Corps, supplemented by volunteers from other arms, the RAF and the Navy. Many of these volunteers had very little experience and required a larger degree of technical supervision than had previously been the case. These utilities involved an installed generating capacity of around fifteen megawatts of power in steam turbine as well as IC engined sets, and the installation and operation of filtration plants, water pipelines and pumping stations, sewage disposal plants, cold stores, ice plants and air conditioning in hospitals, as well as Base and Tn Workshops.

This situation could arise to a greater or lesser degree in conditions of a general strike or the aftermath of atomic war, limited or otherwise, and is already extant in the Congo. The new Works Organization is undoubtedly a potential source of reinforcement in these circumstances, but there can be no doubt that the first responsibility is very likely to be in the hands of the Corps, and in many cases, to remain there.

The restoration of the public utilities in Port Said after the Suez operation was undertaken by an E & M squadron of the Army Emergency Reserve and their work gave great credit to the Corps. The Suez operation was, however, of a scale which permitted the embodiment of Reserve Army units. Others will certainly arise in future, of an urgency or scale that cannot await this procedure and regular units of the Corps must have men and machinery able to undertake such tasks.

RE Workshops

There are two distinct requirements here. There is a need for repair workshops to deal with the range of engineer equipment which is not the responsibility of REME. At present the Corps has three such workshops, in UK, BAOR and Singapore respectively with smaller ones in Cyprus and Hong Kong.

In addition, in wartime, the Corps is expected to undertake production tasks in the field to cope with urgent field requirements which cannot await production in the UK or in overseas industrial bases.

In the last war complete factories were run by Sappers producing such things as anti-tank mines and petrol cans (before Jerricans) and Z Craft in Egypt, substitutes for Bailey Bridging in Italy and locally manufactured pontoons in Burma. This may never occur again on those scales, but it is probably true to say that there is no operation involving the Corps, whether large scale or local, in which the Field Park, Workshop and Park or Independant Field Squadrons are not required to undertake production tasks, often employing hundreds of skilled and unskilled local labourers. Frequently, locally acquired machine tools are essential to reinforce the unit equipment. (How will this work with generators at 400 cycles?)

Is it seriously suggested that nothing like this can happen in the limited atomic concept? And even if this is agreed, that there will be no such requirement in between phases of such operations?

In engineer repair workshops the Sapper finds himself faced with that most difficult problem, to wit jobbing or "one-off" repairs. To get good output from a jobbing repair shop requires real knowledge of the "work content" of the job in hand and the capacity for work of the technicians and machines available to do the job. Only then is it possible for the shop to be "loaded" for maximum economy of effort. A great deal more attention must be given to this aspect of workshop management, at all echelons, if RE workshops are to be efficient.

In addition, the division of responsibility of RE and REME is at times a positive handicap to the RE Workshop Officer. For example, civil engineering plant such as concrete mixers, paving machines and mobile crushers etc, are officially items of REME repair. The hulls and structures of motor tugs are a Sapper responsibility but the engines and transmission are REME. Dry bridging and heavy ferry pontoons are Sapper whilst all hydraulics are REME.

It is impractical to take a large concrete or asphalt batch mixer or a heavy ferry if it breaks down, to a REME workshop (for it is not normally their policy to undertake major repairs by mobile detachments). Yet Sappers have qualified technicians who must form part of the operating teams of such machines who, if permitted, can perfectly well (and of course do) change an engine or other major assembly. Sapper fitters are expected to be able to overhaul large generators in the range from 50 kW upwards to 650 kW, and in some cases beyond, and hydraulic devices are to be found in many RE equipments which are not a REME responsibility.

With closer co-operation between the two technical Corps this could be resolved so that, for example, Sappers could hold and fit replacements such as engines and hydraulics, whilst REME would repair the assemblies using their specialist techniques and return them to a pool for re-use.

There is room for improvement at all levels in the techniques of planning and executing repair and production tasks in RE Workshops and this is one of the fields in which the E & M trained officer supported by E & MOs and Clerks of Works is essential.

Engineer Plant and Spares Provision

Perhaps this is one of the least sought after aspects of E & M and yet it is absolutely vital. It is complex enough without the problems caused by the reduction of "tail" units in the Army.

In brief, the Army, for the shooting war, recognises that repair and maintenance must be kept down to a minimum, to the extent that only the most valuable equipment will be repaired. "B" vehicles, certainly, may well have to be abandoned.

Engineer equipments are usually oddities and come in penny packets. Unlike armour and "B" vehicles, there is little reserve to call on in the field nor can much be really justified. Yet quite often an operation or project may depend on one or two pieces of engineer plant in the whole theatre. The big "Starmix" asphalt plant on Christmas Island, or the overworked generators in the Canal Zone are examples. Clearly, these cannot be abandoned and spares and repair facilities must be found to keep them going. There is the question of selecting and holding in an adequate state of preservation the right number and range of engineer plant for war or other emergency. If too many are held in War Reserve, they will become obsolete before they are used. Too few, and the reserve becomes inadequate. There is also the problem of holding in good condition and disseminating the necessary spares.

These problems are partly statistical, partly economic, but also E & M problems since they require the very soundest practical knowledge to arrive at a workable solution.

The Future for E & M Trained Officers

The E & M Staff Officer

Perhaps the foregoing has illustrated in some measure the duties of the E & M trained officer in his own technical sphere. If so, it must be agreed that there is a wide range on which an Engineer Commander may need briefing or advice from a technically trained officer. However, it is essential that the E & M Staff Officer should have a broad outlook and not fall into the technicians trap wherein he believes his own speciality to be of greater importance than all others.

E & M Trained Officers in Field Units

E & M trained officers have long been regarded in the Corps as specialists who have little if any place in field units, although curiously, this has not been the case with officers who specialized by taking the Long Civil Engineering Course. Yet on many occasions field units have installed elaborate "utilities" of the field type where a quick assessment of the problem and a few tradesman hours would have completely rehabilitated a civil supply. On other occasions it has been necessary to call in specialist units where existing units, properly advised, could have coped.

The Coles bridging crane, now the subject of much criticism by field users, largely on account of its electrical system, indicates a lack of E & M knowledge at that level. (Some of this criticism must also be levelled at REME). The writer is convinced that machines of this type and the coming generation of "C" vehicles generally will rely increasingly on electro-hydraulic, or electro-pneumatic controls to give faster operating response and reduce weight. We must have the skill at all levels to operate, maintain and repair them.

One properly trained E & M officer, supported by two or three E & M trained NCOs can supervise a very diverse range of E & M work, provided that he is given good quality general purpose fitters, electricians and ancillary trades, plus the necessary mates and labour, to execute the work.

A Field Park Squadron seems, therefore, an obvious place for E & M trained officers and this has now been recognized by the War Office.

Clearly, there are other very worthwhile appointments for E & M trained officers, notably in Specialist Teams and in the few Specialist Squadrons which the Corps maintains in peace time.

Finally, the Corps should cease to regard E & M trained officers as employable only in their specialist field. They are Regular Officers who have acquired additional experience in one branch of engineering but that does not mean that they have thereby become less capable combat engineers.

TRAINING

The present arrangement is that suitably qualified officers attend the Long E & M Course at the SME which lasts for two years. This course has had its ups and downs but there is no doubt that it gives a broad basis in E & M which should enable any officer who attends, after further practical experience, to undertake almost any E & M job.

However, up to the present, it has suffered from one major drawback in that, unlike the Long Civil Engineering Course, with its close association with the Institution of Civil Engineers, the E & M course has not been linked with the requirements of the Institutions of Electrical or Mechanical Engineers.

This has now been rectified and the aim of the course altered to the following:—

"*Long Electrical and Mechanical Engineering Course*

Aim

To prepare regular RE officers to plan and control in war and peace the wide variety of engineering tasks allied to mechanical and electrical engineering for which the Royal Engineers are responsible. The Course will give advanced training in mechanical and electrical engineering with the object of:—

(*a*) familiarizing officers with modern developments and techniques in the mechanical and electrical engineering industry, thus increasing the knowledge and experience they can bring to bear on military problems.

(*b*) Assisting officers to attain the professional standard of a Chartered Mechanical Engineer or a Chartered Electrical Engineer, thus enhancing their standing and authority when seeking advice from, or directing the activities of, civilian organizations or individuals.

For an officer who is otherwise qualified for Command, the attainment of professional status at the level of Associate Member of the Institutions of Mechanical Engineers or Electrical Engineers will be to his advantage in considering his selection for certain senior staff and regimental appointments in the Royal Engineers. In addition, successful completion of the Course will be to his advantage in considering his selection for command of a field park squadron.

Note. An officer will follow either the mechanical or electrical engineering content of the Course, depending upon his academic background and, to some extent, his personal preference. Because of the close relationship between the academic and practical training of the Chartered Mechanical Engineer and the Chartered Electrical Engineer, either qualification will be equally acceptable in considering an officer's suitability for employment within the Corps."

Thus the officer who decides to specialize in E & M need no longer give up ambitions to command in the field and at the same time can open up for himself a wide field of opportunity in the most interesting branches of engineering.

The Army must substitute machines for men wherever possible and machines need electrical and mechanical engineers.

CONCLUSIONS

(*a*) All the possible forms which war may take will pose E & M problems, but the "public utilities" aspect of atomic aftermath or the cold war will require the most E & M effort from military engineers.

(*b*) The present charter of the Corps provides for the skill to solve these problems; that of REME does not.

(*c*) There are many aspects of equipment peculiar to the Corps, including development, design, repairs and spares, which demand Sapper officers trained in electrical and mechanical engineering and possibly an increase in RE responsibilities.

(*d*) Mistakes are being made in this field, and mention has been made of some controversial examples. The Corps as a whole will benefit if some of its best officers are engaged in ensuring that it gets the right equipment.

(*e*) There is great scope, interest and training value in E & M projects and workshops and fresh thought is urgently needed in the provision and maintenance backing of RE plant and equipment.

(*f*) A Commander cannot afford to have an E & M adviser with a narrow solely technical outlook.

(*g*) The training of officers for E & M appointments needs improvement not only so that there shall be an adequate number of officers to carry out the tasks which have been outlined above, but so that these officers shall have the opportunity to acquire suitable civilian qualifications.

(*h*) The War Office has recognized the necessity for a reorganized system of training to meet modern requirements and also for an assured career for E & M qualified officers.

(*j*) There is an increasing need for E & M trained officers in field units and service in these units will qualify such officers for engineer command appointments.

ACKNOWLEDGMENT

The writer would like to thank those officers, specialists in their fields, who have given him, consciously or otherwise, the benefit of their knowledge. In particular, he wishes to thank Lieut-Colonel J. H. Frankau, MC, RE, for his most valuable constructive criticism of this paper.

Camp Century, Greenland

By Warrant Officer Class I P. W. James, RE

In April 1960 the Engineer-in-Chief arranged for the attachment of a Sapper Warrant Officer to an American Army team engaged in the task of installing a packaged atomic power station in Greenland. Warrant Officer Class I James was selected for this attachment. After two months indoctrination at the Nuclear Plant at Fort Belvoir, Warrant Officer James joined the erection team in Greenland.

The following article describes the type of work on which he was engaged.

Editor.

One hundred and fifty miles inland from the Greenland coast a camp has been constructed under the snow with comfortable hutted accommodation, well-equipped laboratories and a nuclear power plant to supply all the electrical power required. This is Camp Century, a research and development project in itself.

The camp has been constructed in two summer seasons. This winter is the first time that troops will have stayed in such an isolated location where the temperature can fall to $-75°F$ and violent wind storms sweep the flat ice cap, which at this spot is at an altitude of over 6,000 ft.

The layout of the camp is shown in Fig 1. Swiss snow milling machines were used to excavate the trenches. These machines cut a channel in the snow 5 ft deep and 9 ft wide at the rate of 20 ft per min. Snow can be discharged to a vertical height of 36 ft.

All the tunnels, with the exception of those housing the nuclear power plant and the vehicle maintenance workshop, have stepped side walls. Thus below a 14-ft corrugated iron roof span it has been possible, when excavated to a depth of 24 ft, to have a floor width of 22 ft. The previously mentioned exceptions have straight sides to allow room for the erection of larger buildings to enclose the nuclear power plant and the vehicle workshop. These are covered by 30 and 40-ft "Wonder Arch" corrugated spans.

Getting the camp construction materials, installed equipment and the necessary handling plant out to the site was in itself a formidable task. The port of Thule is only open for three months of the year and during this period all stores, other than those that can be air lifted, must be brought in. Stores are moved by road to the U.S. Army Engineer base, Camp Tuto, which is situated on the edge of the ice cap. A ramp, over a mile in length, has been constructed to enable wheeled transport to carry the stores to the loading site. This obviates the difficulties of getting over the extremely uneven surface experienced on the ice cap rim. At the loading site stores are transferred to sleds of ten or twenty ton capacity. Low ground pressure Caterpillar D.8 tractors fitted with additional fuel tanks are capable of pulling up to six of these sleds, the actual number varying with the condition of the surface snow.

The first twenty or so miles of the trail between Camps Tuto and Century crosses numerous crevasses. The trail is located so that vehicles cross these crevasses at right angles, to do this the trail is marked out as a series of straight sections. Changes in direction are marked by two black and a red flag then a further two black flags in the new line of direction. New crevasses when discovered, usually in the spring, are opened at the surface using explosives and then dozed full of snow to form a bridge. Visual navigation of the trail is the only sure method of avoiding trouble. Compass error in this area is 77 deg and even the light planes and helicopters flying between the camps use the black flags as direction indicators. Spaced every 15 miles along the trail are survival huts stocked with emergency rations, a few of these also have emergency stocks of fuel for the vehicles.

To provide the water required for the cookhouse, latrines, showers and laboratories a well has been sunk through the snow to the ice layer. This well has a capacity of 10,000 gallons per day. The water is produced by piping steam down the well and discharging it below the surface of the water thus melting the enclosing ice. As the water level in the well falls the steam diffuser and the multi stage centrifugal pump are lowered by winch. The well shaft is 3 ft in diameter but the chamber formed in the ice has opened to over thirty feet in diameter and is now extending downwards while maintaining this dimension. Water from the well is extremely pure and is stored in two 4,200 gallon tanks. The tanks are housed in a building maintained at 60°F, but should the heating system fail, steam can be fed to the tanks to prevent the water from freezing. All the distribution lines from the storage tanks are heated where they pass through the unheated connecting tunnels.

Because of the difficulty and cost of supplying an isolated base with fossil fuels for power generation a nuclear power plant has been installed. The estimated annual diesel oil requirement for a conventional power plant comparable in output to the PM 2A, assuming operation at the same load factor would be more than 850,000 gallons, or in excess of 15,000 drums of 55-gallon capacity.

By contrast to this PM 2A will operate for twelve to fifteen months on a single loading of fully enriched uranium fuel. This fuel was shipped to Camp Century in eleven 55-gallon drums.

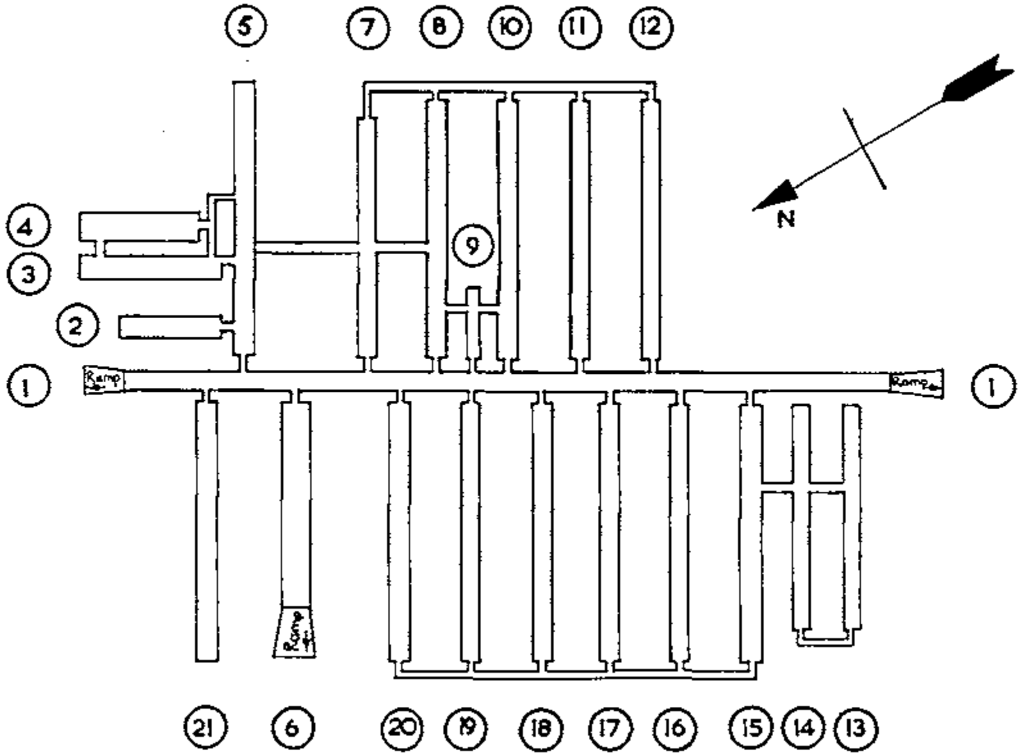
The main requirements in the design of this nuclear power plant were:—

1. A plant that could be prefabricated in the US and, if necessary, be flown to a remote location for speedy erection on site.
2. Must be simple, safe and of such a design that no major maintenance shut down would be required during the life of the reactor core.
3. Must be able to operate for at least a year without refuelling.
4. As a low a cost as possible.

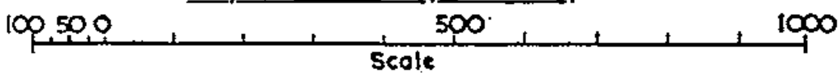
The PM 2A—portable medium power—is based on the existing static plant installed at Fort Belvoir, VA.

All the main components of the power plant are installed on skids, each of these conforming to the size and weight limitations of 30 × 9 × 9 ft and 30,000 lb. The primary system which comprises the pressurized water reactor, the steam generator, pressurizer and the primary coolant circulating pump is mounted on two skids which are aligned and fixed together on site. All the other skids contain components seen in any conventional power plant. The primary system is enclosed in a horizontal, steel vapour container 36 ft

Fig. 1.



Layout of Camp Century



1. Main tunnel
2. Air blast coolers
3. Feedwater tunnel
4. Reactor building
5. Generator, condenser and controls
6. Vehicle maintenance
7. Mess, kitchen and water supply
8. Dispensary and gymnasium
9. Sewage collection tank
10. Latrine, PX, library and recreation room
11. Post Engineer
12. Labs
13 and 14. Fuel storage
15. Standby power
16–19. Quarters
20. HQ and storeroom
21. Disposal trench

long and 13 ft 6-in. in diameter which was shipped in three flanged sections and assembled in position. The function of this gas-tight vessel is as an additional safety measure to contain all liquids, gases, corrosion and fission products released during a rupture of any part of the primary system.

As Camp Century has no natural body of water for use as a heat sink, air blast coolers are used. Ethylene Glycol is the condenser cooling medium, and this also removes heat from various other cooling systems such as the primary blow down cooler, turbine lubricating oil cooler and the shield water cooling coils. The Ethylene Glycol rejects this heat in the air blast coolers where cold air, from the spaces between the buildings housing the plant and the snow walls of the tunnels, is drawn over the finned cooler tubes and discharged to atmosphere.

When in operation the heat generated by nuclear fission in the reactor core is removed by water circulated by the primary coolant pump. To prevent the coolant in the core from boiling, and to allow a higher coolant temperature, the complete primary system is pressurized to 1,750 psi. The transfer of heat from the primary to the secondary system is made in the steam generator. Here the temperature of the primary water is lowered from 518°F to 500°F this heat being used to produce steam on the shell side of the generator at 465 psi. This relatively small reduction in the primary coolant temperature is to avoid heat stresses within the reactor core. To produce the steam required by the steam turbine at full load it is necessary for the primary pump to circulate the coolant at the rate of 4,200 gallons per minute.

The power plant was erected and tested by a team of seventeen servicemen, all of whom had received training in the operation of nuclear power plants. This team was augmented as required by a further twelve tradesmen. The erection team were present at the factory when the plant was assembled for test purposes and so were quite familiar with most of the erection problems as they arose. During the installation of the electrical systems it was found necessary to place the cable in a warm area to allow the insulation to become pliable enough to be uncoiled and placed in the cable trays. The complete plant was assembled in less than three months, this including the time required for hydraulic tests on the primary loop and individual cooling systems. The contract for the plant also called for helium leak testing of the primary system and the vapour container.

The reactor core was loaded by the same team under the supervision of one of the contractor's nuclear engineers. Fuel elements and the europium absorbers were loaded into the spent fuel rack which is located close to the reactor pressure vessel. The start up neutron source, a small polonium berrilium plug was placed close to the rack and after every four elements had been taken from the shipping barrels and placed in the rack an average count rate was recorded. The original count rate, taken before any of the elements were inserted in the rack, divided by the count rate recorded after every four elements were put in was plotted against a base of total mass of uranium in the rack. The points plotted when projected on to the base line give a direct reading of the mass of uranium required to cause criticality. This is known as an inverse multiplication plot.

On completion of this test the start up source and the fuel elements were transferred to the reactor pressure vessel and on completion when the control rods were raised a few inches the reactor became critical.

Once the plant became operational the erection team became the maintenance and operating crews. Three shifts of three men operate the plant, six men forming the electrical, mechanical and instrument maintenance sections and the two remaining NCOs forming the process control and health physics team. The complete crew being commanded by a Captain as OIC and a Chief Warrant Officer as the plant superintendent.

To provide camp stand-by and nuclear power plant start up power, three 300 kW diesel generating sets have been installed.

Some aspects of the installation of a plant, such as the MP 2A, in a remote location are worth consideration. The tremendous advantage of having the erection team working at the contractor's works and becoming thoroughly familiar with all the components before the site installation commenced probably reduced the erection and testing time by 50 per cent. There is a tendency however in training such as this for use to be made of factory tools and equipment which will not be available on the site. An example of this was the tightening of the three flanged joints of the primary loop. At the works these were tightened before the two-piece primary skid was inserted into the vapour container, this meant that there was ample room for the use of long extension bars on the spanners to reach the required torque. On site, because a large overhead travelling crane was not installed, this procedure was reversed and these nuts had to be tightened up in a restricted space. Against this it can be noted that special torque multiplying tools were provided for the site erection, but in fact these were only of use on a small proportion of these nuts. In fact, each of these flanges absorbed 100 man hours of effort to get the twelve nuts tight.

The need for close control of all stores arriving on a site is worth some emphasis. Seldom can stores be delivered to a work site in the sequence in which they are to be used. Heavy swings bringing in miscellaneous stores would arrive and unloading would start immediately in order to get the swing turned about for another load. Often the items were unloaded without recording where they were put. Other smaller items would sometimes be air lifted in or received from the Pole Cat personnel carriers. This sometimes meant that several hours were spent in searching the stores site to locate a particular box, and when snow started falling it was often a case of having to dig out where the required items were thought to be located. Time spent in planning and recording the location of stores on an open site will most certainly pay dividends.

Summing up it must be said that all the units and individuals concerned with the planning and building of Camp Century have done an extremely difficult job in an extraordinarily short period of time. The lessons learnt during construction and the knowledge being acquired now in the maintenance of such a large camp under such unusual conditions will be of great use to future polar projects.

APPENDIX "A"

Operating Data PM 2A

1. *Plant performance*

Thermal power developed in reactor	10 megawatts
Gross electrical power generated (0.8 pf)	1,980 kW
Power required for auxiliaries	420 kW
Steam supplied for outside heating	1×10^6 B Th U/hr

2. *Thermal Data. Reactor at full power*

Operating pressure	1,750 psi
Design pressure	2,000 psi
Coolant flow	4,200 gpm
Coolant inlet temperature	500°F
Coolant outlet temperature	518°F

3. *Core*

Configuration	7×7 array—three elements in each corner omitted

4. *Stationary fuel element*

Type	Plate type containing enriched UO^2 dispersed in stainless steel matrix clad with stainless steel
Number of elements	32
Plates per element	18
Active length	21.75-ins

5. *Control rod fuel elements*

Type	As stationary elements
Number of elements	5
Plates per element	16
Active length	21.13-ins

6. *Steam generator*

Tube side

Operating pressure	1,750 psi
Design pressure	2,000 psi
Flow	4,200 gpm
Inlet temperature	518°F
Outlet temperature	500°F

Shell side

Operating pressure	465 psi
Outlet temperature	463°F
Inlet temperature	306°F
Flow	37,700 lb/hr
Blowdown	400 lb/hr

7. *Pressurizer*

Operating pressure	1,750 psi
Design pressure	2,000 psi
Design temperature	650°F
Number of heaters	20
Total heat output	20 kW
Steam volume	13.8 cu ft
Water volume	5.1 cu ft

8. *Turbine generator*

Throttle steam pressure	450 psi
Throttle steam temperature	459°F
Turbine speed	7,323 rpm
Generator, 3 phase, 60 cycle	4,160 volts
Condenser vacuum	8-ins Hg
Condenser surface	2,500 ft²
Condenser flow	29,750 lb/hr

9. *Air blast coolers*

Number of coolers	3
Circulating fluid	2,000 gpm Ethylene Glycol
Blower capacity	58,000 cfm
Air blast cooler surface area:—	
Tube surface	8,925 ft²
Extended surface (fins)	116,300 ft²

10. *Physical data*

Maximum size of largest package	30 × 9 × 9 ft
Maximum weight of heaviest package	30,000 lb
Total weight of packages	288 tons
Number of packages	27

(The above excludes the vapour container.)

Jubilee of the Royal Engineers' Association

THE Royal Engineers' Association celebrates its fiftieth birthday next year. The aims and objects of the Association, which are well known to all Sappers past and present, are to foster a spirit of comradeship amongst all ranks of the Corps, both serving and retired, to assist in finding employment for ex-Royal Engineers, to give financial help to those needing it and to assist widows and orphans in their claims for pensions and in legal matters, to visit sick members and to obviate the burial of members by the local authorities.

Membership is open to all who are serving or have served in the Corps of Royal Engineers in the Active and Reserve Armies or in the Engineer Corps of any of the Commonwealth countries.

The origin of the Association goes back to 1906 when a few serving and retired Sapper Warrant Officers and Senior NCOs formed themselves into an Association for the purpose of holding annual reunion dinners in London for all ranks of the Corps. These reunions were so successful that in 1911 a committee, under Colonel B. R. Ward, was set up to explore the possibility of extending them to all retired members of the Corps. The proposals of this Committee were accepted by the Corps Committee and by the Committee of the RE Charitable Fund, the forerunner of the RE Benevolent Fund, and at an inaugural meeting held on 12 October 1912 under the Chairmanship of General Sir Harry Prendergast, VC, GCB, in the Royal United Services Institute, Whitehall, the Royal Engineers' Old Comrades Association came into being.

General Prendergast became the Association's first President and Colonel Ward was elected Chairman of the Central Committee, and on his shoulders fell the initial responsibility for seeing the newly-born Association through its first difficult teething troubles. The Association was controlled by a Central Committee that met in London and a number of local branches were formed. The Committee consisted of a Chairman, a Vice-Chairman, an *ex officio* Honorary Treasurer (ADFW The War Office), the IGRE, the Officer i/c RE Records and a number of elected members, both serving and retired, who either worked or lived within easy reach of London. The Association also held an Annual General Meeting in London.

On the death of General Prendergast in 1913 Field Marshal Earl Kitchener of Khartoum became President of the Association.

At first the activities of the newly-formed Association were mainly social but in 1913, only one year after its formation, the operation of the Corps Labour Bureau, administered up to that time by the Officer i/c RE Records, was transferred to the Association which most clearly indicated the confidence placed on the viability of this new Corps organization. Accommodation was provided for the Bureau, then renamed the RE Civil Employment Registry, in the Horse Guards, Whitehall and from that day forward the Association has done all in its power to place ex-Sappers in employment.

The 1914–18 War curtailed the Association's social activities and slowed down its development. The Association and the whole country suffered a grievous loss on the tragic death of Lord Kitchener in 1916. General Sir Richard Harrison took over the appointment of President and he remained in office until 1923, steering the Association through the last difficult war years and the troubled period that immediately followed the Armistice. He was succeeded by Lieut-General Sir Ronald Maxwell and, on his death the following year, Lieut-General Sir Aylmer Hunter-Western became President and he held the appointment for eleven years. In 1935 General Sir Charles Kirkpatrick was elected President but he resigned the following year on completing his tenure as Representative Colonel Commandant RE. His place was taken by Lieut-General Sir Ronald Charles who followed General Kirkpatrick as Representative Colonel Commandant. He retained the appointment of President of the Association on becoming Chief Royal Engineer in 1940 on succeeding General Sir Bindon Blood, and the Presidency has since then been held successively by the Chief Royal Engineer of the day.

In 1918 King George V graciously honoured the Association by becoming its first Patron and each reigning monarch since then has similarly honoured the Association. The Association was further honoured by HRH The Duke of Connaught, who was commissioned into the Corps in January 1868, when in 1927 he graciously consented to become a Vice-Patron and he so remained until his death in 1942.

The years following the First World War saw an amazing growth of the membership of the Association and many new local branches were formed both at home and overseas. Friendships made on active service were kept alive in the various branches and a great deal of encouragement and practical help was given to the many who needed it in those difficult, post-war, hungry years. The fallen were not forgotten. On Armistice Sunday 1920 a wreath of Flanders poppies was first placed by the Association at the Cenotaph and in 1933 the Association's wreath was first laid at the Royal Engineers Cross in the Field of Remembrance in Westminster Abbey. On Sunday 9 October 1927 the first Kitchener Memorial Parade Service was held in The Guards Chapel, Wellington Barracks. It was attended by a large congregation which included representatives of the Corps and of the Association. Afterwards the parade marched to Horse Guards Parade and the Association's wreath was placed at the foot of Kitchener's statue. In 1930 the Kitchener Memorial Parade Service was held on the Horse Guards Parade and the RE Band was in attendance.

In 1932 the then Chairman of the Association, Major-General R. N. Harvey, introduced a scheme to obtain a more representative body of members on the Central Committee. The newly constituted Committee consisted of eight serving officer and *ex-officio* members and twelve elected members from branches or groups of branches, and it met quarterly instead of monthly as was the previous custom. So that financial matters and urgent business could be attended to as quickly as possible a General Purposes Committee, which met monthly, was elected. This Committee consisted of the Chairman, Vice-Chairman, Hon Treasurer and three members of the Central Committee. In 1934 it was decided that an Annual Conference of Branch Delegates, to which each branch was entitled to send a delegate, should take the place of the Annual General Meeting, and the status of the Chairman of the Central Committee was changed to that of Chairman of the Association. The Chairman became an *ex-officio* member of the Regular Forces Employment Association and this link between the two Associations and the pooling of ideas, knowledge and resources helped materially in those days of widespread unemployment.

In January 1933 services were held at St Paul's Cathedral, Westminster Abbey and Trafalgar Square to mark the centenary of the birth of that famous Sapper hero General Gordon. Two hundred and fifty members of the Association attended these services.

In 1935 a hundred members of the Association attended King George V and Queen Mary's Silver Jubilee Celebrations in London. On Sunday, 27 June 1937, 400 members of the Association, including the President (Lieut-General Sir Ronald Charles) and the Chairman (Major-General W. H. Beach), attended a Grand Review of Ex-Servicemen by King George VI in Hyde Park.

The Second World War brought the Royal Engineers Old Comrades Association into the front line. The Headquarter Staff of the Association, except for the Chairman, the Hon Treasurer and the General Secretary were recalled for service with the Corps and an Emergency Committee was formed to administer the Association's affairs for the duration of the war. The Association's Annual Dinner and other annual functions were cancelled. Many branches had to close down. There were, however, other tasks to be done.

An RE War Comforts Fund was at the invitation of the Corps Committee set up by the Association. The Central Committee ran the Fund, Major-General W. H. Beach being the Chairman with Colonel Stokes as Honorary Treasurer and Mr J. G. Walker, the General Secretary of the Association, acting as Honorary Secretary. A Ladies Committee was set up by Lady Williams and many ladies volunteered to act as helpers. Lady Collins was Chairman of the London Centre and she was most ably assisted by Mrs Cave-Brown, Mrs Davidson, Mrs Tuck and others. The wives of Chief Engineers of Home Commands and local branches set up Ladies Committees for which knitting groups were enrolled. Vast numbers of comforts were received daily and donations in cash came pouring in from which the Association bought cigarettes, thousands of books, playing cards, dart boards and other indoor games for inclusion in the war comforts parcels. Over two tons of knitting wool was also purchased, enough, if stretched out, to go twice round the world. The London Centre was responsible for packing comforts sent overseas, a vast task. All helpers and the staff of the fund gave their services entirely free and the RE War Comforts Fund was one of the very few similar Corps and Regimental Funds run on a completely voluntary basis. The Fund, in spite of enemy action, never failed to carry out its commitments and comforts of all kinds continued to reach men in the field and in prisoner of war camps throughout the world. The General Secretary of the REOCA was awarded the MBE for his services, a tribute to his staunch work throughout the war.

The Association's first war casualty was its Standard, presented in 1938 by the President, Lieut-General Sir Ronald Charles. On the outbreak of hostilities it was sent to Bath for safe keeping but it was destroyed during a

German "Baedeker" air-raid on the city in 1940. It was, however, in London that the Association suffered the worst effects of the Luftwaffe. In 1941 the Association's Headquarters in Lower Belgrave Square experienced a "near miss" and all the windows were broken; further damage was caused by another bomb that fell near Eaton Square. The RE War Comforts Packing Centre in Victoria Station received a direct hit and new premises had to be found in Lower Belgrave Street. Here work was carried on under difficulties until the floor collapsed as a result of further bombing. Temporary accommodation was then found in Lower Belgrave Street and finally accommodation for both the Association Headquarters and the Packing Centre was found at Denison House, Vauxhall Bridge Road where the Headquarters remains situated today. Throughout the blitz there was no question of evacuating the Association Headquarters nor the Packing Centre from London to a safer area, nor were their activities suppressed by the worst the enemy could do.

On the conclusion of hostilities in 1945 most of the Association staff returned from military service. Soon thousands of ex-members of the Corps called at the Association's Headquarters seeking employment. During the first few months up to a hundred would call in one day, and many others applied by letter. Fortunately most of the applicants were able to be placed in employment.

In order to help Sappers returning to civil life the Chairman of the Association introduced a "pink sheet", which was included in the demobilization documents issued by the Officer i/c Records, which gave details of the REOCA Civil Employment Registry and invited all Royal Engineers on discharge to take advantage of its services. The Association made a most generous donation to the Royal Engineers' War Memorial Fund from which thirty-three RE homes were built in England, Scotland, Wales and Northern Ireland for disabled ex-members of the Corps and their families or widows under the auspices of the British Legion Haig Homes, and later two REOCA representatives were co-opted on to the RE War Memorial Fund Committee. A most generous donation was also made to the RE Roll of Honour Fund. Once again those fallen in the war were not forgotten.

With the return of peace many branches were able to reopen and many new ones were formed. In 1946 a scheme was introduced for regrouping branches under the Chief Engineers of Home Commands to allow for wider representation of branches on the Central Committee. The scheme also made all Chief Engineers of Home Commands Group Directors of the Association. The following year the Royal Australian Engineers Association and the South African Engineer Corps Association (The Sappers' Association) became affiliated to the Royal Engineers Old Comrades Association and members of both these Associations became Associate Members of the REOCA, the aims of both these Associations being similar to ours.

In 1950 the award of the Merit Badge and Certificate was introduced for outstanding services to the Association. These are, where possible, presented by the Chief Royal Engineer, the Association's President, at the RE Veterans' Week-ends at Chatham and at Aldershot.

On 7 April 1951 the Royal Engineers held a rally at the Royal Albert Hall, and the REOCA were entrusted with the sale of tickets and other administrative tasks connected with it. The rally opened with a fanfare written by Major-General I. S. D. Playfair followed by the march "Crown Imperial" played by the combined bands of the Corps. This was a preliminary to a series of tableaux and films depicting the exploits of the Sappers throughout the ages which culminated in a grand finale when all those who had taken part in the tableaux marched on to the stage followed by representatives of all branches of the Corps, the Old Comrades with their standards representing many branches of the Association and the last joined Bugler Boys from Aldershot. This great gathering of past and present Sappers stood to attention as the Corps march "Wings" was played. A gracious message from HM King George VI, Colonel-in-Chief of the Corps and Patron of the REOCA, was read and afterwards many of the large audience split up to meet old friends. The evening closed with singing "Hurrah for the CRE" in the traditional manner.

In November of that year, however, the REOCA were presented with a more serious task and once again a War Comforts Fund was organized, this time for the despatch of comforts to Korea.

In 1952 the title of the Association was changed from the Royal Engineers' Old Comrades Association to the Royal Engineers' Association. A suggestion to change the original title had first been made as far back as 1914 when the Association was only two years old, but that suggestion and other similar resolutions made since then had consistently been defeated at General Meetings. The change took thirty-eight years to bring about, but the present title indicates more clearly that the Association, and all it stands for, belongs to the whole body of the Corps, both to those serving and to those old comrades whose days of active soldiering are over. Once a Sapper always a Sapper.

1953 was Coronation Year. Ten branches with their Standards were selected to represent the Royal Engineers' Association at the Coronation and Major-General C. G. Woolner, the Association's Chairman, attended Westminster Abbey for the ceremony in that capacity. On 7 July of the same year HM Queen Elizabeth II reviewed a gathering of ex-Servicemen and Women in Hyde Park, drawn from all parts of Great Britain. Over 70,000 were on parade grouped into brigades. The Royal Engineers' Association was represented by 400 members with thirty-two Branch Standards. The detachment, commanded by Major-General C. G. Woolner and headed by the RE Band, marched from Denison House to Hyde Park. After the Review Her Majesty sent a gracious message expressing her thanks for the token of loyalty sent to her and her congratulations on the bearing of all members of the Royal Engineers' Association who had been on the parade.

On 24 October 1956 Her Majesty visited the School of Military Engineering, Chatham on the occasion of the hundredth anniversary of the absorption of the Corps of Royal Sappers and Miners into the Corps of Royal Engineers. General Sir Edwin Morris, the Chief Royal Engineer, presented Mr Walker, the Association's General Secretary to her, and later fourteen Merit Badge holders were presented to Her Majesty by the General Secretary.

In this resume of the first fifty years of the Royal Engineers' Association it has been possible only to highlight the major events, and no account has been given of branch activities; nor has it been possible to name those many members who have devoted so much of their time as Chairman, Vice-Chairman and Honorary Treasurer of the Association, nor to record those who have served on the Central Committee or as active members of the Association's many branches at home and overseas, nor indeed to tell of the unfailing efforts made by generations of serving Warrant Officers and senior NCOs to keep alive membership in the Active Army. No account of the Royal Engineers' Association, however, would be complete without a tribute to the Association's Secretaries. The present Secretary Mr E. Dummer took up his duties in May 1960; he had previously been a Warrant Officer Class I Superintending Clerk and Secretary of the Singapore Branch of the Association. From 1912 until 1960 the Association was served by two Secretaries. The first was Mr J. McB. Robbins. As an Engineer Clerk Quartermaster Sergeant he had been one of those serving Warrant Officers and Senior NCOs who, in 1906, had formed themselves into an Association for the purpose of holding reunion dinners in London. On the formation of the REOCA on 12 October 1912, being then retired, he became the Association's first Secretary and he held the post until his death in February 1934. It was largely due to his personality and drive that the Association found its feet and continued to prosper and his zeal and enthusiasm never failed during his twenty-two years as Secretary. His funeral at Thornton Heath, for which all arrangements were made by the REOCA, was attended by over two hundred members of the Association, including General Sir Bindon Blood, the Chief Royal Engineer, then aged 92 years. Mr Robbins was succeeded by Mr J. G. Walker who left the Corps with the rank of Regimental Quartermaster Sergeant. He became Assistant Secretary in 1931 and took over the appointment of General Secretary three years later. During his twenty-six years of office until his retirement in May 1960 the service he has rendered the Association has been incalculable, particularly during the perilous but famous days of the blitz.We wish him well in his retirement. Both he and his predecessor Mr Robbins fully lived up to the Association's motto: "*Service not Self*".

The Carriage of Heavy Lifts by Sea

By LIEUT-COLONEL R. C. GABRIEL RE

MUCH emphasis of late has been placed on the need for air portability of military equipment, and by careful design many items of plant, including some pretty big ones like a motor grader and a Size 2 crawler tractor, can be flown to a trouble spot if required. There are many equipments, however, that cannot possibly be flown in, because of their weight or size, and these may well have to be moved by sea. Unless LSTs or LCTs were available and the conditions were suitable for their employment, merchant shipping would have to be used. In the case of very heavy equipment, this is not as easy as it sounds since normal ship's gear is not designed to lift loads greater than about five tons. Some modern vessels have 7- or 10-ton derricks to serve all holds, but quite a large number of the older ships have gear with only a 3-ton capacity.

Nearly all ocean-going freighters, however, have at least one heavy-lift derrick or "jumbo". This is usually stepped by the foremast to plumb No. 2 hold and may have a safe working load (SWL) of 30, 50 or 60 tons, or even more. This figure includes the weight of the lifting gear itself which, in the case of heavy items, may be as much as 5 or 10 tons. A second one of smaller capacity is often found at the mainmast, serving No. 4 hold. The rigging and operation of a jumbo derrick, with its multi-sheaved tackles and four powered winches, is very slow, however, and should a floating crane be available in the port, it is usually preferable to use it for very heavy loads. All large ports have at least one floating crane, and some, like London and Liverpool, have several with lifting capacities up to 200 tons. But small ports, especially those in Africa and Asia, are not so fortunate, and even though a crane may have been used for loading at a European or American port, it might be necessary to use the ship's gear for discharge at her destination. In military operations, moreover, the equipment may well have to be transferred to special craft or lighters off a beach, or ferried ashore from a sheltered anchorage; thus, once again, the ship's own gear would be required. For normal supplies and equipment, this is the usual procedure, and such a task would be carried out in wartime by personnel of RE (Tn) Port units, who must also be conversant with the more heavy and difficult loads.

Let us see what some of these items are, what sort of ships might be expected to carry them and how they are lifted on board and subsequently unloaded.

Tanks leap to mind as the most likely heavy military load, an unladen Centurion weighing about 47 or 48 tons, but there are many others such as the 24¼-ton heavy artillery tractor, the 12-ton Scammell recovery vehicle, the 18½-ton tank transporter and certain heavy and awkward radar equipments. Typical weights for heavy engineer plant and similar equipment are as follows: a Size 1 crawler tractor with angledozer and winch 22 tons, a 12-yd scraper 10 tons, a 33 RB excavator 39 tons, a small WD harbour tug 40 to 70 tons, a Ramped Powered Lighter 60 tons, barges 50 to 100 tons or more, and military locomotives much the same, e.g. 40 tons for a 0-6-0 tank engine, 50 tons for a 350 hp diesel-electric and about 70 tons for a 2-8-0 Austerity locomotive. Most of these can be stowed in the hold, but many are too bulky and must travel as deck cargo.

A ship with only one 50- or 60-ton jumbo obviously couldn't carry many of the above items, but there are some heavy-lift ships designed and built specially for the purpose of carrying locomotives and other such equipment in quantity. They have derricks, and several at that, capable of lifting well over 100 tons, their holds are spacious and strengthened, as are their decks, while extra large hatches, 75 ft long or more, facilitate the handling of awkward cargoes. To distinguish these heavy-lift ships from those well-equipped modern freighters that have one or two or even three "jumbos" of 60-, 80- or 100-ton capacity, they are sometimes referred to as super-heavy-lift ships. Examples are the British flag *Benalbanach* and *Benarty* of the Ben Line that have three 120-ton derricks, and the famous Norwegian Bel-ships (*Belbetty* and *Belocean* are but two examples) of the Christen Smith Line. Differentiation between these special ships and others is becoming increasingly difficult, as the reader will soon realize, for the more ordinary ones have lately become more and more sophisticated and able to handle just as large loads as those once classified as super-heavies. The whole problem is like explaining the difference between heavy and medium tanks. Thus we find the *Clan Sutherland* has a 165-ton derrick (the largest one made in Britain) besides lesser jumbos, and the new Harrison *Adventurer* a 180-ton one, but neither are comparable in many respects to the special Ben liners. At this stage it is necessary to emphasize two points. First, that no one type is better than another, for a ship is built for a particular trade and purpose which is probably quite different from that of another, even though the gear may appear to be somewhat similar. Secondly, it should be noted that only a few ships (there are four) in the large Ben Line fleet have the super-heavy-lifting capability. These are the remnants of a Ministry of War Transport (as it was then called) class built at the end of World War II; the *Bermuda Trader* is another one, and there are one or two others.

Before examining the problems involved in lifting and carrying heavy cargoes, the following few brief remarks on the capacities of derricks and relevant dimensions would not be inappropriate:—

(*a*) The SWL figure is applicable for a jumbo lowered only down to an angle of 45 deg with the deck. Sometimes SWLs are specified in writing near the heel of the derrick for two different angles, as on the Nederland Line's M.V. *Karakorum* which has

i. 45 deg 120 tons; 30 deg 103 tons.
ii. 45 deg 80 tons; 30 deg 68 tons.

(*b*) Typical lengths of heavy derricks are

i. *Registan* 57 ft (50 tons since reduced to 40 tons).
ii. *Clan Maciver* 64 ft (80 tons).
iii. *Benalbanach* 76 ft 3-in (120 tons).
iv. *Tabaristan* 68 ft (150 tons).

(*c*) Typical ship breadths are:—

i. *Registan* 58 ft.
ii. *Adventurer* 65 ft.
iii. *Benloyal* 71 ft.

(*d*) Typical hatch dimensions (for largest hatchway) are:—

i. *Registan* and *Tabaristan* 58 ft × 22 ft.
ii. *Benalbanach* 75 ft × 26 ft.
iii. *Lichtenfels* 80 ft × 20 ft 6-in.
iv. *Treuenfels* 109 ft 7 in × 21 ft 6-in.

(cf normal size, e.g. 36 ft 6-in × 21 ft on *Benloyal*).

The reader has doubtless already worked out what sort of outreach to expect, but exact figures cannot be quoted, since so many other factors have to be taken into account, viz. exact design and dimensions of the ship, what other loads are on board, the degree of list permissible and whether there are shrouds that impede the swing-round of the derrick, etc., etc. A theoretical figure, however, of something between 10 and 15 ft would not be unreasonable.

The "drift", which is the vertical clearance between the cargo hook and any part of the ship over which it passes, must be carefully worked out for each operation, to ensure that the load does not foul the bulwark or any other part of the ship as it is swung in or outboard. This "drift" varies for individual ships, and with the angle of the derrick; because much of the possible height (up to something like 20 ft) is lost due to the size of the giant blocks and tackle, it is probably no more than 25–30 ft. Even with the ship's rails removed, there is often little room to spare with certain loads, and sling lengths obviously play an important part. It is largely for this reason that special lifting beams, sometimes belonging to the ship's gear, are used for long and heavy loads like locomotives and barges. These have spreaders, and the position of them and their slings is often adjustable to suit the CG of the load. Four-legged slings of several special designs are used, however, for most military equipment including tanks. Tugs, landing craft and large launches often present a severe slinging problem since their superstructure usually precludes the use of a lifting beam. This is where the overall height of the load with its slings must be carefully calculated.

Topping a heavy derrick under load is possible, of course, but in practice one cannot raise it much, because of the risk of the load fouling the derrick itself. However, this operation may just enable an awkward load to clear the gunwhale or hatch coaming (e.g. topping a 64 ft derrick by 5 deg will raise the load by nearly 4 ft). Sometimes it is the length rather than the weight that makes some item of cargo a particularly awkward load, and it is then that two heavy derricks lifting in unison can sometimes solve the problem. In practice, however, two 120-ton jumbos, of the conventional type, as on the *Benarty* for instance, cannot lift a 240-ton load on to the deck, but only one of about 160 tons, i.e., two-thirds the combined total.

Improvization is often the lot of the military engineer, and there is one particularly interesting stevedoring example that occurred at Port Said during the Suez operations in December 1956. It so happened that many of the vehicles of the Yugoslav United Nations contingent arrived in the Yugoslav former LST *Çelik*, whose bow door had been welded up and whose own derricks could only lift about 1½ or 2 tons. The winches were unreliable, and the forward hatch had been converted into a lift shaft for light stores only.

The sixty-five to seventy vehicles all weighed 5 tons or a little over, except a few that weighed about 8 tons, and they had been cleverly loaded both on the upper deck and in the hold or lower tank deck—mostly athwartships—

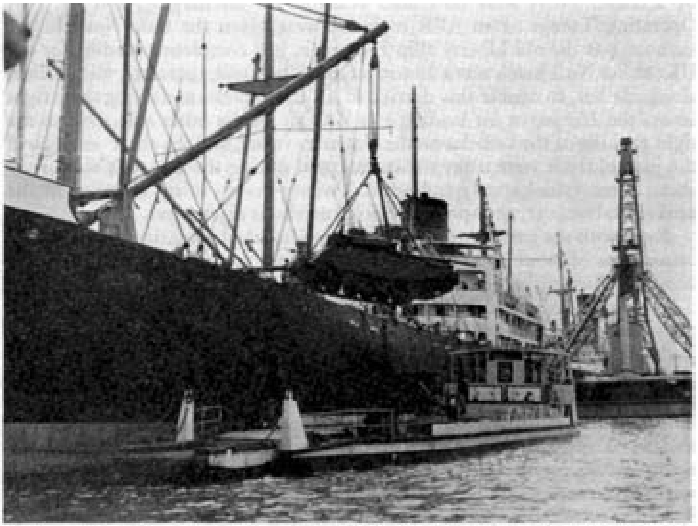


Photo 1. A Centurion being discharged to a Z-Craft at Singapore, using the Glenshiel's 50-ton derrick. Note the presence of the floating crane which was used for the tanks loaded in the after part of the ship.

Photo 2. The super-heavy-lift ship *Benarty* (three 120-ton jumbos) with a deck cargo of tugs and barges.

The Carriage Of heavy Lifts By Sea 1,2

by a crane. There were no cranes available for discharging, and RE Port Operating Troops of an AER regiment were given the task. Now, in the harbour was the old Liberty ship *Harpagon*, just completing loading for the UK; at her No 2 hatch was a 25-ton jumbo. The *Çelik*, therefore, was berthed alongside her, to enable this derrick to lift the vehicles and swing them right across the *Harpagon* for loading to a Z-Craft on the other side. Due to the tight packing of the vehicles on the Yugoslav vessel, and the short outreach of the jumbo, there were many difficulties, and during the first 8-hr shift, only about three vehicles were unloaded. Twenty-five to thirty followed in the next shift, however, and soon the whole vessel was discharged.

Even with the correct gear, some heavy lifts take a long time to move, and cause a lot of trouble. Four or five hours were required once to unload a 103-ton refuelling barge from a Ben ship at Christmas Island.

Normally, however, about four heavy lifts per hour can be handled, once the initial difficulties are overcome, and this rate has been actually observed in the case of Centurion tanks. What may take a long time, however, are the preliminary arrangements,especially in the case of deck cargoes where special angle-iron cleats or securing rings may have to be welded to the deck, and timber cradles or other supports prepared on deck. For locomotives, short lengths of rail are sometimes laid, but passenger coaches and wagons are nearly always carried with their bogies removed. In all cases, most thorough securing arrangements have to be made, and turnbuckles are widely used. Specialist firms quite apart from the stevedoring companies or port authority are usually engaged for this sort of work. Before accepting a heavy deck cargo, a shipping company must consider all sorts of factors in great detail, besides the obvious ones concerning strength and stability, such as the weather in the North Atlantic (sailing South to Gibraltar, the starboard side is liable to be exposed and vulnerable), or monsoon conditions in the East. Can an athwartships stow be accepted, and if so where and how should any overhang occur? Does diagonal placing help, and what about wind resistance, etc? Does the height affect the conning of the ship? These and many other points must all be thought of in the planning stage.

We have considered the sort of ships, and also some of the practical problems involved when they carry heavy equipment; let us now see if there are ample British ships for the task, and then review what other NATO merchant navies have to offer.

Great Britain

The number of British flag ships equipped for lifting 50 tons or over is very large, certainly more than 450 and probably over 500. Of these, just over 100 have derricks with a 60-ton SWL or over, but the figure drops to 75 for 70 tons and 55 for 80 tons or more. More than half these are Clan Line ships. Those with a derrick of capacity above 100 tons are relatively few, about eighteen, of which half again are Clans, 120 tons and over approximately a dozen, of which only four have jumbos rated at 150 tons or more.

Space does not permit mention of all British heavy-lifting owners; the following, however, are those most interested in this special trade:—

(*a*) Ben Line. UK–Far East. (eg *Benwyvis* 3 × 120 tons.)

(*b*) Clan Line (part of British and Commonwealth Shipping Co.) UK–India and Pakistan and UK–E. Africa via Suez and via The Cape. (eg *Clan Mactavish* 125 tons.)

(*c*) Elder Dempster. UK–W. Africa. (eg *Onitsha* 150 tons.)

(*d*) Ellerman Lines. UK–S. and E. Africa, Persian Gulf, India, Pakistan and Far East. (eg *City of Ripon* 70 tons.)

(*e*) T. & J. Harrison Line. UK–W. Indies. UK–S. and E. Africa, Persian Gulf, etc. (eg *Adventurer* 180 tons.)

(*f*) Palm Line. UK–W. Africa. (eg *Bamenda Palm* 70 tons).

(*g*) Strick Line. UK–Persian Gulf. (eg *Nigaristan* 110 tons).

Apart from these, Union-Castle, Brocklebank, Shaw Savill & Albion, P & O, Port Line and others have units in their fleets fitted with heavy derricks.

Our NATO allies also have heavy-lift ships and in these days, when the Common Market is being so actively discussed, we would do well to see what numbers and types sail under the flags of Western European countries.

West Germany

Under the black, red and gold flag of the Federal Republic, we find a formidable array of modern vessels all lavishly equipped with heavy-lifting gear in the Hansa Line fleet; their names all end in "fels". Many of them have Stülcken derricks which can lift well over 100 tons; the *Lichtenfels* is typical, with a 120-ton derrick and a 30-ton one.

This design of derrick is most ingenious, and embodies the principles of maximum efficiency and economy in that it can plumb holds on either side of it with virtually no change in the rigging arrangements. Furthermore it can lift the maximum load with a topping angle (the angle the boom makes with the horizontal) of 25 or 30 deg, thereby obtaining a very useful outreach. When not in use, it rests in the vertical position between a pair of giant posts widely splayed like a V, and at first sight looks like a mast. It is claimed that two used in tandem can lift the full combined SWL (see illustration of *Treuenfels*.) H. B. Stülcken & Sons of Hamburg are the makers, and during the last year they have provided their special derricks for several British ships, notably the *Adventurer*, already mentioned, and the *Custodian* and *Tactician*, all of the Charente S.S. Co (Harrison Line).

Included in the Hansa fleet are no less than three ships each with a 205-ton derrick (the *Bärenfels* class), and three with a 165-ton jumbo; all these have conventional gear, but there are about a dozen others equipped with heavy Stülcken derricks.

Hansa ships compete with Strick and Clan mainly in the Indian, Pakistani and Persian Gulf trades, but there are other West German heavy-lifters, notably Rickmers, whose ships ply to the Far East. Many of these have very heavy gear, such as *Etha Rickmers* with a 165-ton derrick.

The Netherlands

Dutch companies also have a considerable number of fine modern freighters with heavy lifting gear, though of the conventional type, nearly all in service between Europe and the Far East. Most of these have been built during the last three or four years and have two heavy derricks, either serving the same hatch (eg the Royal Rotterdam Lloyd's *Schelde Lloyd* and her sisters, which have two 120-ton jumbos at No 3 hatch, besides a 65-ton one aft) or serving adjacent hatches but capable of being used in tandem (eg the Nederland Line's "Karachi" class of several ships that have 120-ton and 80-ton derricks which, when used in unison, can lift 160 tons). There are more ships of this type in the smaller "Banda" class with slightly smaller gear, and in the very latest "Neder-Ebro" class, but mention must be made of the "kerks" of the United Netherlands S.S. Co. These also trade to the Far East and several, like the *Serooskerk* and *Zaankerk* (both 120-ton jumbos), have very heavy gear.

France

France has some ships well-equipped for heavy cargoes, but nothing like so many as either the Netherlands or West Germany; as one might expect, some of these are new Messageries Maritimes freighters like the "Tigre" and "Malais" classes (each with 60-ton jumbos) and the Ocean Transport Co's (C.T.O.) *Tobago* and *Tocansa*, each of which has a giant jumbo with SWL of probably over 100 tons.

Italy and Belgium

Italy has relatively few ships of this kind, but even the small Belgian merchant navy has some, including three new vessels with 110-ton gear, the "Mokambo" class, intended for their owners' line to the Persian Gulf. A further three have just been ordered.

Norway

The best-known Norwegian heavy-lifters, of course, are the Bel-ships, all in the super-heavy class, if one excludes two car carriers, and belonging to the Christen Smith line. Captain Smith was one of the pioneers in this trade, and many of his first ships were built in Britain. One of them, the *Beldis*, loaded the first big shipment of seventeen locomotives, with tenders, for the Argentine in 1924, using her 120-ton derrick for the purpose. With their engines aft, these ships were the forerunners of a fine fleet that served the Allies wonderfully well in the Second World War. Hundreds of locomotives and wagons were shipped by them from India and UK to the Middle East. A typical load once carried by the 3,200-ton *Belpamela* consisted of sixteen 90-ton locomotives, nine tenders, a seaplane tender and a light-vessel for the Persian Gulf, all unloaded with her own gear. Some other examples of Bel-ship cargoes are (1) forty-eight locomotives and tenders, (2) fifty-two railway coaches and (3) one 190-ton lighter which was 152 ft long. Only one ship has a name without the Bel-prefix, viz the *Christen Smith*, which has a 200-ton derrick besides two 100-ton ones. It is interesting to note that, prior to the installation of the first Stülcken derrick in a German ship, this firm had attempted to effect the same sort of economy by having one derrick (this time a conventional one) to plumb two adjacent holds. This was achieved by stepping the jumbo to starboard of the mast; loads, however, could be handled only on that side of the ship. The *Belkarin* of 1954 is so equipped with a jumbo of 140-ton SWL.

Unlike the Hansas, the Bens, Clans and others, these Bel ships are really highly specialized tramps that ply worldwide as and where required, and not on a fixed route, though even the Bens are chartered for special voyages such as to Christmas Island in the Pacific, or for the Suez Operations of a few years ago.

Denmark and the United States

There are many Danish East Asiatic freighters with 60-ton derricks, and others of NATO countries not yet mentioned. Strangely enough, the United States does not have as many heavy-lift ships as one might expect; there are

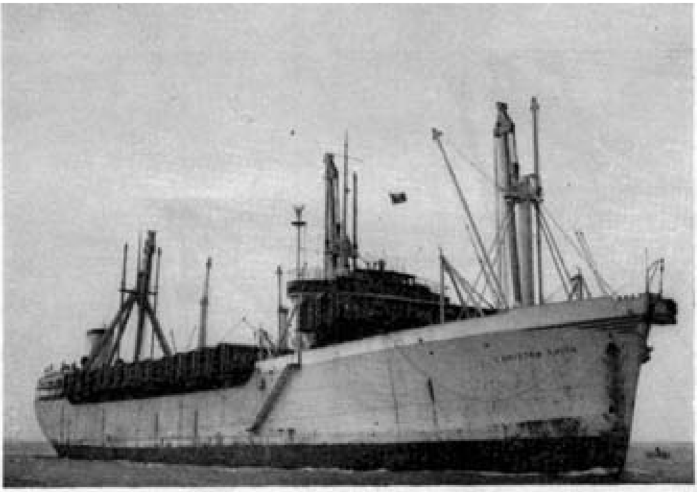


Photo 3. A deck cargo of railway coaches on the Norwegian Bel-ship *Christen Smith* (one 200-ton jumbo and two 100-ton).

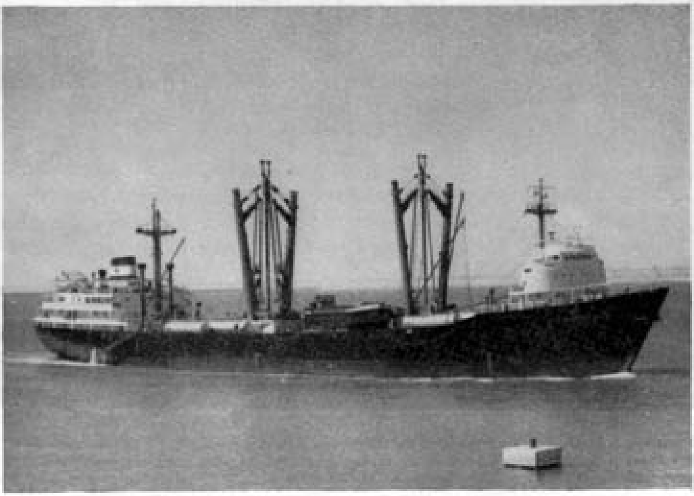
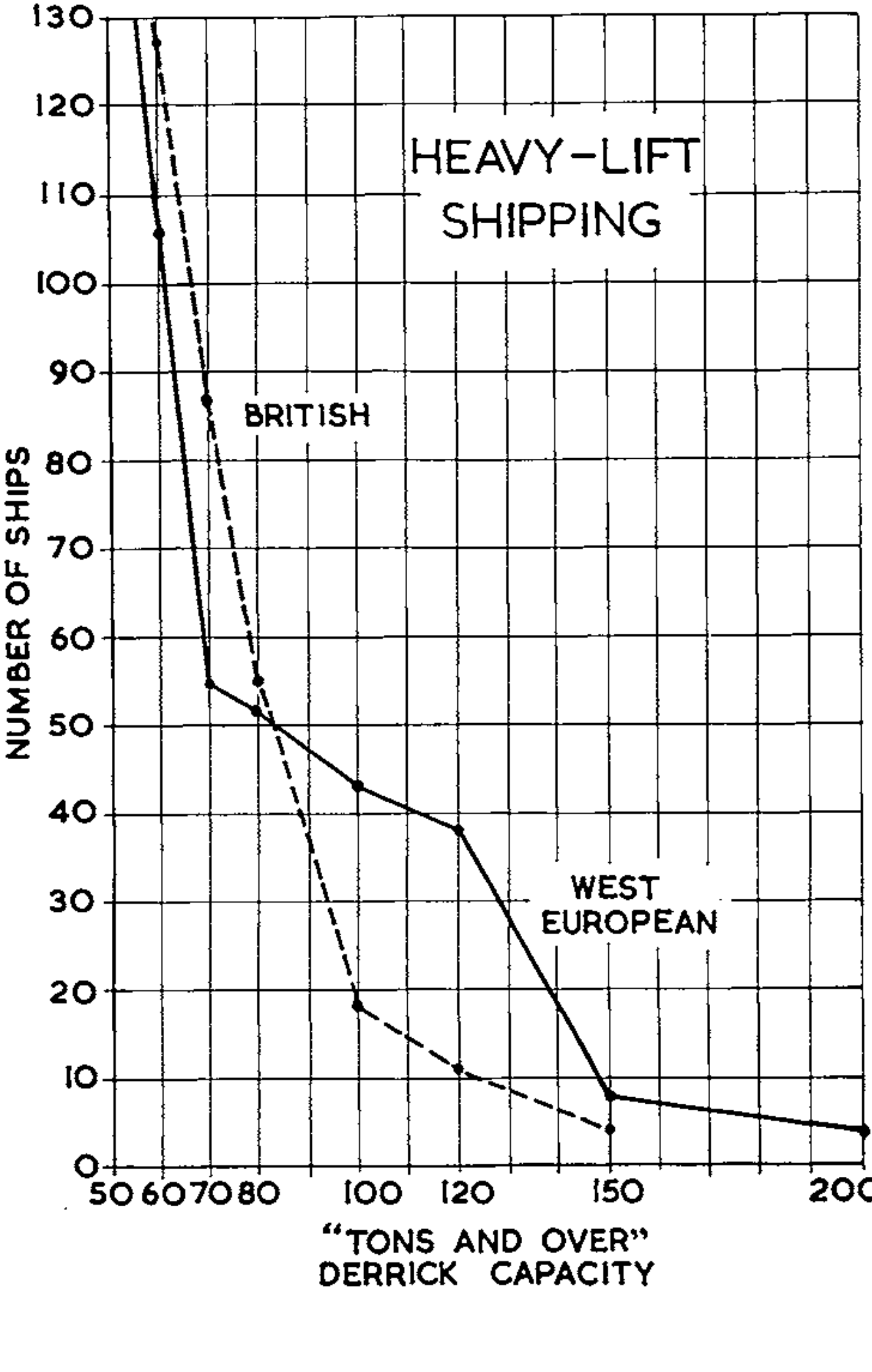


Photo 4. The West German Hansa ship *Lichtenfels* showing the two Stülcken type derricks for 120 and 30-ton lifts.

The Carriage Of heavy Lifts By Sea 3,4

Photo 5. A 60-ton NL pontoon ferry for Christmas Island is lifted aboard the *Benwyvis* using her 120-ton derrick. Note the use of the lifting beam and spreader arms, and also the power guys which enable the load to be pulled horizontally with the least strain on the derrick.

Photo 6. A 260-ton test load being lifted by the two Stülcken derricks (each 130-ton SWL) of the Hansa liner *Treuenfels*, working in tandem. When lifting a craft out of water, an initial loss in pull, due to suction, must be allowed for. (By kind permission of H. C. Stülcken of Hamburg.)



HEAVY-LIFT SHIPPING
BRITISH
WEST EUROPEAN
NUMBER OF SHIPS
130
120
110
100
90
80
70
60
50
40
30
20
10
0
50 60 70 80
100
120
150
200
"TONS AND OVER" DERRICK CAPACITY

a number of vessels with 60-ton jumbos in the President, United States and other lines, and a few in the super-heavy category such as the MSTS *Marine Fiddler*.

There are some ships that carry very heavy loads, but in a less spectacular manner, in that they have no heavy-lifting gear of their own, but rely on port cranes, floating or otherwise. Some of them are mere tiny coasters, but nevertheless specially strenghtened and with a long hatch. The British *Stream Fisher* is an example, and she has carried many locomotives between Britain and the Continent in post-war years, and also items of heavy machinery. Many war-time Liberty ships are equipped with a 40- or 50-ton jumbo, but have carried heavy cargoes weighing over 50 tons.

Those who served in the Canal Zone of Egypt will recall the two small ex-Bosphorus ferries *Empire Chub* and *Empire Roach* that did such sterling service in the Suez and Aquaba areas; they each had a 25-ton derrick.

Approximate numbers of British heavy-lift ships have already been given, and it is of interest to note that the figures for other Western European countries would work out roughly as follows:—

(*a*) For 100 tons and over—twice the British numbers.

(*b*) For 60–90 tons and over—three-quarters the British numbers.

(*c*) For 50 tons and over—half the British figures.

The accompanying graph, moreover, shows clearly that Britain is relatively stronger in the 60-, 70- and 80-ton categories, but not in the heavier grades, where our ships are not only few but getting old. Western Europe, on the other hand, has plenty of super-heavies, nearly all of them very new.

Let us just see where all these might be located on any given day. First, in the case of the British, say for 70-ton jumbos and upwards, ie approximately eighty-five ships:—

(*a*) 25 per cent, viz twenty-one, will be in UK and North Sea waters.

(*b*) 18–20 per cent, viz sixteen, will be in the South Atlantic including off West Africa.

(*c*) 12 per cent, viz ten, will be off East Africa.

(*d*) 8 per cent, viz seven, will be in the Mediterranean.

(*e*) 8 per cent, viz seven, will be in Arabian Sea/Persian Gulf areas.

(*f*) 7 per cent, viz six, will be in the Far East.

(*g*) 6 per cent, viz five, will be in the South Indian Ocean or Western Australia.

(*h*) 5 per cent, viz four, will be in the Bay of Bengal.

(*j*) 3–4 per cent, viz three, will be in the West Indies.

(*k*) 2–3 per cent, viz two, will be in Australia/New Zealand.

There will also be one or two in mid-Pacific, etc.

In the case of the forty-five to fifty West European ships, also with 70-ton lift and upwards (excluding the Bels, which are distributed world wide), we have:—

(*a*) 25 per cent, viz twelve, in North Sea ports.

(*b*) 20 per cent, viz ten, in Red Sea and Persian Gulf areas.

(*c*) 14 per cent, viz seven, in the Far East.

(*d*) 10 per cent, viz five, in USA ports and Gulf of Mexico.

(*e*) 8 per cent, viz four, in the Bay of Bengal.

(*f*) 6 per cent, viz three, in the Mediterranean.

With three or four in East Africa, West Africa, etc, etc.

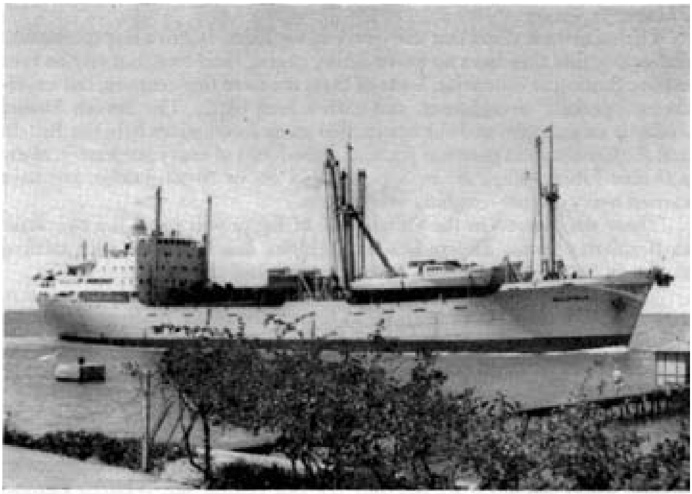


Photo 7. The Norwegian *Belkaria* showing her 140-ton jumbo, which can plumb both No. 1 and No. 2 hatches but work to starboard only.

Photo 8. A deck-load of locomotives for India on the Scindia Co.'s Liberty ship *Jalamapur*.

The Carriage Of heavy Lifts By Sea 7 & 8

To summarize, for three zones of indirect military interest, we might expect, on any one day:—

(*a*) In the Mediterranean	Seven British Three West European
(*b*) In the Arabian Peninsula area	Seventeen British (mainly off East Africa) Ten West European (mainly in the Persian Gulf)
(*c*) In the Far East	Six British Seven West European

One other point that must not be overlooked is, of course, the strength of the quay or ramp where the heavy equipment is eventually to be put ashore. Even if the quayside is strong enough, are the road or railway bridges that lead from it capable of taking such a heavy load? Possibly the equipment is large enough to be classified as an out-of-gauge load on the railway—but that is quite another problem for Movements and Transportation.

From the foregoing, the following conclusions can be drawn:—

1. There is still a military need for heavy-lift ships.

2. There are plenty of British ships that can lift 50 tons, and a fair number that can lift up to 80 tons. Above that figure, the numbers fall off rapidly to a mere handful.

3. Shipping limitations must be considered when new military equipment is designed, and the weight of the lifting gear should not be forgotten.

4. In spite of the paucity of British flag super-heavy-lift vessels, the number of Western European ships of this type, nearly all very modern, is considerable.

5. On any day, a reasonable number of British and West European heavy-lift ships are strung out on trade routes and in zones where they could be commandeered fairly rapidly in an emergency.

6. Nevertheless, the carriage of heavy equipment requires much detailed and meticulous planning. All sorts of complicated preparations may have to be made and exact knowledge is necessary, not only of the load and of the prospective carrier, but also of the gear available.

The Use of Gellants in Anti-Corrosive Paints

By Major D. M. R. Esson, BSc, AMICE

The formulation, application and performance of heavy-duty coatings is occupying an ever increasing amount of the time of paint chemists. The work done by various research and development organizations in this country has shown clearly that long-term protection of steel structures under adverse and polluted atmospheric conditions depends on the attention paid to two principal factors; the thorough preparation of the surface, and the application of sufficient paint to give a thickness of at least 0.005-in (0.127 mm). With normal oil emulsion paints which dry by oxidation this requires at least three coats.

Since the war it has become common to specify higher film thicknesses which with some paints such as vinyl and chlorinated rubber, which dry by solvent evaporation, means the application of a considerable number of coats to build up the specified thickness. With the high cost of labour this has become prohibitively expensive. The development of means whereby thicker dry films can be applied have acquired considerable financial urgency. Some gellants have now been developed and can be used to assist the paint technologist to formulate systems which will give adequate thickness of film with a minimum of coats. At the same time these gellants increase the ease of application of the paint, and by reinforcing the film give increased life to the painting.

A suitable gellant results from the chemical reaction between montmorillonite (the chief constituent of bentonite) and long chain amine salts and marketed under the trade name of "Bentone". Essentially these products are very thin platelets having long aliphatic chains attached by strong electrochemical bonds through a nitrogen atom to the surface of the plates. They are hydrophobic in contrast to the hydrophilic nature of bentonite. Such a gellant improves pigment suspension and brushability, prevents sag, accentuates water and chemical resistance, enables viscosity control to be exercised, and aids spraying and dipping techniques. It is temperature stable, and does not affect adhesion or solvent release.

The various systems usually met in practice are described below. The bitumen, pitch and the urethane/pitch formulations are not necessarily the best. However, the aim is to show how gellants may be used to develop certain properties in these coatings so that the best use may be made of them.

Bitumen

Additions to bituminous solutions give considerable and predictable thixiotropy to the system. The degree of thixiotropy is dependant upon the quality and quantity of the gellant used, and the method of incorporation. About 5 per cent of gellant in the solution enables coats up to 0.020-in (0.500 mm) thick to be applied without sagging or running. This gives highly impermeable coats at a reasonable cost, with greatly improved weathering characteristics, particularly with regard to crazing, retention of plasticity at low temperatures and non-flow properties at high temperatures. These effects are produced by the extremely thin plate-like particles of gellant being dispersed through the film and anchored into it by long hydrocarbon chains attached by electrochemical bonds to the surface of the plates. The use of mica at loadings of 5–25 per cent on the paint improves the control of crazing on exposure.

Panels of various bitumen coatings containing suitable gellants which have been subject to intense accelerated ultra-violet radiation and water spray together with periods in saturated water vapour containing sulphur dioxide at 45°C (113°F), are then compared with heavy duty bituminous emulsion paint films and invariably show the very superior impermiability of the solvent thixiotropic bitumen type.

In these types of paints it has been found that gellants aid solvent release to a marked degree. This type of coating is finding an increasing use as a reasonably cheap and effective protective coating requiring much less skill in application than hot applied bitumen, and can be used in some situations where the latter cannot.

These gellents give non-melt and non-flow properties to these coatings at any temperature and are of considerable value where bituminous coatings are used on roofs. A number of instances have occurred of recent date where hot tar and bitumen have flowed off the roofs of burning buildings seriously increasing the fire damage and gravely hampering the work of the fire-fighting team.

Coal Tar Pitch

These coatings are extremely slow drying, but gelling and thixiotropic properties can be developed in this class of compounds. It is of interest that coal tars with gellant will dry quicker than those without gellant when applied at similar thicknesses.

Chlorinated Rubber

Thixiotropic heavy duty chlorinated rubber paints have been used for some years, and gellants can be used to give films easily applied at high film thicknesses on steel structures or on porous surfaces such as breeze blocks. It is interesting to note that thick glossy films are produced with gellants as opposed to semi-matt ones when using hydrogenated castor wax as the thixiotropic agent. These gellants also exert a plasticizing action on the film and it is possible to reduce the amount of normal plasticizer in the formulation.

Vinyl

One difficulty encountered in this system, which is quite popular in America, has been the large number of coats necessary to give an adequate film thickness because of the relatively low proportion of film forming material. Gellants contribute the necessary body to the system to give good film thickness without sagging and enable the number of coats to be greatly reduced. The well known vinyl/cuprous oxide antifouling paint can be suitably modified with gellant to enable 0·005 in (0·127 mm) to be applied in two roller coats.

Alkyd

A two-coat system to be applied to shot blasted steel to give a dry film thickness of 0·010 to 0·015-in (0·254 to 0·381 mm) for protection against severe exposure has been developed. The primer is based on a castor alkyd pigmented with basic lead silico-chromate with the addition of gellant to give 0·006-in (0·174 mm) dry film thickness in one sprayed coat using a special equipment for this purpose. The finish is based on an isophthalic alkyd and sprayed to give 0·004 to 0·005-in (0·012 to 0·127 mm) dry film. This system, which is used extensively on oil tanks in America, is reputed to save up to 80 per cent of labour costs.

Epoxy and Epoxy/Pitch (Solvent Containing)

These types of coatings are well established, are finding increasing markets, and give excellent thixiotropic body to the system, minimising sag when heavy coats are applied when used with gellants. The gellants also have the effect of easier application, prevent the settlement of pigments, and reduce the probability of pinholing.

Epoxy (Solventless)

Sag and penetration control is obtained by the addition of gellant in these systems. Controlled and stable thixiotropic characteristics are acquired when the gellant is ground into part of the resin system. Its presence aids application, and does not affect the rate of cure.

Urethane/Pitch

This is the most recent addition to the types of systems described. Normally they are applied in thin coats, and four or five are generally required to give adequate thickness. Research is still in progress to discover the best lines along which formulations to give thicker films per coat may be achieved.

It is not only in paints that these gellants may be used. A most important application is in printing inks, where the false body imparted by the gellant will control consistency, tack, penetration and pigment settling. Misting on high speed presses is virtually eliminated. In the field of plastics the control of sagging during the application and cure of polyester and epoxy resins and p.v.c. plastisols is essential: gellants will provide this. The storage and handling properties of putty, caulking compounds and wood fillers has been improved by gellants and these compounds show very little oil separation or hardening after prolonged storage. The use of gellants in organic solvent types of adhesives makes brushing and spraying easier, with excellent control of cobwebbing. Solvent release is not affected, adhesive bond is reinforced and water resistance is improved. These desirable properties have led to developments in wax reinforcement, polishes, cosmetics, pharmaceuticals, and rope systems.

The liability of paints to gel was long regarded as a most undesirable menace: now this same process has been controlled by chemists for the advantage of us all. Time alone will show the extent of their success, but every extra month of life of a coat of paint in the corrosive atmosphere of some of our industrial cities marks an improvement which we may expect to be reflected in the price of manufactured commodities.

Acknowledgement is gratefully made to F. W. Berk and Co Ltd, who distribute "Bentone" gellants, one of the best developed gellant systems, for their advice and assistance in the preparation of this article.

Kitchener's Orders for the 1911 Coronation

By Lieutenant J. R. Sargant, RE (TA)

Field-Marshal H. H. Viscount Kitchener of Khartoum, GCB, OM, GCSI, GCMG, GCIE, commanded the 65,000 troops on parade in London for the Coronation of Their Majesties King George V and Queen Mary in June 1911, and a copy of his Orders for the day has recently been presented to the Corps Library.

The Orders form a substantial foolscap book, the first eighty pages of which are devoted to a meticulously detailed parade state, comprising 3,762 officers, 60,302 other ranks and 6,031 horses. The countless units of the whole Empire from which the parade was drawn suggest the amount of staff planning involved, and their names alone are an evocative commentary on the Land Forces of the British Empire fifty years ago. An added fascination is that many officers are named individually, either as commanders or orderly officers, and many of the Sapper subalterns' names mentioned therein may be found in widely separate parts of today's *RE List*.

In 1953 the television and film coverage of our present Queen's Coronation showed the splendour of the scene to a wide public, and we may now more easily imagine the magnificent spectacle planned in Kitchener's Orders. But we can sense changes behind the scenes; in 1911 the Orders stated that "means of destruction of horses must be at all times available", and that officers detailed for special duties should provide their own horses, for which separate forage supplies were to be arranged in temporary London camps. One would like to compare these plans with the complex arrangements for transport and fuel at such a parade today. Again was it ordered in 1953 that at each of the gates, "erected to prevent a rush of crowds from one part of the route to another", the contractor should supply a labourer "furnished with materials to strengthen the gates if required?"

The pace of change in the Armies of King George V may have been apparent to the planners who allocated space for fifty spectators from the Crimean Survivors of the Brigade of Guards next to that reserved for the Army Motor Reserve. The changes since that day enable us to see in a new light such extracts as this one from an alphabetical stores list, which includes as consecutive items:—

Bedsteads, FS	1 per Colonial Rank and File
Chairs, Camp	1 per General Officer
Covers, Saddle	1 per horse

The strict orders of the route to be taken by each unit between its temporary camp and the processional route show some of the difficulties of the operation. Every movement depended on the recognition of neighbouring units, which were often composite and difficult to identify by sight, and London must have resembled a seething ant-hill of marching troops as the great force assembled from every direction, at a time when civilian traffic was far from light.

One of the most responsible tasks must have been that of the Royal Engineer Communications Officers, who were to ensure that the Royal

Salutes at the Tower and Hyde Park should begin at the precise moment of the Coronation, and precisely at Their Majesties' leaving and reaching Buckingham Palace. "The signals for the Artillery Salutes will be given by flag signalling and telephones, the signal reaching the Battery first from either source will be acted on."

The spirit of the occasion and of these Orders is contained in this extract:

Orders for Buckingham Palace Telephone Officer (Lieutenant C. V. S. Jackson, RE).

1. You will be in your place at Buckingham Palace at the telephone at 8.45 am. At 9 am you will be rung up from Horse Guards; you will speak to the Officer in Charge there, reporting "Line clear and all correct", or otherwise.

(Should the line NOT be clear, ring up 1010 Central and ask them to have it put right at once.) *REPLACE RECEIVER.*

2. At 1015 am you will ring up Horse Guards and give the caution "Listen continuously". *LEAVE RECEIVER OFF.*

3. When the glass coach moves from its position in the centre of the quadrangle towards the portico, you will give the caution "Ready", listening to make sure your signal has been received.

4. When Major Brinton, MVO, DSO, holds up his handkerchief, you will give "Fire"!—listening to make sure your signal has been received. *REPLACE RECEIVER.*

5. You will take up your position at 1.15 pm, at the S corner of the front of Buckingham Palace in the forecourt. When the head of the procession returning reaches the Queen Victoria Memorial, you will return to your telephone, ring up Horse Guards and give "Listen continuously." Leave receiver off and place yourself again in the forecourt.

6. When the heads of the lead creams in His Majesty's Glass Coach enter the forecourt you will return to the telephone and give "Ready".

7. When the heads of the lead cream horses enter the portico at W end of quadrangle you will give "Fire".

Balance of Payment

A Jamaican Story Without Comment

By Colonel H. Nelson, OBE

The British captured Jamaica from the Spaniards in 1655. The military garrison on the island was gradually increased over the years until by 1835 over 3,000 troops were stationed there. They lived in forts and barracks in the low parts of the island and died there too. In 1838, which was a good year, only 91 men died. In 1839, 110 men died and in 1840, 121. They died of "the fever". These were the days before the habits of the mosquito were known. No doubt "not yet diagnosed" was even then a popular medical phrase.

On 14 January 1840 the following notice appeared in *The Falmouth Post and Jamaica General Advertiser:* "Major General Sir William Gomm, KCB, etc, Commander of Her Majesty's Forces in this Island, arrived in the ship Clarendon on Monday last and has, we understand, taken up his quarters at the Government House in Duke Street." On the same page as this notice appeared an editorial deploring the incidence of fever in Kingston "where scarcely a family has escaped the sad ravage which has of late laid many prostrate, never to rise again."

The new Commander was worried about the situation and he first broached the subject of a new barracks up in the hills away from the fever-ridden plain in a letter to the Governor dated 7 April 1840 in which he pointed out that, although the plain was an ideal position for a barracks, it was "subject to sad visitations of disease, which has from time to time assumed the character of pestilence, and this it would appear, in defiance of all professional or local vigilance". A camp on high ground was clearly necessary and his letter ends: "What I would, therefore, invite you, Sir, to urge with Her Majesty's Government would be, to give their sanction for building a substantial barrack for quartering a battalion of 600 men, somewhere in the Port Royal Mountains, overlooking, and within a few miles march of, Kingston. . . ."

The Governor liked the idea. Gomm then consulted his Chief Engineer, Major W. M. Gossett, RE, who produced a detailed report on "a situation which had engaged his attention for some time". This report was sent to the Secretary of State. Her Majesty's Government were, however, worried about the expense of the venture and proposed instead that the garrison should be reduced by one-third. Presumably, they argued that this would cut the number of deaths by one-third. Later in the year there was an epidemic of fever "of the most virulent type". In December Gomm wrote to the Governor the following letter: "I fear I am too well borne out by the fact, when I state my apprehensions, that the 82nd Regiment will have lost the flower of their Corps when this invasion of disease shall have been repelled. . . . It is upon this showing, that I would entreat your Excellency to urge it with Her Majesty's Government, to permit, and to authorize us, with the least possible delay, to erect an experimental barrack capable of quartering one hundred men, upon the spot now recommended for approval. . . ."

This letter was passed on to Lieut-General Lord Fitzroy Somerset, Military Secretary, who wrote to Gomm telling him that the Secretary of State was still loath to grant the money. Gomm sadly replied on 26 December 1840: "that the erection of a barrack to the extent proposed—that is to say, ultimately for the accommodation of 600 men, in any of the mountain stations of this Island—must involve considerable expense to Government I cannot be blind to; but neither can I to the sad alternative so forcibly brought under my eyes at this moment, and from which there is no escape—none. . . . Her Majesty has lost, within the last four weeks, 30 to 40 as fine young men as ever breathed in her service. . . ."

In the new year Gomm decided to take matters into his own hands and, knowing that he had the approval of the Governor, he acted without Government consent. In March 1841 he ordered his Chief Engineer "to build a barrack with all possible speed".

In May 1841 the Government gave reluctant approval to the project but were still worried about the expenditure, and Gomm in justification wrote as follows: "My plea is, in reply, that within the last eight months the 82nd has lost by malignant yellow fever, 5 officers, 9 serjeants, 140 rank and file, 13 women, 22 children, and the number of deaths has gone on increasing with each successive week".

The new barrack, New Castle, was built at first with "rude hutting" and tents and a permanent barrack to house a battalion was not authorized until December 1841. By this time the project was clearly justified by the remarkable reduction in the number of deaths. The 60th had arrived in the summer of 1841 and were first stationed near the sea. In five weeks they lost 60 men by fever. The Regiment then moved to New Castle where the 82nd were assisting in the construction of the "rude hutting". In September the 60th lost four men and the 82nd three. In a letter to Somerset dated 4 December 1841, Gomm exclaimed "We have carried the hill!" Gomm then returned to England to assume command of "the Northern District of England".

In 1859 Gomm received the following letter from Sir Sidney Herbert, then in the Foreign Office, who had been a Cabinet Minister in 1841:—

"Wilton
October 30, 1859

My Dear Sir William,

.. ..

In point of fact, the case in favour of New Castle seems to me even better than it stands on the papers. Sir John Burgoyne (Field Marshal Sir John Burgoyne, Inspector General of Fortifications 1845 to 1868) gives the cost of the barrack up to the end of last year; that is, he includes all alterations and repairs since its original construction. These, however, should be thrown out, as they are not peculiar to the situation, and wherever the barrack was placed, it must have been kept in repair. Indeed, being a new barrack, it probably had cost less than the old ones at Spanish Town, Port Royal, &c, &c.

The figures therefore (£43,346), are an over-statement of the cost of the experiment. Against this must be set the saving of 1,230 lives of trained soldiers. The value of a trained soldier has been variously estimated from £60 to £100. Taking the higher estimate as including passage to Jamaica, the saving would be £123,000; at £60 it would be £93,800, to be set against the cost of the barrack. But that, again, does not show the full amount of saving, for invaliding soldiers costs more than killing them, as you have to pay the substitute and pension the invalid too.

.. ..

Your opinion comes to me when it is very valuable, for it encourages me in the course I have taken in ordering sites to be sought for at high altitudes both in Trinidad and Hong Kong, and huts built to test the climate before any large body of troops are moved up.

At Hong Kong we have a fearful mortality; but with this curious circumstance, that the native Hindostanee troops there suffer more than the British. . . .

(Signed) Sidney Herbert"

Acknowledgement

This article has been composed from material collected mainly from the Institute of Jamaica by the Royal Engineers and the Royal Army Education Corps during 1959, and acknowledgement is due to the Director and Staff of the Institute for the generous help received in tracing and putting at our disposal many papers and books.

One-Inch Maps of Great Britain

By COLONEL J. R. RAWLENCE, OBE, BA, ARICS

THE Press, in August 1961, announced the publication of the last six sheets of the Seventh Series of 1-in. maps, and this is the first time in our history that there has been complete cover of the country in a single 1-in. series, all the 190 sheets of which are similar in projection, size and style.

The Ordnance Survey was founded in 1791, and its first task was to make maps to help in stemming the threatened French invasion. The first sheets produced were those of Kent in 1801 and Essex in 1805. But their value for peace as well as war was soon appreciated and the survey was extended northwards, reaching a line between Preston and Hull by 1840. In this year there was a change in method which arose from the decision to make a new 6-in survey of the whole country. Thereafter the fieldwork for the 1-in map was based on the 6-in. This 1-in "New Series" as it was called, was completed in 1892. Subsequent editions were begun in 1893, 1919, 1928 and immediately after the last war. But by this time it was realized that it was no longer possible to maintain the original drawings up to date to an acceptable standard and it had become necessary to re-draw the map. Accordingly the new Seventh Series was designed as a completely new 1-in map. The first sheets, Hereford and Chester, were published in 1952 and it has taken nine years to complete the whole series from Sheet 1 in the Shetlands to Sheet 190 in Cornwall.

The original map was printed in black only, and relief was shown by hachures. For the Third Edition, contours and colours were introduced for the first time. At the Fifth Edition, relief was accentuated by the addition of hill shading. The Seventh Series was planned as a ten-colour map, and great care was taken in the design in order to satisfy user's needs to the greatest extent possible. During the nine years spent so far on the series there have been minor modifications in the design, but with only one exception the last sheet to be published shows no significant change from the first. The exception lies in the typescript used for names. Initially these were all hand-written, but subsequently letterpress was adopted since this lessens considerably both the time and cost of preparation. Many regret the passing of the craftsmanship involving in the writing of names, and the character they gave to the sheet. But reluctantly hand-written names had to be sacrificed for the sake of speed and economy.

More information is hidden in the names than is generally known. Buildings and other objects dating from before 1714 are shown in Lutheran type, except for the Roman period for which Spartan type is used. At one time pre-Roman names were written in Old English type, but many places, Old Sarum for example, have been occupied continuously from pre-historic times and qualified for three different styles. Because of this, and of the difficulty of dating some objects, only two styles are now used.

The old distinction between a BH (Beer House) and a PH (where spirits can be had) is no longer shown; beer houses are now rare. But inns in the country are distinguished from public houses because the innkeeper is obliged to afford food and lodging to the traveller if there is room.

A finer point is that villages bearing the parish name are in upright type whereas others are written in sloping type; the parish name when it differs from that of the parish village is in light type. Such details can have repercussions and Tregoney Parish had to be shown as well as Tregony Village because of a local disagreement over spelling.

Spelling can excite strong feelings as was found when a lake in Shetland was named Neugles Water. A letter arrived ". . . I do urge you to put right NJUGALS Water at least. The NJUGAL is the mythical water horse, the traditional Shetland beast, and it is an insult and an affront to the whole race of Shetlanders that our symbolic animal is thus misused and misspelled". The Njugal is now correctly spelt, but who can say at what point going north, Wick becomes Wikk?

Developments are never ending and already, soon after printing the 190th sheet of the series, a version in six colours is planned to replace that in ten. With modern techniques there will be little change in appearance, and large economies in printing will result. The military version, with some additions in red, will now be the same as the civil edition, and can be printed from the same plates. Another important change is the showing of rights of way in England and Wales as they are decided by local authorities. So far only one sheet "The Solent" shows them.

Revised editions of 7th Series sheets are already being published and a race is developing between the builders and roadmakers who alter the countryside, and the surveyors and cartographers who record the changes as they occur. One day an Eighth Series will be needed, but for the moment it is worth recording that the Seventh is complete, and is being maintained up to date.

Boundary Journal

In February 1962 the Canadian Institute of Survey is holding a Convention in Ottowa in which one of the displays will illustrate the activities, over the years, connected with the survey of the Canadian/United States and the Canadian/Alaskan boundaries on which many Royal Engineer officers were engaged.

The following article, submitted by Major D. Veitch, CD, RCE, is, therefore, particularly appropriate. It describes the work carried out by Lieutenant C. W. Wilson, RE (later Major-General Sir Charles William Wilson, KCB, KCMG, FRS) between 1858 and 1862 when a member of a Boundary Commission, headed by Colonel J. S. Hawkins, RE (later General Sir John S. Hawkins, KCMG). The Commission marked out the line of demarcation from the Gulf of Georgia, opposite Vancouver Island, along the 49th parallel to the summit of the Rocky Mountains. The country was very difficult, swampy in the Western parts, then thickly wooded and in the very rugged mountains. Little dependence could be placed on the resources of the country and food and forage had to be brought from a considerable distance. Lieutenant Wilson had charge of the interior economy of the Expedition, and the transport and administrative arrangements and, at times he was engaged on actual survey work. The manner in which he carried out his very arduous duties proved his selection to have been an excellent one, and when the Commission completed its work he was personally thanked by the Secretary of State for Foreign Affairs.

* * *

In April 1858, a young man of 22 left England for British North America. He was Lieutenant Charles William Wilson of the Royal Engineers, and he was to spend the next four years west of the Rockies with the British section of the Boundary Commission. Throughout the whole of his life, Wilson kept detailed records of what he did and saw, sending these home at intervals. His accounts of his service with the Boundary Commission were copied into two hard-covered exercise books, probably by his mother, and these two rather battered journals are now in the Provincial Archives of British Columbia at Victoria. Not only did Wilson write about his surroundings, he also painted them, and there are twenty-six water colour pictures pasted into each book at the beginning and at the end. Some of these are 9 × 7-in, others smaller, while they range in subject from a humorous sketch of a native reclining in a grass hammock at Tobago to an awe-inspiring view of the Rocky Mountains showing the Boundary Pass. In the first volume there is a detailed map showing all sections of the boundary between British and American territory, the camps of both parties, and the routes travelled, and throughout the text there are small sketches showing such items as an Indian head in the process of flattening, and the new hoop skirts recently acquired by the young ladies at Victoria.

While the journal is a delightful personal study of the country, it also gives an accurate account of an important historical event. The surveying and marking of the international boundary from the Pacific Coast to the Rocky Mountains took place between 1858 and 1862. By the terms of the Treaty of Washington of 1846, the boundary between British territory and that of the United States was to follow the forty-ninth parallel from the Rockies, where the boundary ended, to the coast, and then to curve through the straits to leave all of Vancouver Island in British hands. There was some confusion about the water boundary and this was not settled until 1872, but the land boundary was quite straightforward and the entire task of ascertaining its location and clearing and marking it was done in the four-year period. The work was carried out by an American party under its commissioner, Archibald Campbell, and a British party under Colonel J. S. Hawkins, RE. Each group was accompanied by a contingent of troops to help with the work and to provide protection against the Indians.

When the British Commission was appointed, Charles Wilson had only recently completed his Young Officer training in the Royal Engineers, and he was employed on defence works at Dover and Portsmouth. His appointment came as a surprise to him, but a most welcome one, as he was eager to see something of the New World. His family had held land in Virginia at the time of the American Revolution, while an uncle, Thomas Wilson, had travelled in the United States and had been associated with the Philadelphia Academy of Natural Sciences.

Wilson's official position on the Boundary Commission was that of Secretary, and he was to have charge of all records and accounts—"the 'Money Chief' as they have christened me from my handing out the dollars", he records. He was also to command the detachment of Royal Engineers, and to act as commissariat, stores and transport officer. Because of these duties he probably travelled more than any of the Commission members, having to visit all parties working on the line and to keep them supplied with food and equipment. He also had to be present at all official conferences with the Americans and to have access to all documents. It was no wonder that he complained that he had little time for hunting and shooting as he was expected to be a jack of all trades, the common lot of a Sapper officer.

The British Commission was made up of Colonel J. S. Hawkins, RE, Chief Commissioner, Captain Darrah, RE, astronomer, Captain Haig, RA, astronomer, Lieutenant Wilson, RE, secretary and transport officer, Dr Lyall, RN surgeon, John K. Lord, naturalist, and Dr Bannerman, geologist.

Wilson seemed to be at home anywhere and to enjoy thoroughly the different locations in which he found himself. First he described life on board ship on the journey out. The party travelled by regular steamer from Southampton to St Thomas, and then to Colon where they crossed the isthmus by rail to Panama and boarded HMS *Havannah* which was to take them to Esquimalt on Vancouver Island. Some very bad weather was encountered and the journey took three months. They landed at Esquimalt where they made their headquarters, and soon "took the trail to Victoria" which they found crowded with miners preparing to go to the Fraser River "gold rush".

Wilson started work at once by going "to see the Hudson's Bay people about provisioning the men and found them very civil and pleasant kind of people". Later he describes a visit to the same place after some months spent in the interior: "I went up to the Hudson's Bay Company fort at Victoria to get a rig out of some of the new clothes come out by the *Princess Royal*. You would laugh if you were to see the scene and I could not help laughing myself; you would see a very dirty ruffianly looking fellow walk into the store and in about half an hour see quite a young swell come out in the latest fashion of England when the ship sailed; however as everybody follows the same plan it is not noticed here."

While in Victoria, he paid his respects to Governor Douglas of whom he records: "A more entertaining and generally well informed man it would be difficult to find." Although on another occasion he comments: "Though the Governor is a wonderfully clever man with the Indians he does not seem up to governing white people at all." He also attended a ball, went on several picnics, and found his dog, Beppo, "murdered by those filthy Indians: we found him with his throat cut close by a well which we had just made . . . and we have buried him under a cedar."

Actual work on the boundary soon started. After a conference with Captain Prevost, the British Commissioner in charge of the water boundary, and a very cordial meeting with Archibald Campbell, the American Commissioner, on board the steamer *Active*, and then again at Semiahmoo, the British party moved over to the mainland to start surveying. Wilson was left at headquarters at Esquimalt until October when he had to take provisions and mules to the party working in the Fraser Valley. He went on the Hudson's Bay steamer *Otter*, put in at "Tsanaimo" (Nanaimo) for coal, and met there "Dr Benson and Captain Stuart the two Hudson Bay Company officers who were very obliging and showed us everything." On arriving at Langley on the Fraser he visited "Mr Yale the chief man here in the Hudson Bay Company; we dined off some very tough beef at the Fort and landed the mules in the pouring rain. The Fort is a miserable cold place, built out of pine wood hewed out with an axe and the store houses surrounded by a rough stockade with a small bastion, mounting a very old six-pounder, which I would rather anyone fire off but myself." Nothing, however, could spoil the scenery: "Even in the wet we could not help admiring the beauty of the river, the foliage was at its best, the bright red of the dogwood, the yellow of the maple, and the dark cedars and pines made a gorgeous scene which would seem unnatural in painting." Later he came to appreciate the outpost in the wilderness when a year later he records: "The road seemed interminable during the dark and I was heartily glad to see the glimmering of the Hudson's Bay Fort at Langley; here we received all the attention that could be given to us." The same winter: "I rode out to one of our camps at Langley Prairie and after finishing my business there went out to Mr Bedford's who has a farm close by and slept there. The judge of British Columbia, Begbie, was there and we had a great game of whist, amidst the howling of sundry wolves who kept rushing past after the unfortunate calves."

The second year, 1859, was spent West of the Cascades as the parties were working in the Chilliwack and Sumas areas. A conference had been held with the Americans early in the year, but agreement was hard to reach. The British wanted to mark the boundary very thoroughly so that there would be no possible doubt about its location, but the Americans declared that it was impossible to do this in some sections and that such joint activities were not feasible. Each party went ahead on its own, but it was found in the end that neither party were able to visit certain very inaccessible portions of the line, and that in some cases, particularly in the areas between the Fraser and the Okanagan valleys, stretches of as much as twenty-three miles at a time were unmarked. Certain points were visited and observations made from unconnected stations; in the Cascade region, however, and that between the Columbia and the Rockies, the marking was not completed. In other areas, noticeably near the coast, and in the open country between the Similkameen river and the Columbia, the whole line was traced, a 20-ft track was cut at intervals, and iron markers or cairns of stone were put up at distances of about a mile. On the whole line which was 410 miles from the coast to the summit of the Rockies, twenty-nine observation stations were used to determine the boundary. Where it could not be determined, the understanding was that it consisted of a straight line drawn to connect the two nearest located points.

During the summer spent in the Sumas prairie, the parties suffered horribly from mosquitoes. So bad were the effects of these creatures—a new species according to Lord, "fatter than any of its known brethren"—that work had to be stopped in July and the men withdrawn to higher ground. At first Wilson made light of the trouble, describing it with humour: "My present dress consists of a very bad jim crow, a red serge shirt with pockets, a blue serge pair of trousers, stockings and moccasins, a huge gause (sic) bag over my head, and a short pipe puffing to try and keep the 'squitors off." Four weeks later: "The mosquitoes have now regularly set in . . . washing is a perfect torture, they settle *en masse* upon you perfectly covering every portion of the body exposed, we sit wrapped up in leather with gloves on and bags round our heads and even that cannot keep them off. None of us have had any sleep for the last two nights and we can scarcely eat, exposing the face is such a paintful operation." Finally, "As I am now leaving the mosquito country, I may as well tell you some of the effects of these venomous little animals and pray do not think I am inventing stories to amuse you as however incredible they are perfectly true; my hands have been so swollen and stiff that I could hardly bend my joints and have had to wrap them in wet towels to be ready for the next day's work; one's hands are literally covered with them when writing and even when wearing kid gloves, the bites through the needle holes in the seams were sufficient to produce this; each mule as it is packed is obliged to be led into a circle of fires continually kept up as they are quite intractable when they are worried by the mosquitoes; two of Darrah's mules have been blinded, and six of our horses were so reduced that we had to turn them out onto the prairie and let them take their own chance of living. I never saw anything like the state of their skins one mass of sores; our tents used to be so frequently covered with mosquitoes inside and out, that it was difficult to see the canvas and the very action of getting under the curtains introduced so many it was impossible either to kill them or sleep; even after smoking them all out in half an hour it was just the same, whatever pains we took to shut up the tent; we are all of us as you may imagine a good deal pulled down by want of sleep and continuous irritation."

So the mosquitoes won, and Wilson spent the next few weeks in New Westminster and Victoria. The party returned to Sumas in October, and were still in the field in December. Christmas dinner was eaten in camp at Langley Prairie: "Alas, alas, that I should have to say it, but Xmas day is nothing without beef and as we could not get it by any other way, we killed our cow." A week later, they were back at headquarters at Esquimalt, and preparing for a few festivities, notably a ball given by Captain Haig, Captain Palliser and himself in the hall of the Hudson's Bay fort at Victoria. "The rooms were decorated and arranged by me. . . . I had the floor well waxed to make it slippery, the effect of which was two tremendous tumbles during the course of the evening; everything went off with great eclat, and everybody enjoyed themselves keeping it up till after four in the morning".

To Wilson's great delight, April 1860, ended the work West of the Cascades and preparations were made to establish a depot at Fort Colvile on the Columbia River from which parties would work east and west to complete the line. He looked forward to seeing "the real interior with its immense plains, and bracing climate and almost cloudless skies". The party went from Victoria to the Columbia in the *Otter*, and were received at Fort Vancouver "with true English hospitality at the Hudson's Bay Company's Fort". His comment on the situation there is interesting: "The Fort is now surrounded by the garrison of the American troops of General Henry of San Juan renown; alas the poor old fort once the great depot of all the western fur trade is now shorn of its glories, General Harney having taken forcible possession of nearly all the ground and confined the Hudson Bay Company people to the Fort itself. The Hudson Bay Company are going to give up their post here as most of their work is now transacted in Victoria, in consequence of General Harney's disregard of the Treaty of 1846 which secured them their rights; it is most annoying to them to see all the fields and lands they have reclaimed from the wilderness and savage gradually taken from them; we have at present the use of the buildings which are nearly empty now, what a place it must have been in the olden times."

The party travelled to the Dallas, and Haig left for the Okanagan River and the boundary while Wilson went on across the Spokane plateau. "After the hot sandy desert of Walla Walla, the grassy and immense Spokan Plateau and the wild forest of the last two days, the moment I saw it I exclaimed 'Here is the happy valley of Rasselas', descending into the valley we soon were among cornfields, cattle and houses and found ourselves quite objects of curiosity being the first English soldiers that the people had seen; and such a curious medley these said people are, nearly all of them old servants of the Hudson's Bay Company; the old trapper, the voyageur, Canadian French Iroquois and half breeds (who have spent the best part of their lives amidst the dangers of Indians, rivers and the chase and wandering over the vast continent) the hardy pioneers of civilization now quietly settled in the valley with their wives and families round them."

Soon the party reached Colvile where again they were entertained at the Hudson's Bay post and proceeded to set up a camp which was to be their headquarters for the next two years. Wilson marvelled at the beauty of the country with its open range land, and the company farm which was able to provide them with fresh butter and milk. The Indians in the vicinity were very friendly, and Wilson greatly admired the Spokane chief "Carry" who "when a boy was taken over to Red River and educated there by the Hudson's Bay Company and talks English very well". After the camp had been set up and the supplies stored away, Wilson paid a visit to the survey parties to the West, travelling to the Okanagan and Similkameen regions late in the summer. He saw plenty of sage brush, and several rattlesnakes, and visited one portion of the boundary line 7,000 ft up "marked by huge cairns of stones for the edification of any enterprising individual who hereafter may visit these regions".

A week later, going towards Rock Creek, he met a very enterprising individual indeed: "And yes, there it was, as large as life, in all the grandeur of the most expansive crinoline, a 'petticoat in the wilderness'. We could scarcely believe our eyes but yet it was true, this enterprising woman (English, bye the bye) had travelled on horseback over the mountain, through forest and plain, fording the mountain torrents and exposed to all the dangers of weather and was on her way to set up an Inn at Rock Creek, the first white woman who had ever penetrated into these wilds; she was accompanied by her husband, a fine-looking Englishman, and on the back of sundry mules were packed all the household fixings for the future benefit of homeless wanderers in the valley."

Back at Colvile, Wilson prepared for the third official meeting with Campbell and the American Commission. This took place in November and, to everyone's relief, was a great success. Agreement was reached on practically every matter discussed, and plans were made to complete the work the next season. Campbell himself returned to Washington, but most of his party wintered about fifteen miles away, and provided one more place for the British group to visit, and one more group for them to entertain. Christmas was spent at Colvile—"a family party together, being the first Xmas time we had all been together since leaving England" and the Hudson's Bay officers were entertained to a "great spread-out of beef and plum pudding". After dinner a fine entertainment was put on with "innumerable Scotch reels and Highland flings. Mr MacDonald (in charge of the Hudson Bay Company fort) gave us a capital sword dance."

In February, the Hudson's Bay officers put on a grand ball to which the boundary party were invited. Wilson, adaptable as ever, thoroughly enjoyed dancing a "reel de deux" with an Indian squaw. "I concocted one sentence which I found very effective, being the English 'May I have the pleasure of dancing with you' compiled from the three languages, Indian, English and French, and running thus, 'Tlast spos anule danse avec moi'. We all enjoyed ourselves excessively, a regular romp being quite a break in the dreary monotony of the winter life in these parts."

A few days later, Wilson left Colvile for San Francisco to get some of the scientific instruments repaired. The trip was a hazardous one owing to the ice and cold, and is as "what he considered one of the hardest experiences of his life". He took with him his Scottish servant Low, and arrived at Walla Walla after eleven days of "what the Americans would call a 'hard old trip'." He went on to San Francisco where new potatoes and strawberries were waiting for him, and where "the California ladies are very pretty". Two weeks later he went back to Colville, and with 150 mules began to take supplies to the survey parties now working East towards the Rockies. During the summer of 1861 he set up an advance depot at Sinyakateen, travelled in the Kootenay country, and at the end of July was at Haig's camp in the Rockies. He painted several water colours of the country at the end of the boundary line, but his description of it is better than all the pictures:—

"Three of us started off to pay our devoirs to the final monument on the boundary, and after a short scramble we got on to the summit or divide, some distance North of the line, the divide being at that point comparatively low and covered with grass. Leaving the grassy ridge we commenced a fresh ascent and after a good climb over bare rock where hands and feet were well employed, a steady eye needed, and occasional halt to watch the course of a stone sent rolling by the foot into a little lake some fifteen hundred feet below us, we stood upon the narrow shoulder beside the cairn of stones which marked the end of our labours, and here we found tokens of previous visitors in the shape of sundry Anglo-Saxon names engraved on the stones, to which truly English record we refrained from adding ours. The view from this point was very fine, precipices and peaks, glaciers and rocks all massed together in such a glorious way, that I cannot attempt to describe it. Fancy our delight at finding on a grassy spot, close to a huge bank of snow, real 'London Pride' and the dear old 'Forget-me-not', which caused our thoughts (to fly?) far away from the wild mountains to many a pleasant day of 'Auld lang syne' in Merrie England. I send you some which I gathered right on the summit. We returned to camp by an easier but much longer route . . . down a steep grassy slope . . . so we sat down, cast off our moorings and made all sail for the bottom which we reached in safety though much to the detriment of our unmentionables."

At the end of the summer, the parties returned to Colvile, their outdoor work on the boundary completed. Darrah went to the coast to erect markers there, Lyall and Bannerman left for England both in poor health, and the American garrison at Colvile was withdrawn because of the onset of the Civil War. Wilson was getting impatient: "Everything is frozen, even wine and treacle. We have had no letters from England for many a long week." Even Christmas seemed dreary: "Our cook having cleverly contrived to boil up his pipe and tobacco in the soup, we spent a rather cheerless Christmas Eve and everyone went to bed at an early hour with vastly unpleasant sensations". However, three balls, one given by the British party, one by the Hudson Bay Company and one by the Americans cheered things up until early in April "we left our barracks at Colvile four years to the very day of our leaving England", and began the journey down to Fort Vancouver and to Esquimalt.

They left Victoria for San Francisco in May, and once again Wilson was able to appreciate the beauty of Vancouver Island. He laughed at the muddy streets of Victoria: "Indeed it is so bad that a story is told of a merchant who wished to carry on a conversation with a person on the other side of the street, hiring an Indian to shoot letters over with his bow and arrow." Yet from San Francisco he wrote: "We left Victoria with regret, my sojourn there will always be amongst my pleasantest reminiscences. I have a great wish to return and explore the island and the northern coast which are almost perfectly unknown and peopled by a very interesting race of Indians little known to the world."

But he never did return.

After returning home Wilson was posted to Chatham but it was not long before he volunteered to direct important surveys in the Sinai and in the Holy Land. For his outstanding work there he received the Diploma of the International Geographical Congress, held at Antwerp in 1871, and for his Jerusalem Survey he was elected a Member of Council of the Royal Geographical Society. The following year he became a Member of Council of the Society of Biblical Archaeology. In 1874 he received the distinguished honour of being made a Fellow of the Royal Society for his work in Jerusalem, Palestine and the Sinai and he was elected President of the Geographical Section of the British Association the same year.

He was employed by the India Office on a compilation of a map of Afghanistan and in 1878 he was selected as British Commissioner for the delimitation of the Boundary of Serbia under the terms of the Treaty of Berlin. From 1879 to 1882 he was Consul General in Analolia where he had to undertake many arduous journeys in Asia Minor, and during his service in Anatolia he was employed on special missions to Bulgaria, Rumania and Macedonia and also on tours of inspection to Consular Posts in Syria and Palestine. In 1881 he was created KCMG and in the same year he became a regimental Lieut-Colonel in the Corps—such was the calibre of Sapper officers of his day.

In 1882 the political trouble in Egypt was ended by the successful campaign of General Sir Garnet Wolseley against Arabi Pasha. Wilson was sent from Anatolia to Cairo. He reached the city shortly after the arrival of the first British troops, after their victory at Tel El Kebir, and joined the staff of the Consul-General. In 1883 he was sent to the Sudan, but his report for improving the conditions of the country was disregarded. The subsequent Mahdi rebellion annihilated an Egyptian Force in 1883 and the following year Major-General Charles Gordon was sent to the Sudan to superintend the evacuation of the scattered garrisons. The Eastern Sudan also rose, an Egyptian force of 3,500 men was wiped out and Gordon became isolated and in imminent danger in Khartoum. Wilson accompanied the Expedition, initially as Chief of Intelligence, sent from Egypt to relieve him.

The peril to Gordon was so urgent that it was decided to send a small column, 1,500 strong, mostly mounted on camels, straight across the desert to Korti under the command of Colonel Sir Herbert Stewart. After crossing 180 miles of desert the column reached Abu Klea where on 17 January 1885 it was attacked by 5,000 dervishes who were driven off. Stewart was, however, severely wounded and Wilson assumed command of the column.

Eventually his force reached the River Nile where with a small party Wilson embarked on two steamers—the *Bordein* and the *Tell Hoween*—which were among those that had been sent down the river from Khartoum by Gordon to meet the relieving force. The Nile at the time was low and the passage of the sixth cataract was most hazardous. It took four days to make the passage. Wilson and his few redcoats arrived in Khartoum on the morning of 28 January only to find that Gordon and all his garrison had been massacred two days before. His return journey was an eventful one. Both steamers were wrecked and Wilson and his party had to be rescued from an island in the river by Captain Lord Beresford, RN in the *Safieh*, another of the steamers originally sent by Gordon to meet the relieving force. For his services in this operation Wilson was created a KCB.

It was not until 4 September 1898 that the then Major-General H. H. Kitchener, a Sapper officer who had at one time also been engaged on a survey of the Holy Land, returned to Khartoum to avenge Gordon's murder and, in his own word, to bring peace to the country and to acquire the confidence of the people, to develop their resources and to raise their standards to a higher level.

In 1886 Wilson became Director-General of the Ordnance Survey, an appointment which he held until March 1894. While Director-General he did much to improve the scope and efficiency of the service. He also devoted considerable attention to the organization of Survey Sections RE for employment with the Army in the field. His military topographers, trained by the Ordnance Survey, were the forebears of the present Sapper Survey units. Honorary degrees were bestowed upon him by the Universities of Oxford, Edinburgh and Dublin and he became a Member of Council of the Royal Society. His last appointment was Director-General of Military Education at the War Office, and he retired on 13 March 1898 after forty-three years' service.

After his retirement his interests in geography and exploration remained unabated. He devoted himself to the works of the Palestine Exploration Fund and personally supervised many excavations in the Holy Land. In 1901 he was elected Chairman of the Executive Committee of the Society and he produced a series of articles on the Holy Sepulchre at Jerusalem. He died at Tunbridge Wells on 25 October 1905, surely a Sapper officer who fully lived up to the motto of his Corps.

Correspondence

Brigadier F. G. Drew, CBE.
Winterbrook Close,
Wallingford,
Berks.

The Editor,
RE Journal.

14 September 1961.

Dear Sir,

I think the statement on page 315 of the September issue of the *RE Journal* that: "Traditionally the Royal Army Ordnance Corps has always dealt with shells and stray ammunition" needs some qualification.

This may well have become the case in the inter-war period: it was certainly not the case at one period during the 14–18 War.

In January or February 1915, the Gunners produced a trench mortar with a spherical bomb or shell on a stick, to replace the very primitive trench mortar that we had used up to that time and which we had made up in the field. This new mortar was sent out to France for field trials. One morning, 21 Coy Bombay Sappers and Miners, serving with the 3rd Lahore Division, received a signal instructing us to dispose of an unexploded bomb lying in a field a few miles away. Frank Kisch (later killed as Engineer-in-Chief, 8th Army in North Africa) and I rode over that afternoon, and found a field with sentries disposed all round, in the middle of which was an unexploded spherical shell from one of these new trench mortars. We knew that the fuze was of the annular burning time fuze type as used in 18 pounder shrapnel shell. So we lifted the shell, unscrewed the fuze, and deposited the shell in the Gunner Mess.

At that time, there were no RAOC personnel in the Corps or Divisional area other than a DADOS with a couple of clerks at each headquarters, and the disposal of a "stray" of this nature was unquestionably a Sapper responsibility.

Yours faithfully,

(Sgd) F. G. Drew.

The Editor,
RE Journal.

3 October 1961.

Dear Sir,

I notice, with regret, that Brigadier Jarrett-Kerr, in his article on the Development of Engineer Equipment for the Army (*RE Journal*, September 1961) did not mention two increasingly important factors in the design of military engineering equipment. These are *simplicity* and *repairability*. Two examples in the post war range of designs from MEXE spring to mind to illustrate their omission.

The light assault floating bridge pontoon, although fulfilling user requirements extremely well, is of a most complicated design. The basic fault in my opinion, is that in order to achieve the last ounce in lightness, almost all of the light alloy extrusions which form the structural frame of the pontoon have been designed down to fine limits. The result is that there are over a score of different extrusion sections in its composition.

Any unit responsible for its repair must have this wide range of extrusions available plus a variety of special tools akin to those used in the aircraft industry for light alloy work. Added to this, the tolerance in the connecting points where pontoons or superstructure are coupled is limited to a few thousands of an inch in distances of seven or eight feet. These have to be checked after repair by means of cumbersome jigs and optical gauges. The alloys used are weldable and Argon-arc equipment is now becoming available in the Corps, but in many cases the shrinkage which occurs in aluminium alloy welds may preclude the use of this technique if it has to be done on members lying within the close tolerance zones.

For an example in the same field of the other extreme, I commend the Uniflote pontoon, made by Messrs Thos Storey. This is built of only two different mild steel sections, which are readily available anywhere, and one thickness of sheet. It is all welded and, being airtight, can easily be tested for leaks. The coupling tolerances are wide, of the order of better than $\frac{1}{8}$-in, and coupling of pontoons is done at deck level with no complicated remote controls to deal with the underwater couplings. I do not suggest that the Uniflote as it stands should replace LAFB or even HAFB pontoons (although it has much to commend it for the latter). But the simplicity of its design could be adapted into an all-welded light alloy form with very little loss in strength/weight ratio in comparison with the other two examples.

Another, and even more striking example of complicated design is the heavy ferry main pontoon. In addition to a variety of special alloy extrusions, and even closer tolerances over greater distances than the LAFB pontoon, we have a non-weldable alloy in many of its parts (largely because welding would upset heat treatment). On top on this, the whole unit is metal sprayed against corrosion and there is much erudite argument as to the merits and de-merits of this technique. Thus every repair requires respraying if corrosion is to be avoided.

The proportion of "tail" to "teeth" in the Army is being greatly reduced. Workshop facilities are now at a premium and therefore I submit that the two factors of simplicity and repairability must be given greater weight in modern military designs if equipment is to be kept functioning in the field.

J. McDowell, Major RE.
No 3 Long E & M Course,
SME, Chatham.

The Editor,
RE Journal.

MEXE,
Christchurch, Hants.
17 October 1961.

Dear Sir,

Major McDowell quite rightly stresses the value of simplicity and I am very glad he has drawn attention to this. It is, of course, just as important in civilian as in military equipment, and I did not therefore emphasize it as a different factor; but I hope I made clear my realization of its necessity, when introducing the paper for the discussion.

I do not, however, entirely agree that "repariability" is an important factor, except in peace-time—and military equipment is designed for war, when there will not be much opportunity for repair. Major McDowell's experience of shortage of spares in the form of extrusions may have coloured his remarks, but as he will probably know, this shortage is being rectified.

His comparison of the LAFB with the Uniflote is, perhaps, rather like comparing a racehorse with a shire horse and I am not, therefore, convinced that his conclusions are valid. The need for reduction in weight, both of LAFB and heavy ferry, led inevitably to the use of special alloy material, and of close tolerances to achieve interchangeability.

H. A. T. Jarrett-Kerr.
Brigadier.

Surrey House,
Cowes, I. of W.
30 October 1961.

The Editor,
The Royal Engineers Journal.

Dear Sir,

Brigadier Jarrett-Kerr's paper, "The Development of Engineer Equipment for the Army", includes an interesting section on hutting.

During the war of 1939-45 the design and provision of hutting and shedding in vast quantities were one of the largest problems the Directorates of Fortifications and Works and Engineer Stores had to solve. Designs made between the two great wars proved to be unsuitable for production and erection in the climate of war time scarcities. In the first few weeks of the war a quick decision on hutting had to be made. Brigadier W. C. H. Prichard, later DES, decided to revert to the Nissen pared down to bare essentials. Although a number of other types of hut were tried the Nissen prevailed to the end.

There was no ready made solution for sheds. Under the energetic direction of Lieut-Colonel E. F. Brawn, ADFW in charge of design, the Romney and Marston sheds were designed and produced. Both were highly successful, the Romney in particular being a triumph in design for economy in manufacture, transport, stores control and ease of erection. From memory I believe there were only three different parts—including the bolt—in the framework of the vault, an economy in parts which proved of particular value in North Africa where native labour quickly learned to erect Romney sheds but, because of the large number of different parts, made a muddle of Nissen huts.

Availability of material also played a part. The reversion to the Nissen was partly due to its use of very light rolled sections, thin black sheets and an acceptable "life" of three years; a scarcity of heavier rolled sections suitable for shedding had some influence on the selection of tubes for the Romney and the promise of a canvas covered "Semi-Romney" as a first stage shelter was defeated by a shortage of canvas.

This brief summary is intended to show that in war the functional requirements of the users of hutting and shedding are often heavily overshadowed by other factors and I hope that Brigadier Jarrett-Kerr, or one of his colleagues, will be able to deal with them, both in cold and hot war conditions, in another paper.

Yours faithfully,

H. E. Hopthrow, Brigadier.

Note. Brigadier H. E. Hopthrow, CBE, was Director of Fortifications and Works from 1943 to 1945.

Lieut General Sir Lionel V Bond KBE CB Colonel Commandant RE

Memoirs

LIEUT-GENERAL SIR LIONEL VIVIAN BOND, KBE, CB, COLONEL COMMANDANT RE (RETIRED) AND PAST PRESIDENT OF THE INSTITUTION OF ROYAL ENGINEERS

LIONEL VIVIAN BOND, who died on 4 October 1961 at the age of 77, was a son of Major-General Sir Francis Bond, KBE, CB, CMG, himself a distinguished Sapper Officer.

From Cheltenham College he entered the RMA Woolwich, where he gained the Sword of Honour, and the King's Gold Medal, and was commissioned in July 1903. After his YO course at the SME where he was awarded the Fowke Medal, he went to India where his service included periods with No 6 Company 1st PWO Sappers and Miners, with which he served in the Mohmand Field Force (1908) receiving a mention in despatches, and which he later commanded (1913). In the interim he served with 3 Divisional Signal Company 3rd Sappers and Miners; and this experience resulted in his being posted, in September 1913, to AHQ India to undertake the organization of the Indian Signal Service, a task which kept him there, to his chagrin, until 1917, when he was at last "released" to join the Malerkotla Sapper and Miner Company in Mesopotamia. The efficiency attained by this unit, under his command, earned high praise. This was followed by periods as GSO II, CRE and GSO I, with the award of brevets of Major and Lieut-Colonel. He was selected for the first post-war Camberley Staff College (1921) Course, a distinguished company. Then came Instructor at the Senior Officers' School, India (1924), Superintendent of Instruction KGVO Bengal S & M (1926), CRE 3rd Division (1929), GSO I War Office (1931), Chief Engineer Aldershot Command (1933), Commandant SME and Inspector of RE and GOC Chatham Area (1935) and finally GOC-in-C Malaya (1939).

This career was not markedly different in pattern from that of many others. What then were the characteristics which prompted the writing of more than two hundred letters, many from high-ranking officers, and others in high positions, to his family on his death in terms of admiration and affection?

General Bond was a dedicated soldier from the outset. A contemporary at Cheltenham describes finding him studying the Austro-Prussian Campaign of 1866, and refighting the battles, with maps and flags. He worked very assiduously to master his profession, and in the process he developed a capacity for broad-minded but thorough approach to every problem, and the ability to apply his knowledge to problems of the future. He was intensely proud of the Corps, in the widest sense, and especially in regard to its ability to carry out its functions and responsibilities in the Army as a whole.

Combined with his professional ability, he had the happy trait of being able to get the best out of all who served under him, and making them feel that they were all members of a "family". To this were added a deep sense of humanity, and a delightful sense of humour. As one friend has written "this spontaneous gaiety was infectious; how often would he say something, pause, and then would come the tinkling laugh so characteristic of him". All these attributes combined to make up a gifted soldier and inspiring leader, with a lovable outstanding personality, known to, and affectionately remembered by, a host of friends whose lives have surely been enriched by having known him.

The combined duties of Commandant SME, Inspector of RE and GOC Chatham Area—a three-man-job—involved a heavy burden; but, as one of the officers on his staff at that time writes, "he never seemed to be overworked, although he worked very hard, and was never in a hurry and never out of temper". One of his main tasks at this time was the re-examination of engineer tactics under conditions of modern warfare. It also fell to the Inspector of RE to deal with the change-over of several Territorial infantry units to anti-aircraft searchlight units RE and a great tribute has been paid by a senior Territorial Army officer to the human touch which General Bond applied to this delicate problem. By his personal visits to the units concerned, welcoming them to the Corps, and the series of Guest Nights at Chatham to entertain the officers of these units, at which their Colours were displayed in the Mess Room, the conversion was carried out with enthusiastic success.

It was during this period that he took up painting with enthusiasm under the expert guidance of a brother-officer, and developed a hobby which was to give him great pleasure and relaxation, with exhibitions at the Army Art Society.

The difference of view over the defence of Malaya, which resulted in the premature ending of his appointment as GOC-in-C Malaya, was a great disappointment to him.

After his retirement General Bond applied himself to many activities. He was Colonel Commandant RE (1940–50), Representative Colonel Commandant (1946) and President of the Institution of RE (1945–48). Deeply religious, he took an active part in his local church affairs; and became a Member of the House of Laity of the Church Assembly; and he worked hard in the interests of the RE Benevolent Fund, and of the SSAFA. The current SSAFA Hampshire News Sheet comments: "it is with great sorrow that I have to record the death on 4 October of our County Chairman, Lieut-General Sir Lionel Bond, KBE, CB. He had served the SSAFA for over 15 years. By his hard work and enthusiasm he earned for the Hampshire Branch the reputation for efficiency which it enjoys. The many who knew him and worked under his lovable guidance will miss him sorely."

Of his Home Guard Command in Southampton a senior Naval officer has written "Although a seaman, I had the privilege of serving under Lionel Bond in the Southampton Home Guard. It was an inspiring experience". In 1925 he married Dorothy, daughter of Major K. M. T. Reilly, OBE, DL, JP. This ideal partnership diffused its glow of affection by the kindness, interest and hospitality shown by them both to so many, individually and collectively, and Lady Bond's death in 1953 was a cruel blow to him, and a great loss to her many friends.

General Bond became seriously ill in 1960; but in spite of this he maintained his interests in the welfare of his fellow men with great fortitude and unfailing good humour. With his death we have lost a fine man and a true Christian. He has given us a great example to follow.

C.A.B.

The funeral service took place on 9 October 1961 at Christ Church, Guildford. The Rev. J. G. L. Prior and the Rev. D. G. Radford took part in the service. Among those present were:

Major-General and Mrs R. L. Bond (brother and sister-in-law), Air Commodore and Mrs R. K. Hamblin, Miss Lynette Hamblin, Miss E. M. V. Berry, Miss M. Jackson, Mrs H. Mansbridge, Mrs N. de Selincourt, Miss Ann-Marie de Selincourt, Mrs Charles How, Mrs Elles, Mrs M. Bond, Major and Mrs J. A. Inglis-Jones.

Air Chief Marshal Sir Douglas Evill, General Sir Nevil Brownjohn, Major-General W. Cave-Browne, Major-General S. H. M. Battye, Lieut-General Sir Ronald Scobie, Lieut-General Sir Clarence and Lady Bird, Major-General and Mrs M. D. Gambier-Parry, Major-General and Mrs C. G. Woolner, Major-General Sir Douglas Campbell (representing the Chief Royal Engineer and the Institution of Royal Engineers), Brigadier H. W. Kitson (Commandant, RE Training Brigade, Aldershot, also representing the Engineer-in-Chief and Royal Engineer Association, Aldershot), Brigadier G. J. V. Shepherd, Brigadier and Mrs V. G. Stokes, Brigadier and Mrs E. Rait-Kerr, Brigadier G. F. Ellenberger (S.S.A.F.A., Hants), Brigadier and Mrs F. G. Drew, Brigadier W. E. van Cutsem, Major-General and Mrs N. W. Napier-Clavering, Major-General B. K. Young, Major-General C. H. Geake, Brigadier *H. I. Allen (Indian Signals* Old Comrades Association), Brigadier and Mrs E. F. J. Hill, Brigadier E. F. E. Armstrong, Colonel Brian Freeland, Colonel and Mrs F. G. J. Goodyear-Pain, Colonel A. F. Toogood, Colonel and Mrs. A. Bird, Colonel and Mrs G. H. H. Lee, Mrs K. G. Lee, Colonel and Mrs. S. G. Notley, Lieut-Colonel J. F. Batten, Lieut-Commander E. W. Clubb and Cadet Officer J. Parker (representing the Director, School of Navigation, Southampton), Major E. A. Stamp, Major E. C. O'Dell, Major N. N. G. Dixon (representing Commander, School of Military Engineering), Major G. Bishop, Major T. A. Davis, Major H. Boxall, Major F. Collinge, Major R. G. Cork, Captain A. A. Andrews (representing chairman and council of S.S.A.F.A.), Captain R. B. McGuire, Captain Otway Ruthven, Group Captain and Mrs E. G. Keeping, Lieutenant D. F. Kruger, Mr R. Trevor Jones, Mr Stanley Creber (Royal Academy of Music), Mr R. Witham (representing Forces *Help* Society), Mr G. H. A. Wood, Mr P. Conway Jones, and Mr and Mrs N. Mass.

MAJOR-GENERAL J. S. LETHBRIDGE, CB, CBE, MC

JOHN SYDNEY LETHBRIDGE was born on 11 December 1897, the son of Lieut-Colonel Sydney Lethbridge, OBE, RA. He was educated at Gresham's School, Uppingham and at the Shop from where he was commissioned into the Corps on 28 July 1915 when only seventeen and a half years old.

In March of the following year, three months after his eighteenth birthday, he was posted to 123 Field Company RE serving in Flanders with 38 (Welsh) Division, and as a Subaltern in that unit he took part in the Battle of the Somme fought in July 1916. The following year he was posted to India and joined 51 Field Company of the Bengal Sappers and Miners, then being raised at Roorkee, as a temporary Captain. Shortly afterward the Company was sent to Aden where it became part of the Aden Field Force engaged in operations in Southern Arabia.

Early in 1919 he returned to India where he was given command, as an acting Major, of 57 Company of the Bengal Sappers and Miners at that time serving on the North West Frontier. Soon after he assumed command his Company took part in the Third Afghan War and for gallantry in that operation he was awarded the Military Cross. He remained with 57 Company until it disbanded in 1922.

During his Supplementary Course, for which he was sent back from India, he became an undergraduate at Jesus College, Cambridge. In 1924, however, he was back again at Roorkee with the Bengal Sappers and Miners. He first commanded 43 Divisional Headquarter Company and in May 1925 he obtained the coveted appointment of Adjutant of the Corps of Bengal

Major-General J S Lethbridge CB CBE MC

Sappers and Miners. In August of that year he married at Christ Church, Simla, Katherine Greville, daughter of Sir John Mannard, KCIE, CSI, ICS and Lady Mannard. After four years as Adjutant he became Assistant Superintendent of Instruction at Roorkee and in December 1929 he took over command of 3 Field Company of the Bengal Sappers and Miners from Lieut-Colonel Philip Neame, VC at Rawalpindi. The following year his Company was engaged in the Kajuri Plain operations which made Peshawar safe from Afridi raiding. In February 1931 he entered the Quetta Staff College and after graduating from there he officiated as Superintendent of Instruction at Roorkee until he was posted home.

F.D.G. writes thus about Lethbridge's connexions with King Georve V's Own Bengal Sappers and Miners:—

"Lethbridge was one of the first officers to be posted to the Bengal Sappers and Miners during the 1914–18 War who had had previous service in France. With interludes for his Supplementary Course at Jesus College, Cambridge, and at the Staff College Quetta, he served with that Corps with great distinction and ability until reversion to the Home Establishment in the spring of 1933.

He was barely nineteen on his arrival in Roorkee, but his knowledge and experience in France was avidly drawn on for the latest field engineering ideas on trench warfare. From the first, he rapidly proved himself as a keen, energetic, able and conscientious young officer with a flare for organization and imparting instruction. Though he never excelled at any particular game, he was a keen player of polo, hockey and tennis, and he was a very good shot. He took every available opportunity to get down to the jheels after duck and, with his wife, he carried out many treks and shoots into the hills.

As Adjutant under Lieut-Colonel E. F. J. Hill and Lieut-Colonel A. J. G. Bird, and with the advantage of several years experience in command of a field company on service behind him, he was really able to indulge his flare for organization and instruction, and he introduced many improvements in the selection and training of the recruits in his charge. He was also entirely responsible for the organization and training of the Regimental Pipe Band, and laid the sure foundations of the very fine Pipe Band which still exists. Although for many years previously each field company had had its own two pipers and a 'dollwala', they had never previously been brought together to form a regimental band.

He will long be remembered by his brother officers with whom he served in the Bengal Sappers, and by the Indian ranks to whom he was devoted and who were devoted to him, as one of the best type of Sapper officer who had the honour to serve with that distinguished Corps, both in war and in the more spacious times of peace.

On returning home Lethbridge became Field Works Major at Chatham and his first staff appointment came in February 1935 when he was posted to the General Staff of Headquarters Northern Command at York. In November the following year he was posted to the Military Operations Branch of the War Office and shortly afterwards to the Directorate of Recruiting and Organization. In March 1939 he became an Instructor at the Senior Officers' School.

Lethbridge was in France with the British Expeditionary Force for a short while in 1939 before becoming CRE 59 (Staffordshire) Division (TA) serving in Western Command and in September 1940 he was made a Brigadier on taking up the appointment of Deputy Director of Staff Duties at the War Office. From April to June 1942 he was specially employed on liaison duties with the Americans in London and in the United States before being made Director Liaison and Munitions at the War Office with the rank of Major-General. For these important duties he was made a CBE. The following year he led a mission—known as the Lethbridge Mission—to the United States, India, the South West Pacific and Australia. The Mission contained representatives of the three British fighting services and some Canadian and American officers; its purpose was to study the equipment and tactics that would be best suited for fighting the Japanese when a full scale Allied offensive could be launched against them after the defeat of Germany. The experience and knowledge gained as leader of that Mission proved of the utmost value to him when in 1944 he became General Slim's Chief of Staff in Burma. He was awarded the CB in 1946 and in the same year he became a Commander of the American Order of Merit. His final service appointment was as Chief of Intelligence, Control Commission for Germany and BAOR which he took up at a time when the defeat of Germany and the subsequent mopping-up of Nazi elements made his position one of outstanding importance. He retired in April 1948.

In 1949 he became the first Commandant of the newly-formed post-war Civil Defence Staff College. In 1952 he became seriously ill and he had to resign and undergo a major operation. He made a remarkable recovery, however, and in 1955 he returned to Civil Defence as Regional Director for the South West Region. He served in that appointment for five years and he retired at his own request last year.

He died on 11 August 1961 aged 63 years.

Field-Marshal Viscount Slim paid the following tribute to him in *The Times*, which is reprinted by permission:—

" 'Tubby' Lethbridge joined us as Brigadier General Staff at Fourteenth Army Headquarters soon after we had won our first major victory at Imphal. He succeeded a most popular predecessor and entered a close-knit fraternity that had endured many anxious days together and, at last, achieved success. It is not easy for a newcomer to make himself quickly accepted as a leading member of such a team. Yet 'Tubby' had that temperament, cheerfully imperturbable, genuinely friendly and completely unselfish, which, combined with his obviously outstanding professional competence, gained him the immediate loyalty and confidence of all with whom he worked. He showed his team, British and American, the best form of leadership—leadership by example.

He was at once plunged into, not only the staff work of considerable mobile day to day operations, but into the high-pressure preparation of the next great phase which we hoped would destroy the Japanese forces in Burma before the Monsoon. Then, just as we loosed our formations, it became clear that my conviction that the enemy would stand North of the Irrawaddy to defend Mandalay and on which I had based our plans, was completely wrong. Kimura, the Japanese Commander-in-Chief, was withdrawing his main forces behind the great river; a new situation, needing a new plan.

I have never seen a staff officer tested higher or respond more nobly than 'Tubby' Lethbridge. Working literally night and day, he with all the Fourteenth Army staff, had ready with unbelievable speed, the orders and directives needed to realign an army already in movement and to swing half of it wide on a secret flank march to strike suddenly at Meiktila the Japanese communication centre well south of Mandalay. To watch 'Tubby' stripped to the waist—he was suffering from septic prickly heat that would have put most men in hospital—dealing cheerfully and effectively with the frustrations, fears, unexpected difficulties, and sudden alarms that inevitably arose was an inspiration to his staff and certainly to his Commander.

Later, when the time came for the dash for Rangoon, he gain proved himself an outstanding Chief of Staff. He drew and deserved a peculiar satisfaction from seeing a plan we had had at Fourteenth Army, when few people thought it possible, to take Burma from the North, fulfilled. Typical of his robust and determined optimism he had christened this plan, Operation Sob—Sea or Bust!

We in the Fourteenth Army knew then how fortunate we were to have him and now we shall not forget him."

The following tribute by Wing Commander Sir John Hodsoll is also reprinted with permission from *The Times*:—

"I should like to add my tribute to Major-General Lethbridge to those that you have already printed. It was indeed a fortunate day for civil defence when he was selected as the first Commandant of the post-war Civil Defence Staff College. It was no easy task first of all to build up a team of instructors and a staff for the college; but also to evolve suitable training courses to meet new situations, and which at the same time would provide a stimulus to civil defence which was just being revived. In addition new buildings had to be planned since those existing were clearly inadequate for future needs.

By his infectious enthusiasm, his clear thinking and quick appreciation of what was needed, all these aims were successfully accomplished. Above all 'Tubby's' happy personality soon made the Staff College a home from home for civil defence; and for himself and his staff a host of friends.

He had all the qualities necessary for his task and it was a great grief to us all when ill-health forced him to resign.

Having been privileged to work closely with him in all these tasks, I cannot pay sufficient tribute to all he did. He was a great friend, a most loyal colleague and a source of inspiration to all who knew him. He made a great contribution to civil defence at a most critical period. He will always be remembered with great affection; and the 'Lethbridge Hall' at the Staff College will help to keep that memory always green."

Brigadier WG Tyrrell DSO MInstT

BRIGADIER W. G. TYRRELL, DSO, MInstT

William Grant Tyrrell, son of Dr J. D. Tyrrell of Toronto, was born on 6 June 1882, and died at Kingston-on-Thames on 18 August 1961 in his eightieth year. He was educated at Upper Canada College, Toronto, and at the Royal Military College, Kingston, Canada where he was awarded the Gold Medal. He was commissioned into the Corps of Royal Engineers on 24 June 1903. After completing his YO training at the SME Chatham, Tyrrell was attached to the London and South Western Railway for courses in Railway Traffic, Workshops and Locomotives. Next year he joined 10 Railway Company RE at Longmoor. In September 1908 he went to Montreal for five years employment with the Canadian Forces. From October 1913 to November 1914 he was at Chatham in the RE Depot. In November 1914 he went to the Western Front where for a time he commanded 10 Railway Company RE.

Early in 1915 Tyrrell joined the Egyptian Expeditionary Force, and in January 1916 was transferred to Palestine as Officer i/c Military Railways, first as a Captain, then as a Major from August 1916 and finally as a Lieut-Colonel in February 1917. This newly organized Railway Operating Division consisted initially of 53 Railway Troops Company and 274 and 276 Railway Companies with headquarters at Kantara East on the Suez Canal. It eventually expanded however under his command to a total of 6,000 all ranks, and 23,000 local labour. It constructed under active service conditions some 250 miles of standard gauge railway from Kantara, across the Sinai Desert, into Palestine. This rail link carried until 1920 all the supplies for the armies in the field in Palestine across a largely waterless and savage desert. The operation of this intensive service proved a vital factor in the successful prosecution of the campaign and remains to this day a feat of military engineering unequalled in its own sphere. The entire project from its inception to its completion, was of the greatest credit to the brain that inspired it and to the care and attention to detail that made it possible. Tyrrell was awarded a DSO in 1917 and was twice mentioned in despatches. He was made a Brevet Lieut-Colonel a year later.

In the summer of 1920 Tyrrell went to Ireland as Division Officer, Fermoy and within a year he moved to a similar appointment at Gravesend. After this spell of Works Services he went in the autumn of 1922 to join the Staff of the Railway Troops Depot (renamed the Railway Training Centre in 1923) at Longmoor, where he was Officer-in-Charge of Military Railways for four years. Early in 1927 he went to India as CRE Bombay District, and from 1928–30 was SORE 1 (Works), Southern Command at Poona. For a while he officiated as Chief Engineer. He became CRE Deccan District at Bolarum until December 1932, and then went home. In January 1933 he was promoted Colonel, with seniority back dated to June 1923, and remained on half pay until appointed Assistant Director of Transportation at the War Office in November 1933. At this period he will be remembered chiefly for his work in the organization of the Railway Supplementary Reserve, and its preparation for possible active service. He retired in 1937, but was re-employed on the outbreak of war in 1939 to command the Railway Training Centre at Longmoor until 1941, with the temporary rank of Brigadier.

By those who knew him well and served with him Bill Tyrrell will be remembered for many things. His kindliness to those under him, his astonishing technical ability as a railwayman even when he was snowed under by administrative detail, his sense of fun, his zest for life, and his complete inability to suffer fools or the pompous gladly. One recalls typical incidents. It was his preference when AD Tn at the War Office to give a younger officer some piece of unpleasant news over half a bottle of port at his club rather than in his office. He would never interfere with a subordinate, but if appealed to for advice it was quite probable that it would be found that he had already worked the problem out just in case he were asked. At a meeting if one saw him fidget in his chair and heard two sharp sniffs, one had not to wait long for the devastating comment that would bring the subject under discussion back to the realms of common sense. One remembers him standing on the lawn at Longmoor in the spring of 1940, digging his heel into the grass and explaining where and when and how the Germans would open their attack in France. One remembers that events proved him right, in that and in so many other matters.

Tyrrell was never vague nor inaccurate and could not bear these shortcomings in others. He was intensely loyal to his friends, proud of being a Canadian and of Canada, and prepared at all times to do anything to promote the well being of Longmoor.

In 1906 Tyrrell married Frederica Moffat Buckner, daughter of Commander W. H. P. Buckner, RN of Totnes, Devon and had one son, who also became a Sapper officer, and two daughters. After her death he married Sheila Mary Susan Plummer, daughter of the late Thomas Plummer of Shrewsbury, who survives him. Towards the end of his life increasing age and weight reduced the distances he could walk and curtailed his ability to call on others and to pay his usual periodical visits to London; nevertheless he retained his circle of immediate friends. Right up to the very end he was cheerful and gay and as good company as he had always been, and as busy as ever collating papers and photographs, surrounded by those whom he loved and who loved him. Perhaps his best epitaph is a remark overheard at his funeral: "Being with Bill was always fun." J.C.B.W.

R.E.B.W., an officer who served under him both as an officer under instruction at Longmoor and later as a Staff Captain writes: "Although Tyrrell's methods of instruction were unorthodox, I probably learned more from him than from any other officer. 'No, it won't do', he would say: 'Do it again.' Then gradually, after doing it again several times, the reasons why it would not do became clear either in the office or over an excellent lunch at the 'Rag', and they remained clear for ever."

Book Reviews

HIGHLY EXPLOSIVE

By John Frayne Turner

(Published by George Harrap & Co, Ltd, 182 High Street, Holborn, WC1)

Highly Explosive is a short book about the work of bomb disposal in general, and the work of Major A. B. Hartley, MBE, GM in particular. It starts with some account of the formation of the Bomb Disposal Branch of the Corps, before Major Hartley joined it, and carries on with the story—through Major Hartley's experiences—until he left the Army to keep a public house in 1961.

In the early days of bomb disposal the equipment was primitive, the intelligence about enemy mechanisms was scanty and the hazards in disposing of bombs were very great. Gradually equipment and intelligence improved, but the work remained extremely dangerous. Bomb disposal is still an active Corps interest because bombs, the aftermath of the war, are continually being found; and Bomb Disposal also interests itself with the removal or rendering safe of any kind of warlike explosive that would otherwise obstruct the public in its lawful pursuits. The reader will be surprised to learn that on an average one child per day throughout the year is killed or injured through finding some lethal weapon and playing with it. The most extraordinary carelessness on the part of parents and other adults is described in this book.

The Author gives a good description of many wartime episodes and conveys to the reader the tensions and stresses of the time; though your reviewer thinks that a few sketches might have made some of the technical descriptions a little clearer.

The reader may be amazed at the scale of the task involved in clearing Britain's beaches of mines. At Fairlight Glen, for example, near Hastings, work went on for two years. A VI had hit a cliff and brought debris down on a minefield which had been laid in swampy ground. Thirteen and a half million tons of sand, clay and rock had to be moved, and forty acres of the Glen had to be cleared of scrub with flame-throwers before the beach was made safe for public use.

The book is written in a racy manner that makes for quick reading; but your reviewer feels that occasional deviations into somewhat slipshod language does not always do justice to the theme. However, it is an interesting little book, telling of a side of military life that few people know much about. M.C.A.H.

CHANGING VIEWS OF THE UNIVERSE

By Colin A. Ronan

(Published by Messrs Eyre & Spottiswoode, London. Price 15*s*)

This book is the first of a series of six books, namely, this book and
Astronomical Spectroscopy by Dr A. D. Thackeray
Solar Research by Professor G. Abetti
Fact and Theory in Cosmology by Professor G. C. McVittie
Stars and their Evolution by Dr O. J. Eggen
Galaxies by Dr E. M. Lindsay.

The book is an entity in itself tracing man's theories about himself, poised on the planet Earth, from the dawn of history to the present day.

It is also an important prelude to the other five books; it shows how swings the pendulum of man's theories and philosophy about the space through which he travels. As man probes more deeply into measureless space, where all his standards of measurement in space and time must change, the theories of the ancients and of today swing the pendulum wildly.

With increasing knowledge the theories of the Universe are more diverse today than ever before in recorded history: the subject of creation alone engenders theories which are highly divergent.

I recommend this book to the layman, who may wish to know about a state which has encompassed him from his beginning; he need not be put off by the drawings, nor by the elementary mathematics; the book will make good reading whether or not these matters are appreciated.

I also recommend it to the student, who may wish to study these subjects; it is a first class introduction to the Universe; I suggest, however, that he should realize from the start that man has only begun to understand the universal environment, in which he lives. J.V.B.-J.R.

AUSTRALIA IN THE WAR OF 1939–45 VOL VI. THE NEW GUINEA OFFENSIVE

By David Dexter

(Published by the Griffin Press, Adelaide, 1961. Price 40*s*)

Whilst the Australian forces of 1942 in Papua were nobly holding off the determined efforts of the Japanese to establish themselves at Port Moresby, the USA were assembling ships, aircraft, and men on a vast scale in order to assume the offensive. How best to do this, rapidly became a question, which raged with violence amongst the tremendous American personalities who were directing the war in the Pacific.

As though to give time for such a truly Olympian debate, there ensued an Homeric pause in March 1943, during which the only active land zone in the Pacific was the Australian scattered front in New Guinea.

It is at this juncture that David Dexter takes over to describe in Volume VI the part played by the Australians in the New Guinea offensive of 1943–4. He is well fitted for the task since he took part in the campaign and has studied it deeply for ten years, on the ground and at his desk.

The pattern of the fighting here under review was very different from that of the desperate struggle in Papua. The Japanese had now lost the initiative and were to be compelled to withdraw northwards along the coast, contesting every yard of the way. Without massive support weapons, frontal assaults on narrow Japanese defences near the sea were murderous propositions and the trackless jungle made the movement of field artillery and heavy mortars only feasible from time to time. Thus at the start of the advance, the Australian-American forces had perforce to dislodge the enemy by slow and laborious enveloping movements, often from well inland, occasionally by parachute and increasingly from the sea. Salamaua, Lae and the Huon Peninsula were all captured in this fashion and so skilfully, that the Allied losses were low whilst those of the Japanese were prodigious.

The Americans now began to apply their newly acquired "island hopping" technique in a big way to the New Guinea coast and by the summer of 1944 had captured the island of Morotai far to the north towards the Philippine Islands. By this time the bulk of the Australian forces were left miles away to the south about Wewack-Madang and their great spearhead thrust had done its work. They had disposed of 35,000 Japanese for the loss of 4,098 Australian casualties, of which 1,231 killed—a fine tribute to the efficiency of their training.

Dexter's history is an admirable mosaic of tactical combats pieced together to form a coherent whole. Junior leaders who wish to get a preview of front-line war will do well to read the book from cover to cover, for such excellence of detail is difficult to come by. Those who have soldiered in India will enjoy the story of the Punjabi subadar-major, who, with fourteen Sepoys, found himself wandering about the wastes of New Guinea as an escaped POW. When they were almost at their last gasp, he spotted a low-flying US aeroplane. Whereupon he improvized a ground signal and suspended a message between rifles in the approved fashion. The message was picked up and duly brought about the rescue of the whole party. Somehow the incident takes one back to it all with a particular nostalgic charm. B.T.W.

HISTORY OF THE SECOND WORLD WAR—THE STRATEGIC AIR OFFENSIVE AGAINST GERMANY 1939–45 VOLUMES I TO IV

By SIR CHARLES WEBSTER AND DR NOBLE FRANKLAND

(Published by HMSO. Price 42*s* each)

The first three volumes of this history of the strategic air offensive against Germany describe in great detail the birth of the concept of Bomber Command during the inter-war years, the planning, training and equipping of the force up to the outbreak of the Second World War and a full account of the ever-mounting strikes against strategic targets as the war progressed, and the employment of Bomber Command in direct support of Combined Operations. The fourth volume is devoted to annexes and appendices covering radar, radio counter-measures in support of Bomber Command, training, equipment and armament besides Allied and enemy documents and the directives issued to the Air Officer Commanding-in-Chief, Bomber Command.

At a recent lecture on the "Use and abuse of Military History" given at the Royal United Services Institution, Mr Michael Howard, the historian, developed the theme that many military histories have been written specifically to perpetuate the mythology of some particular Corps or Regiment whereas the true function of a historian is to record faithfully what really happened without inflating heroic episodes or successes attained and to give the whole truth however painful and disagreeable it might be. "Official Histories" are often a misnomer in this very respect.

In this meticulously correct assessment of the contribution to ultimate victory made by Bomber Command the late Sir Charles Webster and Dr Noble Frankland, who himself flew in thirty sorties in Bomber Command during the war, have certainly departed from the path taken by many past military historians. The muddle, financial frustration, inefficiency and waste are not left unrecorded. The terrible casualties, comparable to the total Army officer casualties sustained in the First World War, suffered by bomber crews, all highly technically trained selected men of high courage and all volunteers are not minimized. The inability of Bomber Command to operate over enemy territory by day beyond the range of fighter escort and, until towards the closing stages of the war when equipments and techniques had improved, their inability to reach selected targets with any certain accuracy by night, are frankly stated. The directives ordering the terror raids on German cities where "the aiming points are to be the built up areas" are not suppressed, nor is the Joint Planning Staff Report of 1941 which stated categorically their assumption that the morale of the German civilian would weaken under air-bombing quicker than would the morale of our own people. An assumption which was proved grossly incorrect by the stoic inhabitants of Berlin and other bomb-shattered German cities. Because these unpalatable truths have been so clearly expressed many have said that the History was written with bias, but not in the direction condemned by Michael Howard. On that score the reader of this history must be left to judge for himself. But no reader can fail to be impressed most profoundly by the all-pervading personality of Air Chief Marshal Sir Arthur Harris and his single-minded belief in his bombers as a unique war winning force. To him the authors paid, at the end of their last volume, their final tribute: "Strategic bombing made a contribution to victory which was decisive. Those who claim that its contribution under different circumstances might have been more effective disagree with one another and often overlook basic facts".

Even before the war in the west was over, however, the unmanned bomber, in the form of the V1 and V2, had been used operationally, and the war against Japan was brought to a close by the use of two bombs that made it clear that massed bomber raids, similar to those carried out by Bomber Command from 1939 to 1945, would never be an operation of war again. There is, therefore, a completeness about this account of the stirling exploits of the gallant members of the war-time Bomber Command which greatly adds to the absorbing interest of these fascinating and trenchant volumes.

J.L.

Technical Notes

CIVIL ENGINEERING

Notes from *Civil Engineering and Public Works Review*, July 1961.

"Determining the Maximum Active Thrust on the back of a wall retaining cohesionless material": The article describes a graphical method based on Conlomb's Wedge Theory, for determining the maximum active thrust on the back of a wall retaining cohesionless material. The method is of more general application than Rebhan's construction and is simpler and quicker than the Culmann Line Construction. It includes a paragraph on a method of dealing with a non-uniform surface of backfill.

"Constant Shear Lines for Unconfined Compression Test Apparatus": The author describes how, in conjunction with the pin and bell-crank lever attached to the standard Unconfined Compression Test Apparatus, lines of constant shear for a given size of clay specimen can be drawn on a mask of tracing paper. When superimposed on the rupture curve, this mask enables the shear strength of the soil to be read directly.

"Work Study in Civil Engineering": The value of work-study in increasing output in manufacturing processes is already established. The author of this article discusses various ways in which work study can be applied to the many and varying problems and operations in Civil Engineering. The main value of Works Study appears to be in engineer planning; the author makes the point that whilst the same factors are considered by both the Works Study expert and the project planner, the former is likely to adopt a more analytical and critical approach, with a resultant increase in efficiency.

Notes from *Civil Engineering and Public Works Review*, August 1961.

"Engineering Developments in the USSR": These notes refer to methods of testing the shear strength and water-tightness of joints made in concrete with epoxy resins, and the use of precast concrete frames to eliminate the use of steel sheet piling in open-cut or trench excavations for tunnels.

"Major Economies in the Design of Multi-Storey BC Framed Buildings": The author reviews various ways in which economies can be made in the design of multi-storey RC framed buildings. None of these ways is particularly novel, but the article serves as a useful collation of the various factors and methods.

"The Analysis of Vierendeel Frames and Girders with Non-Prismatic Members": This article extends a moment distribution solution by Lightfoot to frames with members of variable section. The Lightfoot equations are modified depending on changes in the slope-deflection equations, which form the ultimate basis for the method. Two frames are solved as examples, with several assumptions regarding sectional variation and foundation fixity. It is suggested that in preliminary calculation a tolerable approximation to the effect of haunches of practical dimensions is to assume each member to be infinitely rigid for about one-tenth of its length at each joint.

"The Effective Length of Members in Axial Compression": The British Standard Specification 449 of 1959 attempts to provide some positive guidance to the effective length of compression members by modifying the length of the strut from centre to centre of its intersection with supporting members. The modification factors vary, depending on the estimated degree of restraint in regard to position and direction at each end of the member. Variations in the effective length of a strut will materially alter the working stresses in the member, and could lead ultimately to failure. The author of this paper deals with two simple cases in which the effective length of stanchions may exceed the values commonly used. Both cases may be regarded as quite common in practice even though the loading conditions are modified somewhat for the purposes of a stability analysis. D.L.J.

THE CONTRACT JOURNAL

Note from *The Contract Journal*, August 1961.

"Helical-Weld Aluminium Pipe Development": The notes draw attention to the successful development of the process for helically-welding aluminium sheet to form pipe of sizes from 6 to 28-in in diameter. This process was first used for steel pipe at the end of the last century but difficulties over the material itself and welding methods have prevented its application to aluminium until recently. The process was mentioned in the article "Fusion Welding of Aluminium Alloys", published in the *RE Journal* in June 1961. D.L.J.

THE MILITARY ENGINEER

July–August 1961

"Engineers in Wintershield", by Thomas A. Delong. An introductory article describing the general idea of the 7th Army exercise Wintershield held in Germany in January and February this year.

"Panel Bridge of Unique Design", by Arthur Emerson 1st Lieutenant Corps of Engineers. A detailed description of the construction of a Bailey bridge on a site which presented special problems owing to embanked approaches. The time taken over preliminary planning and rehearsals is interesting.

"Bridge Engineers versus the Weather", by Charles E. Edgar, 1st Lieutenant, Corps of Engineers. A description of the difficulties experienced at another bridge site in exercise Wintershield which were mainly due to deterioration in the weather conditions at a site with bad road approaches. The advantages of the French bridging equipment are brought out by implication. The overriding importance of having plenty of bulldozers at hand also stands out.

"Construction on Other Planets", by Colonel James E. Harper, Corps of Engineers. The writer is confident that construction on other planets will take place during the lifetime of some of his readers and in this article he describes the principle factors affecting the success of the indespensible preliminary training which will be required. He assumes that this will take place firstly on the moon. The Corps of Engineers are taking great interest in this problem, and there was an article on the subject "Engineering Problems of Lunar Exploration" in the March–April number of *The Military Engineer*. This article goes further in its consideration of the scientific details and suggestions regarding equipment, feeding, oxygen supply and water. The second part is a summary of the special conditions existing on the various planets in relation to the possibility of establishing conditions in which men could exist.

"First Step in Big River Hydraulics", by L. W. Mosby. In the spring of 1850 for the second year in succession floods had devastated the alluvial valley of the Mississipi. State and local efforts to provide adequate protection had not been successful and in November of that year Congress directed the Army Engineers to find a way to protect the Valley. This article summarizes the work carried out by the two Army Engineer officers to whom the task was given. The method of measuring water flows is described in some detail and their first formula, arrived at after having accumulated masses of data from their measurements, and after comparison with all the useful information available from world sources, is given. There is further information on the development of other formulae. The original proposals made by two officers were not, however, put into effect because the Civil War intervened.

The main interest in the subject lies in the fact that it was the first time that all available world data were correlated and checked against the existing formulae and the new Mississippi data. This led to revised ideas on big river hydraulics which have since had world-wide application.

FIELD NOTES

"COMBAT ENGINEER VEHICLE", by Major James C. Moore, Corps of Engineers. A short account of tests made of the latest CEV at Fort Belvoir. The vehicle is a T 95 tank with a dozer blade attachment and a hydraulically operated "A" frame boom and winch attached to the turret which has a traverse of 360 degrees. The article is illustrated.

"WATER IN GUAM", by Porter E. Ward. This is a fairly full account of the geological and hydrological conditions in Guam and will be of interest to any one studying this subject. There are maps and diagrams.

"POLAR ENGINEERING", A Summary. This consists of summaries of papers read by senior officers of the US Air Force, Navy and Army Engineers at a symposium of the Society of American Military Engineers the subject of which was Polar Engineering. The Air Force paper gives interesting details of the engineering problems set by the design and construction of the Ballistic Missile Early Warning System stations in the Arctic. The Naval paper deals with the construction of permanent research stations in Antartica with some information on the nuclear power station which is already under construction. The Army paper was not included the subjects dealt with having already been described in articles in the *Military Engineer*.

"UNDER ICE CAMP IN THE ARCTIC", by Frank Russell. This is a description in considerable detail, well illustrated with photographs and diagrams, of a tunnel which is under construction in the Greenland ice-cap which will provide winter accommodation for about twenty-five men. The account gives a description of mining methods as well as constructional details and also deals with power supply, water, and sewage disposal.

"BRIDGES THROUGH THE AGES", by Captain C. J. Merdinger, Civil Engineer Corps, US Navy. Part II. New Materials and Modern Methods. This most interesting article, which is well illustrated by photographs, describes the development of bridge design and construction from timber bridges, with a single span of as much as 390 ft, to steel bridges of complex design. It provides a very clear picture of the subject and the author must have consulted a wide range of sources and authorities since his examples cover all Europe as well as the United States. A third article in the next number of the *Military Engineer* will complete the series.

SEPTEMBER–OCTOBER 1961

"From Landmarks to Satellites", by Paul D. Thomas. This article deals with the use of artificial satellites for navigational fixing. Starting with a historical resumé of the development of navigational aids and methods it goes on to give in some detail descriptions of various methods for using artificial satellites, and some indication of the progress made to date. There is a short description of the various transit satellites already in orbit, there are four referred to, with a forecast of the characteristics of the next one. It is an article of particular interest to specialists.

"Civil Defence Public Works Seminar", by Brigadier General Dwight F. Jones, US Army (retd). A summary of the subjects discussed at a seminar conducted by the California Disaster Office. Although containing nothing startlingly new, it summarizes the main factors to be considered under the heading of Civil Defence.

MILITARY ENGINEER FIELD NOTES

"Buildings in Barrels", by L. W. Shanahan and Captain S. D. Falkenberg, Jun Corps of Engineers. This is a description of the initial design and development of a building constructed of polyurethane foaming resins. The resins are delivered in barrels, hence the title of the article, and the arched buttress panels, of which the building is constructed, are moulded *in situ*. These types of building are expected to have special value in the Arctic since the transportation of the materials required for their construction does not present a great problem.

"Operation Quickway", by Captain Homer Ambrose, Corps of Engineers. This is a description, in considerable detail, of the design and construction of tank farms for the storage of fuel at several locations East of the Rhine to support full scale operations. Standard military pipeline sets and bolted steel tanks, capable of servicing tanker trucks and railroad cars, were used for the construction. All the normal safety precautions considered necessary in civilian installations were provided. There are informative illustrations.

"Short-range Electronic Positioning Equipment". The Army Engineer Geodesy, Intelligence, and Mapping Research and Development Agency, "Gimrada" is developing a lightweight positioning equipment which uses radio-hyperbolic positioning technique. It is all weather, day and night equipment and can give position measurements to any point in an area regardless of the intervening terrain conditions. This short article, with an illustration, describes the working of this equipment which will shortly be issued in experimental form for combined engineer and user tests.

"Bridges Through the Ages", by Captain C. J. Merdinger, Civil Engineer Corps, United States Navy. Part III. The Age of Steel. This is the last of three articles, the first two appeared in the May–June and July–August numbers of the *Military Engineer* respectively, and the history of bridge construction is brought up to the present day with descriptions and photographs of outstanding steel arched, cantilever and suspension bridges. There is only a brief reference to reinforced concrete construction and no pictures of reinforced concrete bridges.

"Shipyard Surface Subsidence", by Captain C. H. Plumlee, Civil Engineer Corps, US Navy. In the *Military Engineer* for November–December 1957 an article described the rapid subsidence, at a rate of one foot a year, of the naval shipyard at Long Beach due to the withdrawal of oil and gas from Wilmington oil field which lies beneath it. This article, which is illustrated, describes the measures which are being taken to check this subsidence. The plan is to repressurize the oil field by injecting sea water into selected points at increasingly rapid rates leading to a maximum of 1 million barrels a day. Work started in 1958 and there is no doubt that the remedy is being effective.

"Nuclear Power Plant for Camp Century", by Major James W. Barnett, Corps of Engineers. This is a description with essential technical detail of the nuclear power plant installed in the camp in the Arctic which has been constructed in ice tunnels and which was described in the November–December 1960 number. The plant was made up of pre-fabricated components which were assembled on site. Including the erection of plant buildings and utilities the work was completed in ten weeks. The power capacity is 1,560 kW for the camp. The design life of the UO_2 of the core is 9.2 megawatt years. The plant can be disassembled and moved to another site if required. See article "Camp Century, Greenland", page 402.

"Removal of Radio-Active Decontaminents from Water", by Don C. Lindsten, Richard P. Schmitt, and William J. Lacy. A short, detailed, and illustrated account of the equipments developed by the Corps of Engineers for water purification in the field with the special additions needed for decontamination. The account includes details of test runs carried out. The results were promising in that the necessary standard of decontamination to meet Army needs was attained. From the illustrations two of the equipments are truck-mounted. The third an electro-dialysis unit has not been mounted on a truck altough no doubt it will be eventually.

"BRIT Protection Shelters", by Neal Fitzsimmons. BRIT stands for Blast, Residual-radiation, Initial Radiation, Thermal Radiation." This article touches upon all the considerations which affect the design of shelters intended to give protection against nuclear radiation. It does not include any information on structural design details designed to withstand blast.

Army Engineer School Notes

"Sewage Lagoons". An article in the January–February number described a method of sewage disposal using oxydization ponds and it was claimed that this method had the great advantage of requiring much less construction work than conventional systems. This short note amplifies the information given before and records that the method has the support of the Engineer School. J.S.W.S.

ENGINEERING JOURNAL OF CANADA

Notes from *The Engineering Journal of Canada*, June 1961

THE YARD OR THE METRE—WHICH?: The April issue of *The Engineering Journal* included a paper entitled "The crisis in measurement" (see *RE Journal*, September 1961), sponsoring the universal acceptance of the metric system. The present paper is a report of a panel discussion, which deals not so much with the relative merits of the two systems of measurement as with the practical and economic effects of change on industry and marketing. Interesting points are made by a number of speakers, but no firm conclusion is apparent, except perhaps that there is no "crisis" in measurement.

AN EVALUATION OF PLYWOODS AND PLASTICS IN BOAT CONSTRUCTION: Few Sappers can afford to be entirely disinterested in boat construction, and to many the subject is absorbing. The new materials now being used, to an increasing extent, in the building of hulls up to 100 ft in length are here discussed in terms of their advantages and limitations, and of the techniques developed in their application. It may surprise many to learn that the life of a well-built plywood hull may equal that of solid wood, metal, or plastic hulls.

TRANSPORTATION OF SOLIDS IN CONDUITS: The economic advantages of pipeline delivery of liquids may also be applicable to the hydraulic transport of solids, especially in the case of finely ground materials. This paper gives a number of interesting examples of industrial applications, ranging from a 180-metre vertical lift of coal to the long distance pipeline transport of ground limestone. Theoretical, practical, and economic considerations are discussed.

The other three papers in this issue are primarily of specialist or academic interest. The titles are "A new facility for measuring radiation patterns of model shipborne antennas," "Principles of non-linear automatic control", and "Some problems encountered in underwater sound research."

Notes from *The Engineering Journal of Canada*, July 1961

DESIGN OF THE SUPERSTRUCTURE OF THE PORT MANN BRIDGE: The design of the Port Mann bridge, now under construction across the Fraser River, incorporates some unusual features, and this comprehensive and clearly written paper describes the methods of calculation adopted, and includes interesting and practical constructional details. The total length of the structure is 6,780 ft, and the horizontal alignment forms a flat S-curve, with the main bridge span and side spans straight, between curved approaches carried on plate girder spans. Both horizontal and vertical curves are based on a maximum safe speed of 60 mph.

The main span bridge is a stiffened tied arch 1,200 ft long, flanked by side spans of 360 ft length, forming a continuous structure 1,920 ft long. The bridge carries a four-lane roadway, with 4 ft sidewalks on either side, the total clear width being 64 ft. The vertical clearance under the main span is about 146 ft above high water level, to allow the passage of ocean-going vessels. For the main structure, the conventional concrete deck is replaced by a stiffened steel deck, with a 2-in bituminous surfacing, and the deck is also used as part of the main girders. This type of construction achieves a considerable saving in weight, a most important factor in a long span, the dead load of which absorbs the greater part of the load carrying capacity.

In the selection of the final design, soil conditions at the site were a prime consideration. The author's brief survey of the influence of this factor is particularly interesting.

REARWARD COMMUNICATIONS FOR BMEWS: The Ballistic Missile Early Warning System supplements aircraft detection systems in North America, and is designed to give approximately fifteen minutes warning of an attack by Inter Continental Ballistic Missiles. The three essentials for the communication system between forward detection sites and the operations centre are reliability, fidelity, and practically instantaneous transmission and delivery. Much of this paper is necessarily technical, but it contains a great deal that is of general interest, and that explains why the system is regarded as one of the deterrents against war. It is also easier to read than the type of security document in which one might expect to find some of the information given.

SIDE TIPPING LOG BARGES: This account of the development and characteristics of side tipping barges for the open water transportation of logs, and for their time- and labour-saving discharge, is of some general interest, and it exemplifies the unusual type of problem which engineers are sometimes expected to solve.

Notes from *The Engineering Journal of Canada*, August 1961

THE N.A.E. FIVE FOOT SUPERSONIC WIND TUNNEL: This is an interesting description of a large "blowdown" wind tunnel, designed for model testing throughout the speed range from Mach 0.2 to Mach 4.5. The installation provides short runs of about 20 seconds, with a nominal period of 20 minutes between runs, for the re-accumulation of compressed air and setting-up. The size of the installation, and the complexity of its design, go some way towards explaining the vast cost of modern engineering research.

THE NEED FOR RESEARCH IN PLANNING MECHANIZATION: Mechanization is here defined as embracing both automation and the installation of improved machines. The author makes a logical appeal for the use of analytical research on a national or industry-wide basis, and he cites several convincing examples of erroneous decisions made through the inadequate appraisal of conflicting factors.

THE HYDRAULICS OF THE PIPELINE FLOW OF SOLID-LIQUID MIXTURES: For those interested in the paper on "*Transportation of solids in conduits*" (issue of June 1961), this technical discussion will be of value. The behaviour of "settling" and "non-settling" liquid-solid mixtures is markedly different, and the two types are here dealt with separately. Pressure gradients may be determined with reasonable accuracy from the appropriate equations in either case, provided that the solid size distribution is not unduly wide.

ELECTRONIC AIDS IN CANADIAN MAPPING: The system known as "Shoran" (short range navigation) was described in *The Engineering Journal* for March 1955 (see *RE Journal*, September 1955). It is a radar transponder system which has been extensively used, especially during the period 1952–8, for measuring distances between points on the ground, and for the control of aerial photographic survey of large areas.

Three more recent developments, now in use for land survey, are:—

(*a*) *Airborne profile recorder*. This is a radar-type device which, by making a virtually continuous record of the vertical distance from an aircraft to the ground, produces a profile of ground elevations.

(*b*) *Tellurometer*. This is a portable instrument designed for the accurate measurement of distance between two points, by means of an exchange of modulated microwave signals. Though the system is technically complicated, it has been found simple and reliable in use. It is best suited to measurements in the range from 2 to 30 miles, and it has been extensively used to establish ground control points for aerial photography.

(*c*) *Geodimeter*. This instrument is remarkably accurate, and it has been used for the measurement of base lines instead of the invar tape. It depends upon the transmission and reflection of a modulated light beam, and has the disadvantage that it can only be used on clear, dark nights.

Brief descriptions are also given of the two range Decca, and the Microwave position fixing system, both of which are primarily applicable to hydrographic work, and mention is made of several other electronic devices which bid fair to simplify and speed up photogrammetry.

R.P.A.D.L.