THE ROYAL ENGINEERS JOURNAL—DECEMBER 1963 VOL LXXVII No 4

THE ROYAL ENGINEERS JOURNAL

Vol LXXVII DECEMBER 1963 No 4

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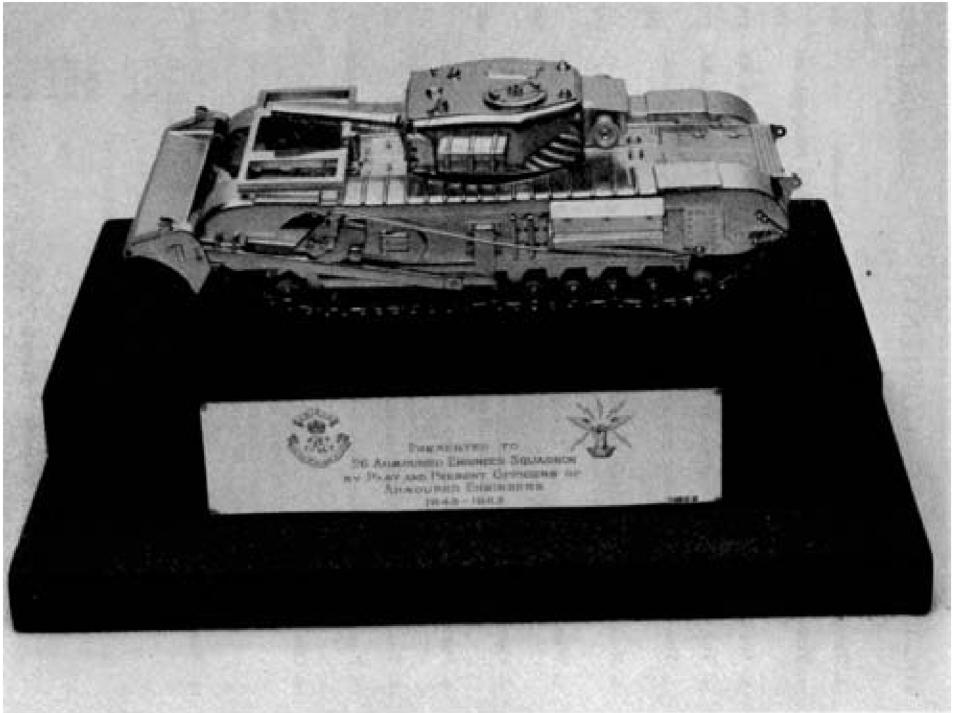


By kind permission of Garrards & Co. Ltd., London, W.1

The Silver Avre 1

The Silver Avre

By Major G. L. Cooper, MC, RE

Just as Peter Holdsworth, my predecessor in 26 Armoured Engineer Squadron was leaving, he mentioned, almost as an afterthought, that he had commissioned Garrards to make a silver model of a Churchill AVRE for the Officers Mess. The Corps Committee had made a grant of £200 towards it, but the estimate was approximately £400. I would have to find the balance!

I quickly put the thought out of my head, but some three months later I was in England for a conference so I looked in on Garrards to see what I had inherited. The model was almost complete and had been made from drawings and photographs sent from the Squadron. Inevitably there were a few errors, such as what looked like a long-barrelled six pounder gun instead of our stubby, and infinitely more lethal, 6.5 in gun. These minor corrections were soon made and the finished product is now perfect in every detail. Even the expert "tankies" in the Squadron cannot find fault with it, a tribute to the care and workmanship of Garrards' craftsmen.

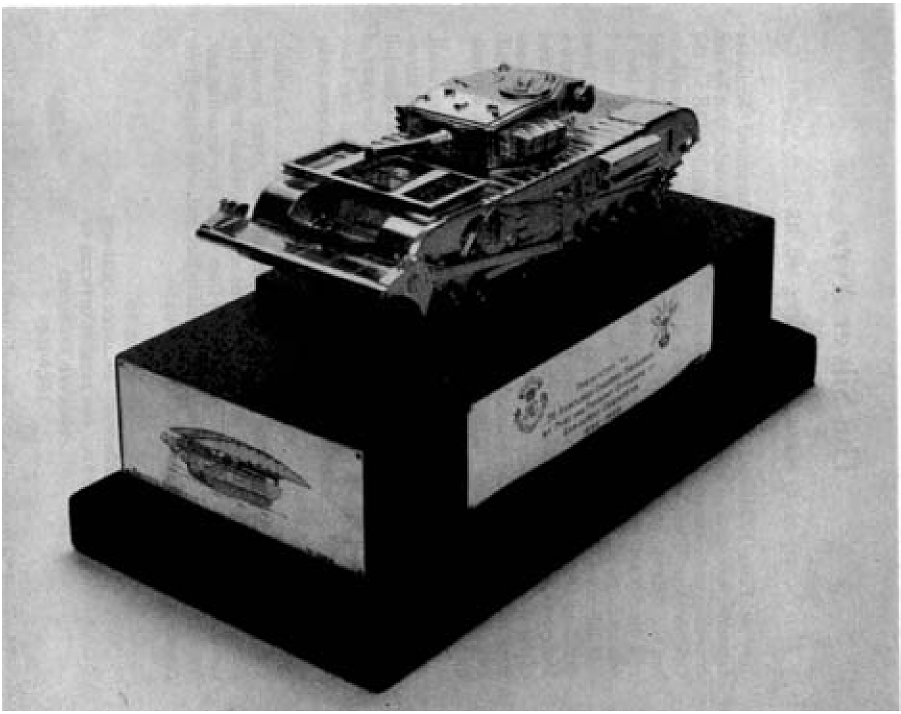
Considering the size of the estimate, the centrepiece appears small, 8 × 6 in, but, in conjunction with the silversmiths, we designed an attractive plinth to set it off, with engravings on three sides, of the Churchill Bridgelayer, Flail and Ark. We also inscribed beneath each one the name of the equipment for the benefit of future generations of YOs, who may have never heard of the Churchill tank, let alone what will doubtless seem to be our extraordinary adaptations of them!

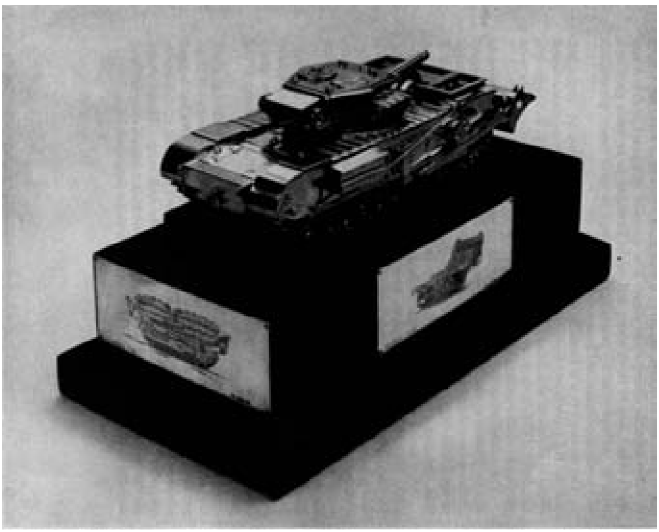
Now came the problem of what to inscribe on the fourth side of the plinth. I was only too well aware that here was the centrepiece and, apart from the Corps Committee's grant, I had no other money with which to pay the inevitable bill. We certainly could not pay it from within the Squadron but, having got this far, I thought I had better trust to luck and, with fingers firmly crossed, told Garrards to inscribe it as follows:—

PRESENTED TO
26 ARMOURED ENGINEER SQUADRON
BY PAST AND PRESENT OFFICERS OF
ARMOURED ENGINEERS
1943–1963

The word "Armoured" was purposely used in combination with the dates 1943–1963 in order to keep the inscription brief—it is hoped that no offence is taken by "Assault" Engineers!

On either side of the inscription were engraved the Corps Cipher and the Squadron crest. I then wrote to all those officers and ex-officers who had served in Assault or Armoured Engineers and invited them to contribute.





The Silver Avre 2 & 3

Despite the fact that my letter was unashamedly a begging one and that the centrepiece was already *fait accompli* (something which would certainly have irritated me!) they responded most generously. Not knowing whether we would get more, or less, than our target, officers were invited to subscribe to a Squadron Silver Fund: any surplus, which could hardly be paid back to subscribers as a dividend, would go towards the purchase of silver candelabra or other suitable dining-room silver. The question of a possible deficit was one I didn't like to think about and might have had to be made good by a raffle or perhaps even by pawning the centrepiece until future generations of Squadron officers could have redeemed it!

The centrepiece was formally dined in on St George's Day, 23 April 1963, and the RE (Aldershot) Band was present to play at a very enjoyable Guest Night in Hohne at which the Chief Engineer, Major-General J. K. Shepheard, CB, DSO, OBE, and many other ex-Assault or Armoured Engineers were present from all over BAOR.

The subscription list soon began to fill up and a notice was inserted in the *Supplement* to the *Journal* so as to reach all those officers whose whereabouts were unknown or who had inadvertently been left off the distribution of the initial begging letter. Vauxhall Motors, the makers of the Churchill tank, also sent a very generous donation and the centrepiece is now paid for.

After seeing the centrepiece, I wrote to Garrards and suggested that they might like to use its photograph in their advertisements. I pointed out that I, for one, was tired of seeing their advertisement in the *Journal* depicting such things as a statuette of a British Grenadier. They responded magnificently; so much so, that on opening a copy of the *Royal Artillery Journal* one saw the Silver AVRE displayed on the first page, and on page iii of the September issue of the *RE Journal*.

We, in the Squadron, are delighted that we have been able to commemorate the Churchill tank in such an appropriate manner. It would never have been possible though, without the very generous help given by so many people who have been connected with Assault or Armoured Engineers in the past. We are most grateful to all of them.

As a postscript it may be of interest to many to know that the old Churchill tank like its famous namesake, is still going strong, and that a number of them are likely to be with the Squadron for some time yet. They have had a good innings of twenty years, not out, and there is many a sad heart as each one is earmarked for disposal as a "hard target" for the tank ranges. However, we are determined that the last AVRE will not meet such a humiliating fate and we hope to keep it and mount it at the entrance to our Squadron lines.

The Portraits and silver of the RE HQ mess

Tunnelling in Gibraltar

By Major J. G. Lauder, RE

Introduction

The present day tasks of the Corps are many and diverse. The construction of heavy equipment bridges and the operation of ferries, demolition work and the construction of roads and airfields are amongst the more glamorous of our wartime duties. It would be wrong to forget, however, that the art of burrowing through the ground was once one of our major roles in war. Indeed the trade in question is largely responsible for the very name by which we are popularly known, and which we ourselves so frequently use when referring to our Corps.

Although the driving of saps is no longer a feature of modern military engineering, tunnelling is a skill which is by no means lost to the Corps. In Gibraltar the work of the Tunnelling Troop of 1st Fortress Squadron RE continues, and the most modern tunnelling techniques are employed. It is by no means inconceivable that in a nuclear war tunnelling may assume a revived military significance.

Brief History

At the Battle of Blenheim, Marlborough shattered the military might of France. That, however, was not the only gain, it enabled an expedition to be sent to the Mediterranean which in 1704 captured Gibraltar from the Spaniards. Extensive work was immediately put in hand to turn the Rock into a fortress capable of withstanding any counter-attack.

These defences were constructed by civilian labour, obtained from England and the Continent, working under officers of the Corps of Engineers. The labour force proved to be most unsatisfactory and eventually the then Chief Engineer of Gibraltar, Lieut-Colonel William Green, recommended its replacement by soldiers subject to military discipline. As a result a Warrant, dated 6 March 1772, authorized the raising at Gibraltar of a Military Company of Artificers which was almost immediately renamed the Soldier Artificer Company. The Company was gradually increased in size and a second Company was formed in 1786. Officers for these companies were found from the Corps of Engineers. The present 1 Fortress Squadron RE, serving at Gibraltar, can trace its descent from the original Soldier Artificer Company, and the present 2 Field Squadron RE is descended from the second Company of Soldier Artificers.

The Soldier Artificer Companies retained their separate identity until they were absorbed into the other ranks Corps of Royal Military Artificers, raised by Royal Warrant dated 25 April 1787, for service at home and at certain overseas garrisons. In 1812 their title was changed to the Corps of Royal Sappers and Miners which in 1856 was incorporated into the officer Corps of Royal Engineers, thus ending the long-standing anomaly of engineer officers and men belonging to separate Corps of the Army.

Gibraltar was the birthplace of the other rank element of the Corps and it also saw the birth of the Corps' tunnelling activities.

The first Company of Soldier Artificers were to receive their baptism of fire during the Great Siege of Gibraltar 1779–83. On the revolt of the British

North American Colonies, France, Spain and Holland declared war against England and Spanish troops besieged Gibraltar. Colonel Green, who raised the Soldier Artificers, was still the Chief Engineer and General Elliott, who had also served in the Corps of Engineers, was the Governor and Commander-in-Chief. During the earlier stages of the siege a successful sortie was made by the garrison. A Company of Soldier Artificers, supported by a body of infantry and sailors, penetrated four lines of the Spanish trenches, destroyed a vast quantity of equipment and spiked many guns. As the siege progressed, however, the Spanish guns caused considerable damage to our fortifications but repairs were completed in every case by the Soldier Artificers, often under heavy fire. The Galleries, a notable feature of the Rock, were excavated during the siege in order to obtain flanking fire on the Spanish lines. Sergeant Major Ince, of the Soldier Artificers, suggested their employment and supervised their construction.

The story goes that General Elliott (later Lord Heathfield) and Colonel Green were one day in May 1782 ruefully surveying the great havoc caused by the enemy's fire, and the General is reported to have said "I'll give a thousand dollars to anyone who can suggest how I am to get flanking fire upon the enemy's works." Sergeant Major Ince, who was in attendance upon the Chief Engineer, suggested the idea of forming galleries in the rock to achieve the desired object. The delighted General ordered the work to start forthwith. It appears that Sergeant Major Ince never received the thousand dollars, but he was given a farm on the Upper Rock which bears his name to this day. The "Galleries" excavated were 6 ft 6 in high by 6 ft wide. By 15 July the first embrasure was opened in the face of the Rock and the Gallery widened to admit the emplacement of a 24-pounder gun with sufficient room for its recoil. By September five more heavy guns had been placed in the ever extending Gallery. Excavations were later extended into a notch on the north face of the Rock where a complete battery of guns was established, now known as "St George's Hall". It was an outstanding tunnelling achievement performed without special mining survey instruments or any mechanical aids whatsoever by men debilitated by the privations of almost four years of siege.

Tunnelling in Gibraltar continued slowly and intermittently thereafter. The ensuing years saw the north front system extended and new complexes started in other parts of the Rock, but by the beginning of the Second World War only about five miles of tunnel had been driven.

The possibility during the Second World War of a German bid to capture Gibraltar in an effort to seal off the Straights to allied shipping resulted in a frenzy of tunnelling activity. Existing complexes were extended and many new ones started. At the height of this activity there were no less than three tunnelling companies and a section of Canadian tunnellers (roughly equivalent to a troop) working on the Rock. In addition to this a garrison of 30,000 troops was able to supply a supplementary unskilled labour force whenever one was required.

By the end of the war five miles of tunnels had been increased to over twenty-five. Thus in terms of linear measurement alone four short years had seen an increase over the previous 164 years' work in the ratio of four to one. In terms of cubic yards the ratio is probably much larger for many of the chambers excavated during the Second World War were of considerable size.

A point worth noting is that much of the spoil from tunnels driven during the latter half of the war was used in the reclamation of land for the extension of the RAF runway. This project was of great tactical significance because the threat to Malta at that time made it imperative to route aircraft direct to Egypt without using Malta's airfield. Gibraltar was the other available staging post, but with a runway only 900 yards long. Completion of the work saw a wider and much safer runway, twice the original length, and able to land the heaviest aircraft then in service. Without the tunnel spoil this work could not have been carried out.

Towards the end of the war a rundown of the tunnelling potential on the Rock began, and in 1945 only 173 Tunnelling Company remained to complete the outstanding tasks. This unit was in turn rundown to troop strength, and the Tunnelling Troop of 1st Fortress Squadron is the proud descendant.

With a few exceptions the work of the troop since that time has been concentrated mainly on the maintenance of existing systems and minor training tasks carried out with the object of maintaining trade skill. Extensions to Calpe Hole to accommodate the new Military Power Station, and the Episkopi Tunnel driven in Cyprus in 1955 are two of the more notable exceptions.

The Episkopi Tunnel was driven for semi-operational reasons and was completed and lined in a very short time despite the extremely difficult rock conditions. Thus the troop demonstrated its ability to "upsticks" and carry out an important project far from its base in Gibraltar.

The New Military Town Plan

In the late 1950s plans were made for the construction of a new "Military Town" at the south end of the Rock. The plan envisaged the construction of new barracks, married quarters, a drill square and other installations on a scale sufficient to enable the garrison to concentrate in one place, so leaving the town of Gibraltar free for civilian accommodation. At that time, however, the only practicable route between Gibraltar Town and Europa, where the military town was to be built, was along the Europa Road—a narrow tortuous route with varying gradients and many constrictions. The new scheme made the provision of a better means of communication between Gibraltar and Europa essential, and a pair of tunnels driven through the high ground between these two places was planned to provide it. (See fig 1). Advantages incidental to the main purpose of these tunnels were that (*a*) they would provide a route for the contractors lorries during the construction of the town and (*b*) they would open up an attractive, but previously almost inaccessible area at Little Bay.

It was decided at the outset that the tunnels should be 26 ft wide to provide easy passing for 3-ton trucks. This in itself is an innovation in Gibraltar where all previously driven vehicular tunnels are only 12–14 ft wide and rely on passing places to maintain the flow of traffic. This large size combined with a rather awkward gradient in one of the tunnels presented problems that will be discussed as the story of the work is told.

Little Bay—Europa (Keightley's Way) Pilot Heading

Work began on the longer of the two tunnels from Little Bay to Europa in April of 1960. The preliminary survey was carried out by the troop surveyor while the rest of the troop concentrated on site organization: that vitally important aspect of all engineering tasks.

Little Bay was the obvious site for a troop headquarters since the tunnel was to be driven from that end. Heavy stores were stacked in the most convenient positions whilst spare parts for the machinery were racked and binned by the troop storeman. Troop headquarters, offices, mess room (snap cabin to the tunneller) electric light, telephones, fitters shops and dozens of other administrative points were attended to so that work could continue "round the clock" on a three 8-hr shift basis.

One of the big tasks at this stage was the erection of the compressor house. This installation is the heart of any tunnelling project and no pains were spared to see that the compressors got a good home. Six 315 cfm compressors were installed each one coupled through a stop cock to the air main and linked to a common pilot valve so that all loaded and unloaded simultaneously. We took a lot of trouble over the compressor house and we never regretted it. The planning estimate of the maximum load on the compressor house was 1,000 cu ft of free air per min, but as the project progressed it was found that a well organized shift used considerably more than this during the mucking-out phase.

Work started on the open cut with a combined Plant Troop–Tunnelling Troop operation. "Breaking in" is always a difficult process for it is rare that tunnellers are presented with a nice flat vertical, or near vertical, bare rock face in which to establish a portal. Generally a considerable quantity of overburden has to be removed before a sloping rock line is uncovered. This then has to be drilled and blasted in order to provide a vertical face of sufficient depth to enable the arch of the portal to stand firm. Blasting in open cut is always a tricky business in Gibraltar, for there is practically no place on the Rock that cannot be reached by a hail of stones if the charges are too heavy or the holes incorrectly drilled. Firing times are generally restricted and safety precautions must be stringently applied. Tunnellers loath these restricted firing times for they like to fire as soon as they are ready and get on with the job!

The basic technique used in hard rock tunnelling is probably well known to most Sapper officers, and it was in any case the subject of an article in RETM No 34 dated February 1959. Briefly, however, the procedure follows a regular sequence of operations, the first being the drilling of a number of holes in the rock face. This is done to a pattern which varies according to the nature of the rock and size of heading. These are then charged (stemmed up) and fired electrically using gasless delay detonators. The detonators are arranged so that the centre of the face, known as the "cut", fires first to create a void into which the remaining holes can successively fire their share of the burden. The rock is thus broken by easy stages starting at the centre and working outwards. After the round has been fired the broken rock is dug from the muck pile using, in Gibraltar, compressed air operated "Eimco" shovel loaders. These load into Decauville wagons (the tunnellers call them "skips",) which are then towed out of the tunnel by diesel locomotives running on Decauville rails, and emptied over the spoil tip.

On Keightley's Way tunnel we finally established a portal by mid June of 1960 and commenced driving a 14 × 14 ft pilot heading. Progress, however, was painfully slow for we had, of necessity, established the portal on faulted ground. The fault was filled with a mixture of clay, conglomerate and friable rock which was extremely difficult to drill and blast. In this type of ground, and there is much of it in Gibraltar, the tunneller is handicapped because he is working in neither one medium nor the other. Rock drills tend to jam in this type of ground and the air vents in the bits become blocked and cease to function. Machinery specifically for use in soft ground would be useless because of the considerable percentage of embedded hard rock. Furthermore, the clay is far too tightly packed and contains too much hard matter to be extracted using picks or light pneumatic tools even if such a tedious operation were practicable. In conglomerate and friable rock the work is still more difficult, for when a hole has at last been drilled the chances are that either the drill steel cannot be withdrawn because of loose material jammed behind the head of the bit, or, if it is ultimately withdrawn, the hole will then collapse and make it impossible to insert the charges. Indeed there can be few more exasperating places than Gibraltar to carry out hard rock tunnelling. However, the fault was eventually negotiated, and in August 1960 we broke through into good ground.

The way now seemed clear for a reasonable rate of progress, but we were to be disappointed. The gradient in the tunnel was 1 : 15 and outside on the spoil tip was 1 : 11 to form the access ramp to the portal (see fig 1). The wheels of the locomotives hauling the full skips would barely hold on the 1 : 15 gradient inside the tunnel, but they could certainly not be relied upon to bite on the 1 : 11 grade outside. In the first fortnights' work there were three occasions when a locomotive with brakes hard on and wheels locked had careered over the end of the spoil tip. Fortunately our locomotives are very rugged and on each of the three occasions we simply carried it back up to the portal and it began work again. Clearly, however, this could not go on and it became necessary to find some other method of hauling the spoil from the tunnel. Various methods of lowering the skips by winching were tried, but the eventual rather crude solution is depicted in fig 2. Briefly, the skips are loaded by the Eimcos in the usual way and then individually trammed back down the gradient as far as the ramp (or "Chinaman") by the simple expedient of jamming a 2 × 2 in timber between the wheels and a chassis member and pressing or releasing as required.[1] At the ' Chinaman" the skips were shackled to the winch cable and pulled up to the top of the ramp where they were emptied into dumpers supplied by Plant Troop. The dumpers, being rubber wheeled, naturally had no difficulty in carrying the spoil on the gradient which had so easily foiled the locomotives. Fig 2 shows the whole scheme including a "Lay on diamond crossover" which we made specially for the task. This equipment enables the skips to be "switched" so that the full ones can be removed from behind the Eimcos and replaced with empty ones. The speed of mucking out depends to a very large extent on how quickly this can be done, for the Eimco types 12B and 21 used in Gibraltar have no hopper or other storage capacity and, therefore, cannot continue to work whilst the skips are being changed. The crossover is constructed with ramps at its ends so that it can lay on the main rails and slide forward as the heading progresses.

There were two major snags in the method of work depicted in fig 2. One was that double handling of the spoil was involved with consequent waste of time and manpower. The other was that as the heading went forward so the distance between the face and the Chinaman grew and it became increasingly difficult to pass the skips up and down the tunnel. The Chinaman was of necessity heavy and solidly located in the tunnel, so it could not easily be

[1] A loaded skip weighs 1½ tons.

moved to keep pace with the work. It was, in fact, dismantled and rebuilt once during the driving of the pilot heading. However if the dumpers could have been loaded direct from the Eimco loaders at the face instead of from the Chinaman the problem would have been solved. This unfortunately was not possible because the loading height of the Eimco 21 is insufficient to enable the spoil to be placed in the 4½ cu yd Aveling Barford dumper.

Despite our difficulties the break out of the 14-ft pilot heading at Europa was achieved in July 1961, a little more than one year from the date of the break in at Little Bay; the Deputy Fortress Commander, Brigadier C. G. Buttenshaw, DSO, OBE did us the honour of personally firing the final round.

For 1,320 ft of 14 ft heading this is very slow going; but normal military commitments must be fulfilled, and out of the thirteen months taken to complete the job only about fifty weeks were spent actually tunnelling. This gives an average advance of 26.4 ft per 4½ day week which, though still not good, represents a fair figure bearing in mind the difficulties already described. The worst week gave an advance of under 6 ft (while still in the clay fault) and the best week yielded 60 ft which in terms of cubic yards excavated just betters the only recorded Gibraltar record.[1]

Thus the first stage of the work was complete. The second stage was to enlarge the tunnel to make it suitable for two way traffic. However before embarking on a description of the methods employed to do this it is best to summarize the haulage difficulties encountered in driving the pilot heading, because the experience gained in this aspect of the first stage of the work led directly to the adoption of an entirely different technique in the second.

The difficulties are summarized as follows:—

(*a*) The extreme gradient on which we had to work made the use of our rail-mounted machinery both difficult and dangerous.

(*b*) Shortage of manpower to operate a system involving a double handling.

(*c*) Difficulty with Decauville rails and Decauville skips neither of which are heavy enough for tunnelling purposes.[2]

Keightley's Way: Slashing to Full Size—The Spoil Elevator

We were now faced with the enlargement project—a task involving the excavation of at least one and a half times the quantity of rock already extracted. (Fig 3 (*a*) shows the relative size of pilot and finished tunnel.) The pilot heading had yielded about 8,000 cu yds solid, or nearly 12,000 cu yds bulked: thus a further 20,000 cu yds of spoil still had to be handled. No special problem existed from the point of view of drilling and blasting, for it is comparatively easy to do this in rock where a preliminary excavation has already been made. However digging, loading and hauling such a quantity of spoil from the tunnel using Decauville equipment, winches and cables, or any method involving a double handling scheme similar to that used in the pilot heading, was unthinkable. There was also the additional difficulty that we should be working in a 26 ft wide tunnel necessitating the use of three Eimco loaders to sweep the extra width. The accompanying "skip switching"

[1] 180 ft in one week in an 8-ft heading during the Second World War.

[2] Over £700 worth of tracking alone were rendered unserviceable in driving the pilot heading, and all the skips required rebuilding and reinforcing before they were strong enough to stand up to the work.

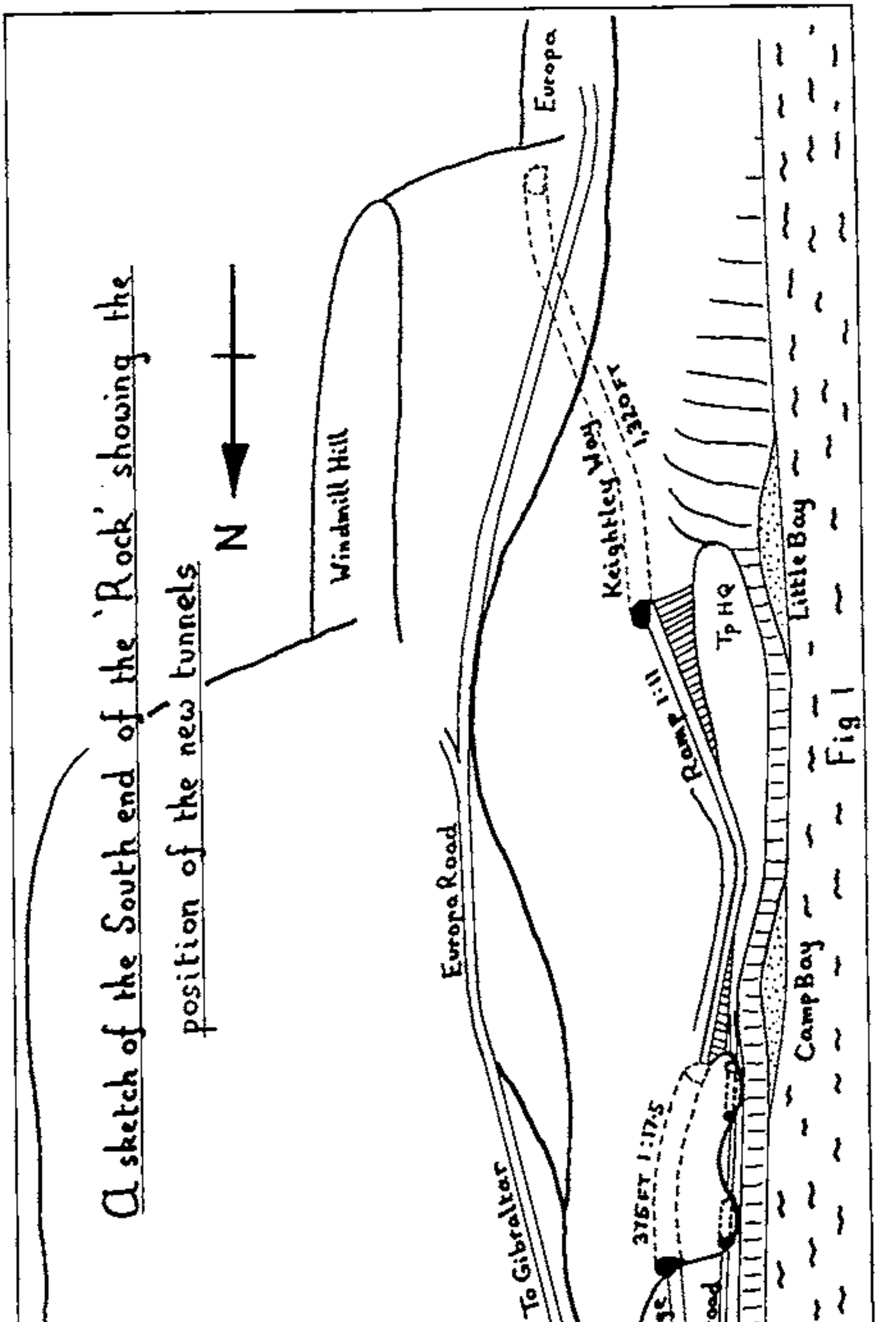

A sketch of the South end of the 'Rock' showing the
position of the new tunnels
N
Windmill Hill
Europa
Keightley Way
1,320 FT
Tp HQ
Ramp 1:11
Little Bay
Camp Bay
Europa Road
To Gibraltar
375 FT 1:17.5
Lower N. Gorge
Existing road

Fig 1

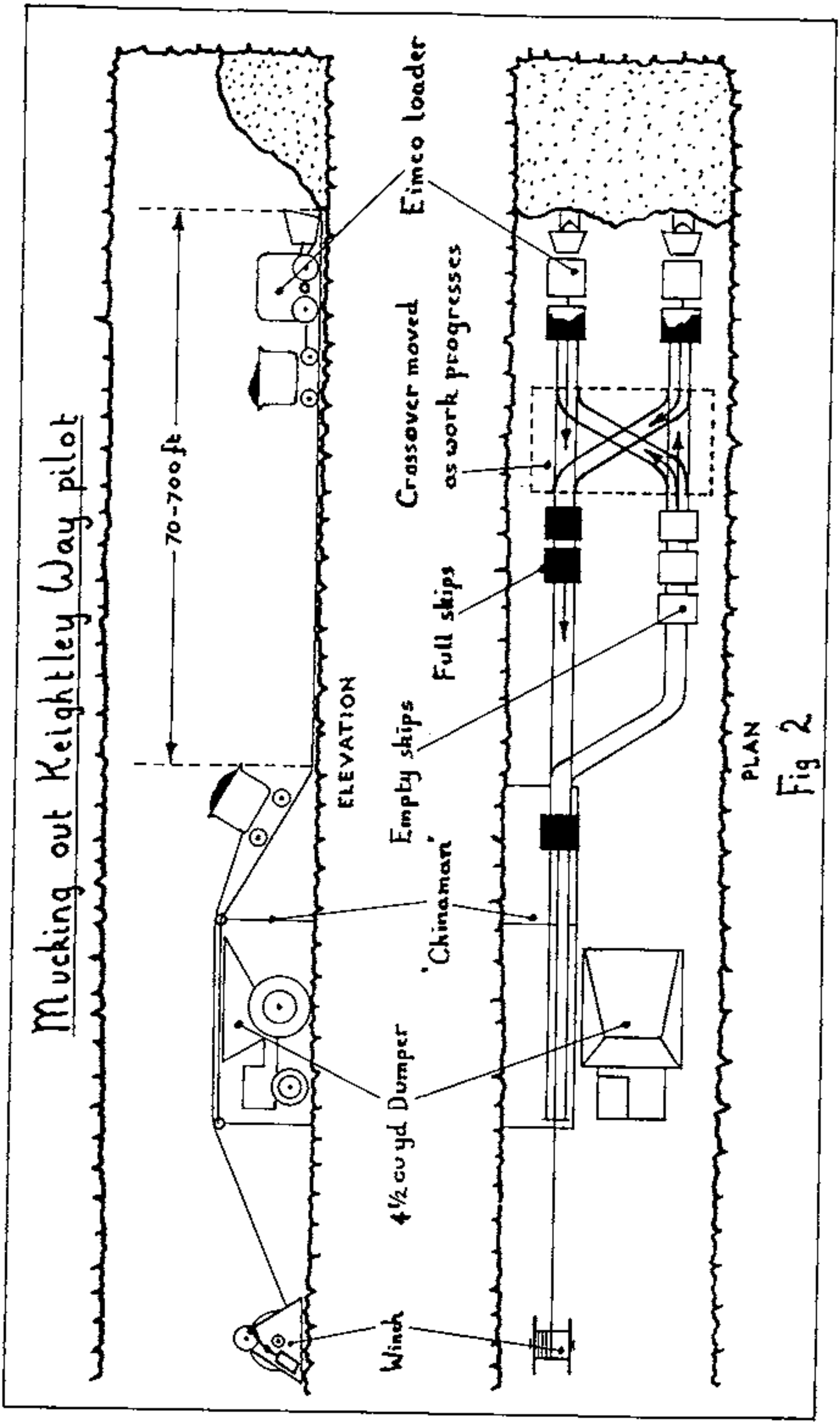

Mucking out Keightley Way pilot
70-700 ft
Eimco loader
Crossover moved as work progresses
Full skips
Empty skips
'Chinaman'
4½ cu yd Dumper
Winch
ELEVATION
PLAN

Fig 2

problem would have been considerable and one visualized a rail layout in rear of the Eimcos strongly resembling Clapham Junction. Furthermore the labour commitment would have been quite outside the tunnelling troop resources.

It was felt that a more direct method of loading and hauling the spoil was needed, and one that, as far as possible, would eliminate the use of rails. The correct answer would have been to use a form of "trackless mining". This is a system in which neither the loading machine nor the transport which it loads runs on rails. Such a method is obviously flexible, can work on any reasonable width and gradient, and cuts down the manpower required. However although we possessed the transport in the form of 4½ cu yd dumpers we did not possess the loading machines.

The problem was solved by building a mobile spoil elevator which could be filled by the three Eimco shovels working abreast. When fully laden it lifted the spoil high enough to deposit it in Aveling Barford dumpers waiting underneath. This machine thus bridged the gap between the loading height of our rail mounted Eimco shovels and the height of the lip of the dumper bucket. It was in effect a mobile "Chinaman" (See fig 4).

The machine consists of a 20 ft wide skip mounted on flanged wheels resting on a ramp. When full the skip is winched to the top of the ramp, at which point the leading wheels engage in notches. The continuing pull of the winch then tips the skip over a hopper which guides the spoil into two Aveling Barford dumpers underneath. The skip, ramp, winch and hopper are built into one unit mounted on cast iron rollers running on short specially made lengths of track. When the distance from the muckpile to the skip reaches between 30 and 35 ft, the machine is jacked on to its tracks and rolled forward to a new position, either by towing with the Eimco loaders or by pushing with a dozer from behind.

The design of the machine although basically simple was in fact not easy, for both money and time were short, and workshop facilities limited. The shortage of money meant, for instance, that as far as possible scrap material would have to be used. The other tunnel systems on the Rock were scoured for scrap steel and much useful material was collected and stacked at Little Bay. The design of the main structure was then decided mainly by the available RSJs. Fitting them together 'on paper' so that they formed a framework of the required size and shape, yet each member possessing the necessary resistance to shear and bending was quite a jigsaw puzzle.

The machine was built in the M and E Workshops of the CWO Gibraltar, and the interest taken and the enthusiasm with which they carried out the task were tremendous. Five months were spent on construction and erection in the workshops and it was then dismantled and transported piecemeal to the tunnel where it was re-erected by the tunnellers. This period although fraught with anxiety for the Troop Commander had its lighter moments. To begin with the comparatively large proportions of the machine prompted one tunneller to nickname it "The Monster" and from then on all the tunnellers invariably referred to it by that name. Even students on trade upgrading classes when asked in examination to write down the names of machines used for handling tunnel spoil would include the "Monster" in their answer. This, although gratifying, did not automatically earn them a pass mark!

There was an interesting cross section of opinion in the troop as to the value of the machine. This ranged from the dismal jimmies who considered that the whole thing was simply a waste of time to those few innocent optimists who imagined that tunnelling would henceforth be merely a matter of pushing a button.

Drilling the Slash

Fig 5 shows how work progressed on the over all project. It will be seen from this that the pilot heading broke out in July 1961 and that this event was followed by the cessation of work for one month while the troop carried out guard duties with the rest of the Squadron. It was at that stage that the decision was made to introduce the novel method of spoil extraction described above. The design and construction of the spoil elevating machine was obviously going to take several months and we were faced with the problem of how to carry out some useful work in the meantime. It was decided, therefore, to attempt all the drilling and blasting for the enlargement of the tunnel in one operation and leave the spoil in situ to be mucked out in a second operation when the new machine was ready. This idea had the advantage that it constituted a mass production technique which, it was hoped, would in itself save considerable time. On the other hand there was a further problem to be solved before the technique could be finally adopted. Any attempt to drill the finished profile of the tunnel in one operation would have been out of the question as the resultant spoil from each round would have made the lower part of the face inaccessible for subsequent drilling of the next. This difficulty was overcome by working three faces simultaneously in echelon (see fig 3) starting with the bottom right (*b*) following with the bottom left (*c*) and finishing with the top (*d*). Thus the amount of hand digging required to get the lower holes in was reduced to the minimum, although a little was generally necessary to get the lowest holes (lifters) in on the bottom left. This method proved completely successful and the entire job was drilled and blasted to finished size in five months without removing any spoil from the tunnel. There were, however, two disadvantages. The first was that it was not easy to get a clean shape and finish on the sides of the tunnel because of the difficulty of locating the top face accurately with the lower portion which, although drilled and fired, was now submerged in spoil and therefore quite invisible. The second was that the nature of the work tended to have an adverse effect on the morale of the troop. Despite careful explanation the tunnellers could not but feel that they were simply filling up a perfectly good tunnel with spoil. Also, as can be seen from the photographs, the muckpile rose to a considerable height and in places came so near to the roof that it was necessary to crawl on hands and knees to get through. To begin with there was little difficulty, but after the first few months when the distance to the face had grown it became a real hardship. It was difficult enough to do the journey empty handed, but carrying a rock drill or a 50 lb case of explosive was quite a feat of endurance. It was noticeable at this stage that the number of visits from casual spectators gradually dwindled to zero. Everyone admired the tunnellers, but few would have changed places with them at that time.

Despite these difficulties the troop carried out its task with singular fortitude and determination, and on the whole their spirits remained high. Nevertheless we were all extremely relieved when, in February 1962, the final round in the slash was fired at the Europa end and we were able to go back to Little Bay and start digging out the spoil.

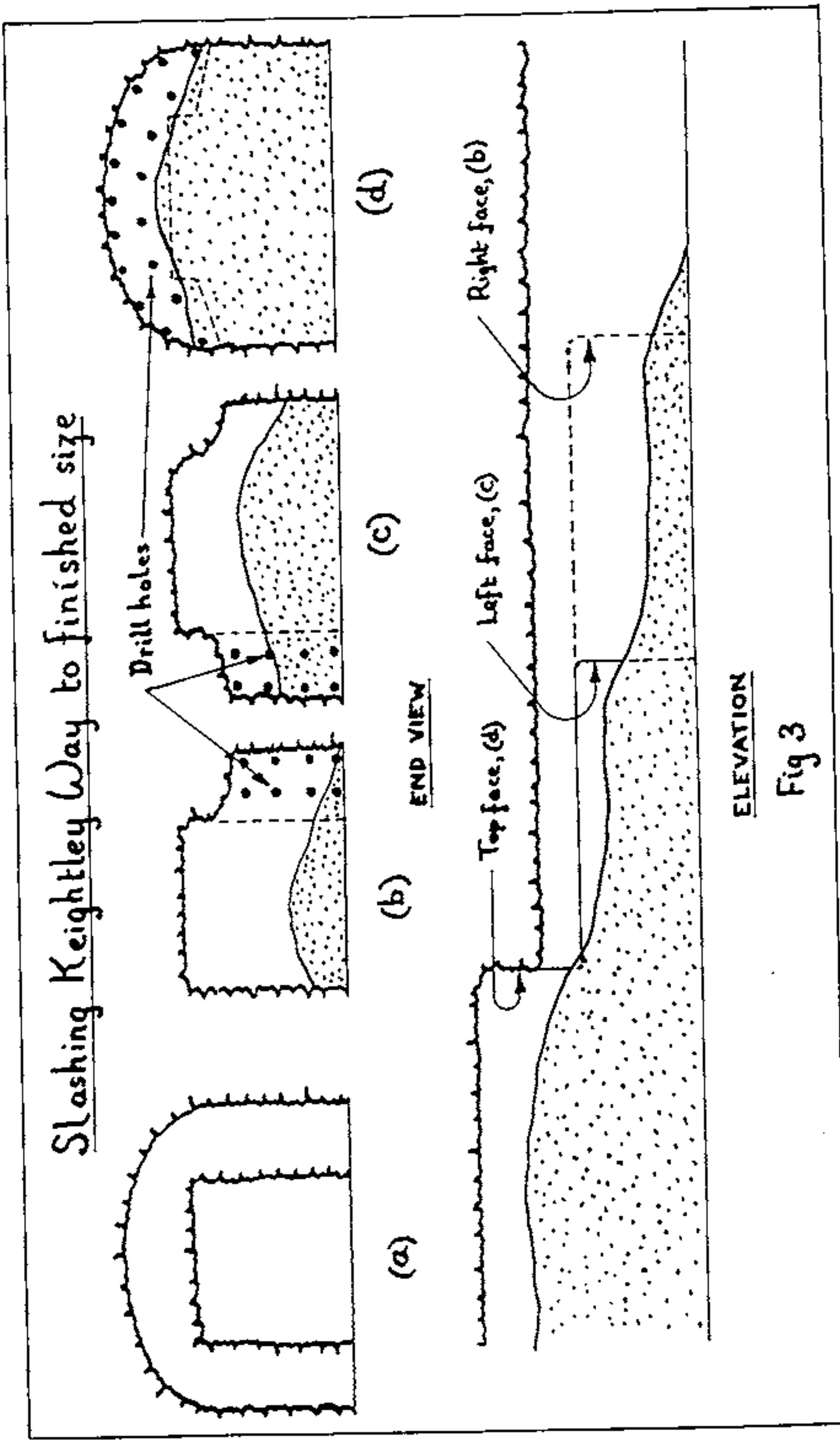

Slashing Keightley Way to finished size
Drill holes
(a)
(b)
(c)
(d)
END VIEW
Top face, (d)
Left face, (c)
Right face, (b)
ELEVATION

Fig 3

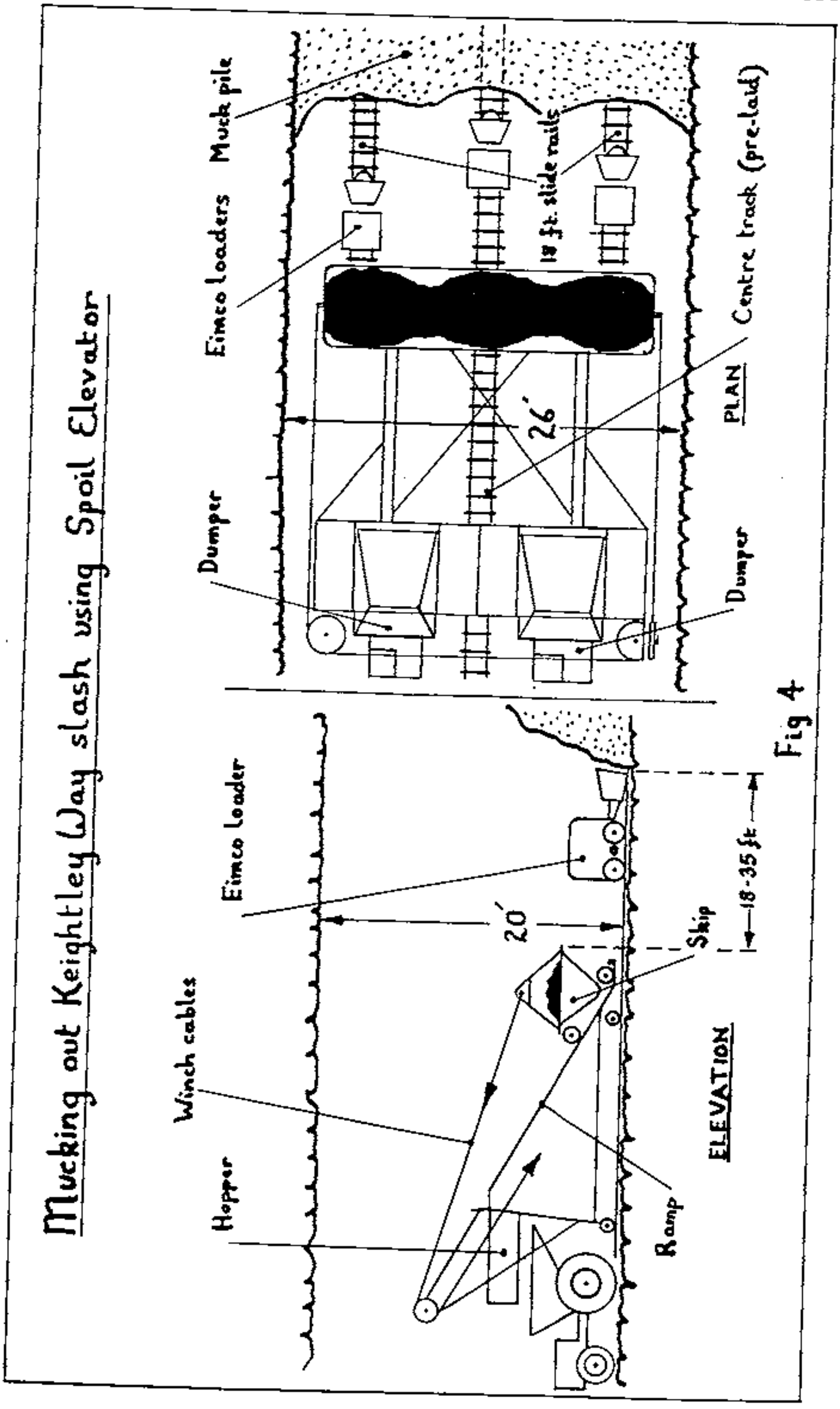

Mucking out Keightley Way slash using Spoil Elevator
Muck pile
Eimco loaders
18 ft. slide rails
Centre track (pre-laid)
26'
PLAN
Dumper
Dumper
Eimco loader
20'
18-35 ft
Skip
Winch cables
Hopper
Ramp
ELEVATION

Fig 4

The 'Spoil Elevator' in Use

There was a slight delay while the finishing touches were put to the spoil elevator and whilst the Squadron had its annual administrative inspection, but by early April 1962 work had started in earnest. The two outside Eimcos worked off specially designed 18 ft "slide rails" which they forced into the muckpile ahead of them. It was thus possible to advance about 16 ft before taking up and relaying the under-rails. The centre Eimco worked from normal Decauville rails which we laid on the centre line of the pilot tunnel prior to the slashing operation. After slashing it lay buried under the muckpile until uncovered by the mucking machinery. It was subsequently taken up as it emerged from the rear of the spoil elevator and stacked out of the way of the dumpers. In this way it was made possible for the centre Eimco driver to work without using a slide rail, and his job was much easier in consequence.

The total volume of spoil extracted between the beginning of April, when mucking out commenced, and the end of September when we arrived at the Europa end was 20,000 cu yds. This gives an average of 3,340 cu yds per month which is approximately 170 cu yds (200 tons) per day of two 8-hr shifts. On the good days we were able to handle as much as 300 cu yds, but all days are not good days in tunnelling and there were inevitably some delays and break-downs. Taking into account periods when, for military or other reasons, we were not tunnelling the average output while working was probably between 200 and 250 cu yds per day of two 8-hr shifts.

A comparison of labour and output using the new and old methods is shown at Table A. The reduction in labour that was effected using the new method of mucking out made it possible to begin work on the second tunnel from Camp Bay to Lower North Gorge at the scheduled time, see fig 5.

Camp Bay to Lower North Gorge

On this tunnel it was essential for local political reasons to establish a portal by the beginning of the bathing season so that work could continue on the pilot heading with the minimum of nuisance to bathers on the nearby beach (fig 1). Failure to do this would have meant that work would have been stopped in mid May and could not have continued until September or October 1962.

Working from the Camp Bay end we experienced the usual break in and open cut problems, but with the assistance of Park Troop dozers and face shovel we just managed to establish a portal by the due date. We were fortunate on this job in that the gradient was a constant 1 : 18 which made the use of locomotives feasible. In all other respects, however, we were most unlucky, for after 40 ft of rather poor rock we came upon severely faulted ground. The faults contained the usual mixture of broken rock and clay, and tunnelling was both difficult and dangerous. In this type of ground the tendency is for the roof to fall in after excavation. Falls continue until the ground above eventually stabilises itself in the form of an inverted V shaped cavity which, in an 8-ft heading, can be as much as 20 ft high. This bad ground was not unexpected for it was possible to see the fault from the outside. It was for this reason that we drove an 8-ft pilot heading instead of the 14-ft heading used in the other tunnel.

There followed several weeks of extremely arduous and dangerous work. At the earliest opportunity a timber lining was inserted, but there was the

PROGRESS ON LITTLE BAY AND CAMP BAY TUNNELS

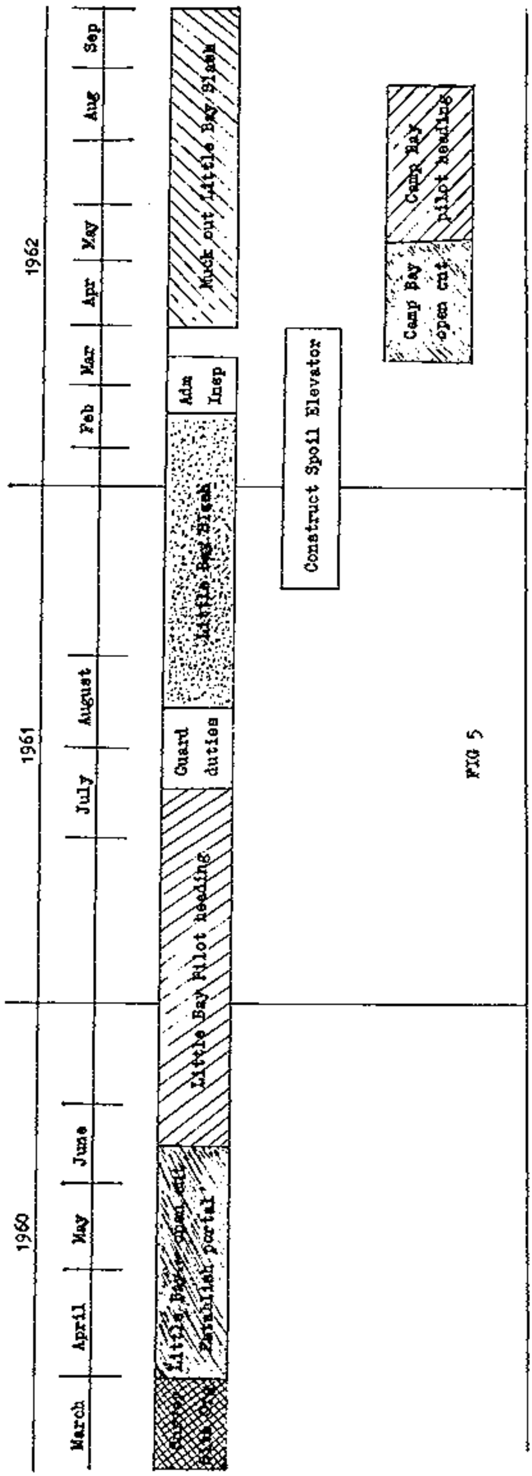


FIG 5

inevitable delay before this could be done in order to get the working face far enough advanced to prevent the timber being blown to matchwood by the force of the blasting. Many times there were falls of several tons and at one period it became necessary to leave the work for a week in order to allow the roof to settle.

In these circumstances the tunnellers must rely on their wits and experience to get through safely. The roof of the tunnel was illuminated and constantly watched. Eyes and ears were always alert for the tell-tale trickle of small stones that generally precedes a fall. The first job on a Monday morning was to muck out the five or ten tons of clay that had fallen over the weekend!

We tunnelled through about 130 ft of this ground in six weeks. The fact that we got through at all reflects great credit on the tunnellers and exemplifies the guts and persistence of Corporals Dee, Heaton and Farthing, the three shift bosses who were in charge of the work. It is worth noting here that in a Tunnelling Troop the shift boss is responsible not only for the conduct and safety of his shift, of perhaps twelve men, but also for the planning of his work and supervision of every aspect of it including the drilling of the face, drawing of explosives from the magazine (sometimes as much as 300 lb), inserting the charges, wiring up, firing the round, mucking out and laying Decauville tracking. In addition to this there are many other minor administrative points to which he must also attend. This he does entirely on his own, often in the middle of the night. For a corporal this is a tremendous burden of responsibility, and one never to be taken lightly.

By late August the ground had improved to such an extent that in reasonably solid rock the tunnellers coasted easily to the break out point. In the week before break out 47 ft of heading was driven despite the lack of a night shift and the severely restricted firing times. Reference to fig 5 will show that while all this was happening the mucking out of the Little Bay—Europa tunnel was still in full swing. Thus the troop was carrying out two major projects simultaneously and both were going extremely well.

The break out at Lower North Gorge was followed by the usual alcoholic celebration at the Troop HQ. I do not think there can be a single tunnelling organization in the world that does not so indulge itself on these occasions—it is a ritual.

This break out marked the completion of only the first stage of the project. The troop are now faced with the work of enlarging the tunnel so that it too will be capable of taking two way traffic. This promises to be a difficult task because the poor ground will have to be lined or "ringed" with steel sets *as the work proceeds*. Were this not done the entire roof would collapse over a 26 ft span and the resultant void above would be 50 or 60 ft high. Steel beams for the construction of sets have been ordered by the CWO Gibraltar, and the Troop awaits the arrival of this material before work can continue.

A possible method of carrying out the enlargement of this tunnel is depicted at fig 6. It relies on a number of steel "polling boards" to hold the roof steady so that excavation and work on the erection of sets can continue safely underneath. Danger to the sets from blasting would not be great because the existence of the pilot tunnel obviates the use of powerfully charged holes. Also the cavity cut for the polling boards would considerably reduce the transmission of shock waves to the roof, and so assist in minimizing disturbance of the ground above.

Progress by this method would undoubtedly be tedious, but in such difficult and treacherous conditions it is doubtful if any rapid method could be devised that would be both safe and sure.

Windmill Hill Shaft

In the meantime the troop prepares for another and rather unusual task which, although still only at the preparation stage will be briefly described for the sake of interest.

The CWO Gibraltar has a requirement for a vertical shaft for water supply purposes in connexion with the new military town at Europa. The Tunnelling Troop undertook to produce this using a method which, so far as we know, has only been used once before; in fact by Mitchell Construction Company on the Breadalbane Hydro Electric Scheme in Scotland.

The CWO was specific only in terms of the minimum diameter of the shaft (2 ft) and its location. The shaft was to enter the rock at Windmill Hill and emerge in an existing chamber about 140 ft below.

Basically we had two alternatives; we could either "sink" the shaft, ie drill and blast working from the top downwards, or, since there was an existing excavation at the lower end, we could "raise" the shaft working from the bottom up. The problem of mucking out a small vertical shaft from above is considerable. We, therefore, chose the second method, and 6 ft as the smallest practical diameter.

A 3-in diameter hole will first be drilled on the centre line of the shaft using a diamond drill. Simple head gear will then be erected over the hole and a steel wire winch cable passed over it and down the hole to a drilling cage below. The drilling cage (see fig 7) will be lifted into the shaft, and the face drilled up using a Holman Short dry-ductor rock drill mounted on a 40-in double telescopic stoper leg. The roof of the cage has hinged guides built in which guide the drill steels to the correct pattern and angle. After the round has been drilled it will be charged with explosive in the normal way and the cage will then be lowered, running out a fine expendable firing cable as it goes. At the shaft bottom it will be lowered on to a trolley, disconnected from the bob and wheeled out of the way. The winch cable and bob are then raised to a safe position and the round is fired. The spoil drops to the shaft bottom where it is mucked out by an Eimco shovel loader working against a concrete retaining wall.

A few details of the equipment that will be used on this project may be interesting. The dryductor drills are equipped with vacuum apparatus which draws the dust and chippings through the drill steel and deposits it in a special dust canister. Whilst we do not normally adopt this method of dust suppression in Gibraltar, it was considered to be ideally suited to shaft work of this nature where conditions in the cage will obviously be difficult enough without the additional discomfort which the dust and chippings would cause. The dust canister will be slung on light chains underneath the cage.

The crew of the cage will be two men. They will have at their disposal all the tools and stores required to complete their task, racked and stored in such a way that the maximum possible working space remains. In addition the cage will be fitted with duplicated telephone communication to both shaft bottom and winch man (who will wear headphones). A latrine, drinking water, first aid kit, escape rope, light weight emergency line and emergency lighting will also be installed.

The Future

Apart from Windmill Hill shaft and the enlargement of Camp Bay Tunnel a considerable programme of work awaits the troop. Arow Street, a tunnel at the south-east corner of the Rock, recently closed because of the dangerous condition of the roof, must be by-passed with a 2,000 ft long two-way vehicular tunnel. Until this is done it will remain impossible to drive a vehicle all the way round the Rock of Gibraltar. The CWO also plans underground garage accommodation for the residents of the new military town of Europa. It is estimated that there is sufficient work in the foreseeable future to keep the Troop busy until at least 1967. This commitment combined with the ever present necessity of keeping military engineering techniques abreast of the times made it desirable to review the troop G 1198 scale of equipment with the object of obtaining an increase in the rate of tunnelling and, if possible, a simultaneous reduction in the manpower required.

Experience in Little Bay tunnel showed only too clearly the limitations imposed by the Decauville haulage equipment, and the enormous waste of time and manpower resulting from its use. It is most unlikely that either the rails or the wagons were designed for use in tunnelling operations. The construction of the spoil elevating machine was a temporary expedient only, and was not done with the object of providing a permanent solution to our problems. It was, in any case, tailor made for the Little Bay Tunnel and would be unlikely to be of use in any excavation which was not of exactly the same dimensions. In considering the future, therefore, we had two alternatives; either we could ask for the supply of a heavier rail and ancillary equipment including proper mine cars, or we could revolutionize our techniques altogether and request the supply of machinery designed for trackless mining. In considering this question two points were evidently overwhelmingly in favour of our adopting a system of trackless mining. Firstly the introduction of heavier rail and mine cars would solve only one of the problems encountered in Little Bay Tunnel: that of the inherent inability of the existing equipment to stand up to the rough usage. It would leave unsolved the difficulty encountered when tunnelling on steep gradients; and there can, of course, be absolutely no guarantee that all future military tunnelling projects will be carried out on gradients within the capabilities of rail mounted equipment. The second was that trackless mining represented a highly flexible and versatile method of tunnelling requiring no large stocks of rail and heavy ancillary equipment. As such it seemed ideally suited to military purposes. However, it should not be inferred from this reasoning that rail mounted methods of loading and haulage are considered obsolete. For hauls of, perhaps, several miles in tunnels with comparatively gentle gradients it is still probably the quickest and most efficient method, which is why tunnelling contractors engaged on long vehicular or hydro projects tend to favour it. Military projects, however, are more likely to consist of systems of chambers with comparatively short intercommunication tunnels on varying gradients. For such work trackless mining methods are ideally suited. With these arguments in mind the manufacturers of our existing loading machines (Eimco, Great Britain Ltd,) were approached to see if they manufactured a loading machine suitable for trackless mining. The following desirable features were presented in our inquiry:—

(*a*) It must be compressed air operated.

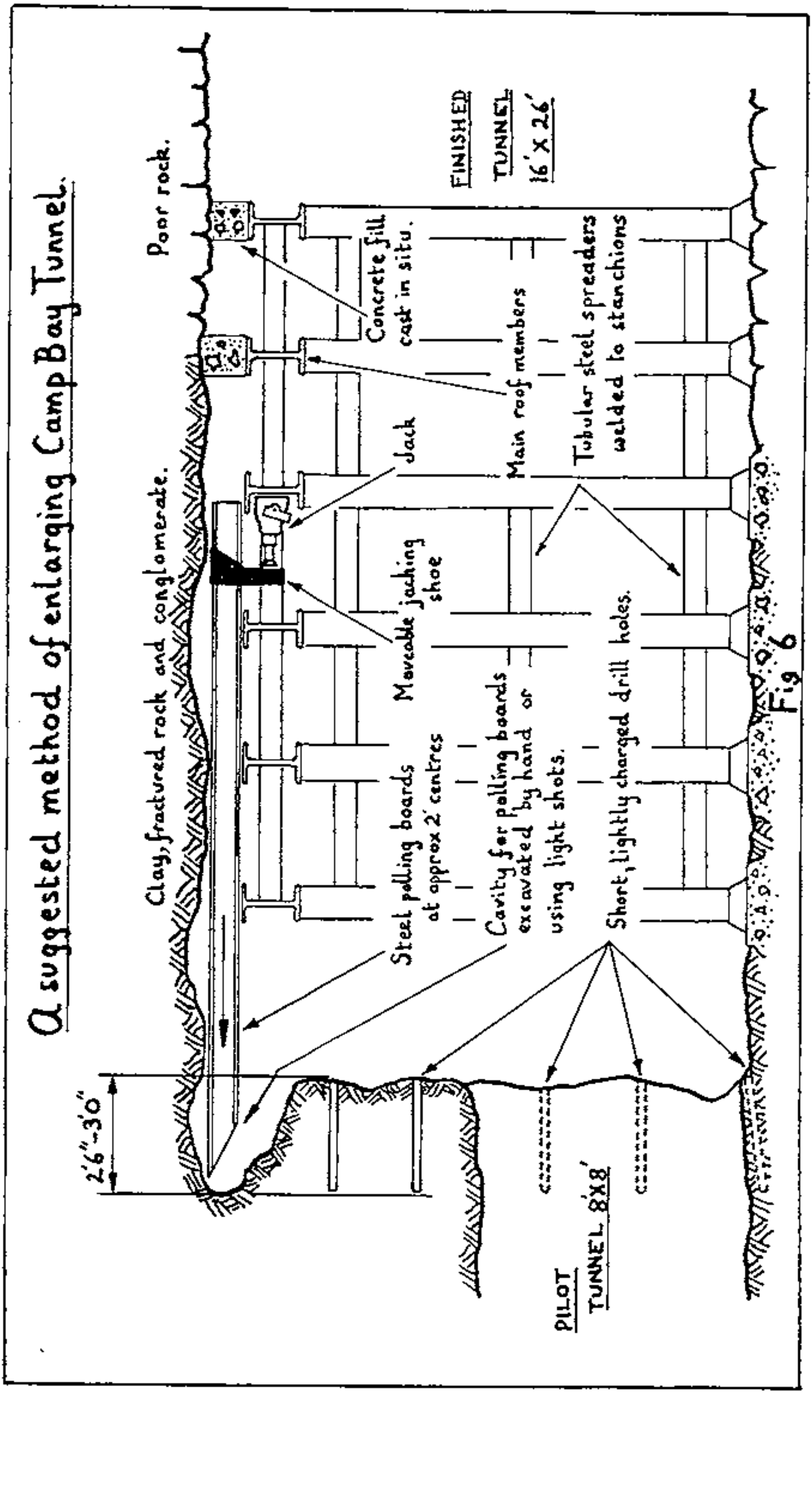

A suggested method of enlarging Camp Bay Tunnel.
Poor rock.
Clay, fractured rock and conglomerate.
FINISHED
TUNNEL
16' X 26'
Concrete fill cast in situ.
Main roof members
Tubular steel spreaders welded to stanchions
Jack
Moveable jacking shoe
Steel polling boards at approx 2' centres
Cavity for polling boards excavated by hand or using light shots.
Short, lightly charged drill holes.
2'6"-3'0"
PILOT
TUNNEL 8'X8'

Fig 6

(*b*) It must be capable of working independently of rails—preferably crawler mounted.

(*c*) It must be capable of loading direct into Aveling Barford $4\frac{1}{2}$ cu yd dumpers.

(*d*) It must be capable of working in headings as small as 12 × 12 ft.

It appeared that the Eimco Corporation in America had recently developed a machine (the 631) which seemed to suit our requirements exactly. Accordingly a case for the supply of two of these machines was put to the War Office and was accepted. Delivery in Gibraltar was effected in early 1963.

A few of the salient features of the Eimco 631 may be interesting:—

(*a*) Loading height 8 ft.

(*b*) Overall height with bucket raised 11 ft $2\frac{3}{8}$ in.

(*c*) Bucket capacity .463 cu yds.

(*d*) Power—three 22 hp radial air motors—one for bucket hoist and one for each crawler track.

(*e*) Output obtained on a project in the USA—2.1 cu yds per min loading into Keohring 6 cu yd dumptors.

It is confidently expected that these machines will not only ease the mucking-out problems in Gibraltar but that they will also reduce the manpower commitment and may well double the troop output.

Unfortunately in redrafting the Troop equipment tables to include the Eimco 631 machines it was not considered possible to eliminate the rail-mounted loaders altogether. In difficult ground—as in Camp Bay Tunnel for instance—it is sometimes necessary to reduce the heading size to 8 × 8 ft, and in these circumstances the smaller rail mounted machinery would have to be used.

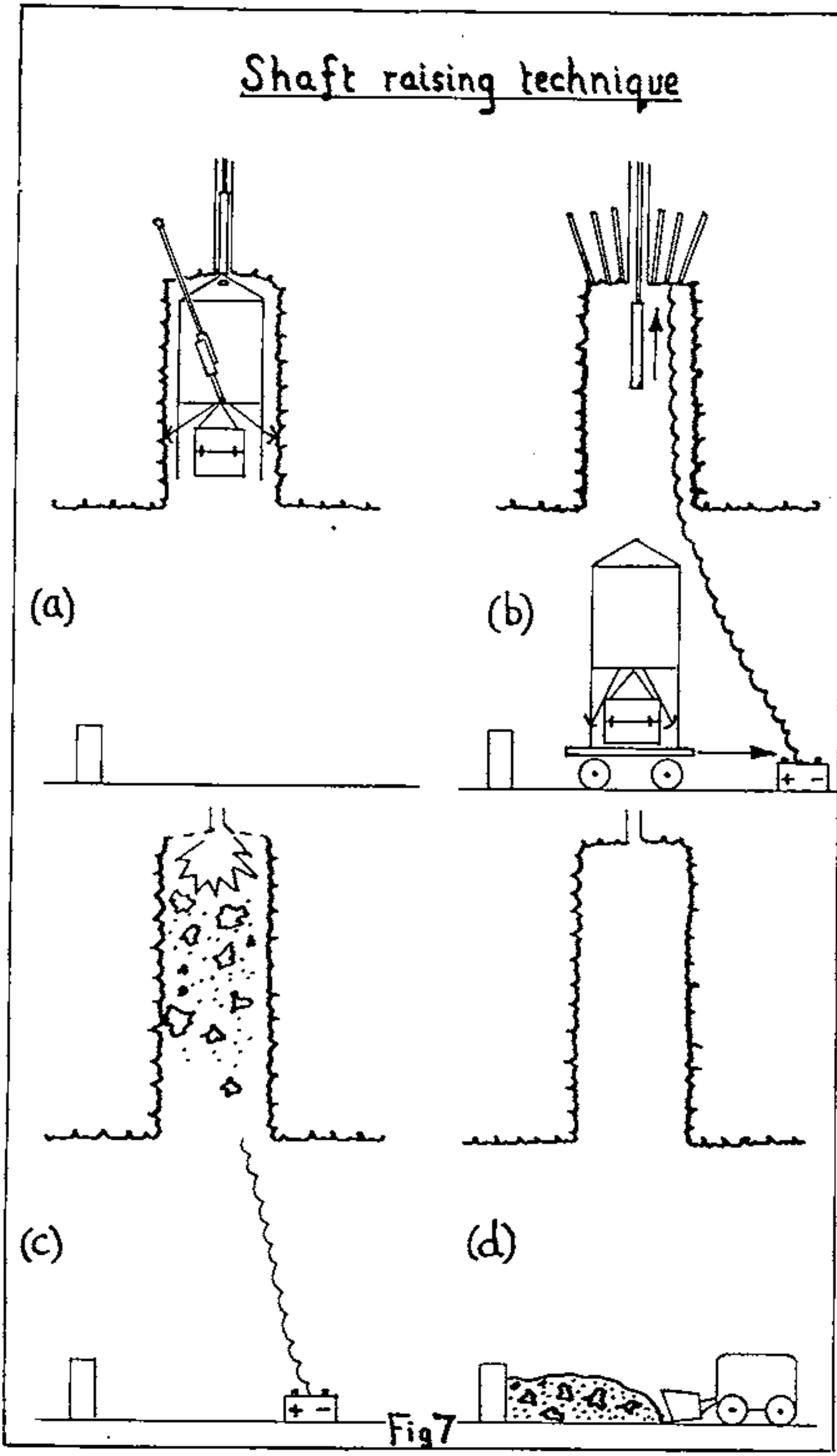
The Tunnellers

An article of this kind cannot be ended without some reference to the tunnellers themselves. They are of course, recruited in the normal way, and after basic training are posted to Gibraltar as potential tunnellers. It is incumbent on 1st Fortress Squadron to train them in their trade and RE Records rely on us to achieve at least basic rate and if possible to upgrade to B11 standard by the end of a three-year tour.

By and large they come from the mining areas of Britain, although there are in the Troop representatives from most parts of the country. A typical cross section of the Troop at any one time might be as follows:—

Twenty-five per cent Geordie, 20 per cent Scots, 20 per cent Yorkshire, 10 per cent Lancashire, 10 per cent Welsh, 5 per cent Irish, and the remaining 10 per cent from other areas.

It is surprising how quickly the majority of these men grow accustomed to the work and learn to handle unfamiliar machinery. They also become members of a very close knit unit which takes a sullen pride in the difficult and dangerous work it does, and strongly resents any interference from outside. In fact the tunnellers tend to regard themselves as a special breed—almost as members of a secret society; a characteristic which seems to have been handed down through generations of Sapper tunnellers. This fault in the Troop is understandable and is probably attributable to the nature of the work. One must remember that they operate in shifts doing a difficult, dirty and dangerous task in cramped underground conditions. The safety of each man depends on the responsible conduct of his mates, and the burden which



(a) Round is drilled up from drilling cage. Cage is steadied during this operation by built-in jacks braced against shaft wall.
(b) Cage is lowered on to trolley and bob is disconnected. Bob is then raised to safe position above the new round.
(c) Round is fired using expendable cable.
(d) Round is mucked out by Eimco loader working against concrete retaining wall.

each man carries depends on the co-operation and assistance offered by the man next to him. It is an interesting fact that whilst tunnellers sometimes argue outside the tunnel, in the snap cabin for instance, one never hears any quarrelling or arguing at the face. The spirit which exists in the troop is probably best summed up by quoting the citation which accompanied the Victoria Cross awarded to Sapper Hackett of the 254th Tunnelling Coy RE in 1916:—

"For most conspicuous bravery when entombed with four others in a gallery owing to the explosion of an enemy mine. After working twenty hours, a hole was made through fallen earth and broken timber, and the outside party was met. Sapper Hackett helped three of the men through the hole and could easily have followed, but refused to leave the fourth, who had been seriously injured, saying 'I am a tunneller; I must look after the others first'. Meantime the hole was getting smaller yet he still refused to leave his injured comrade. Finally the gallery collapsed and though the rescue party worked desperately for four days the attempt to reach the two men failed. Sapper Hackett, well knowing the nature of sliding earth and the chances against him, deliberately gave his life for his comrade."

This spirit is probably found in all teams of men who work hard in difficult circumstances, and it is certainly alive in the Tunnelling Troop today.

One is frequently asked why the tunnellers work so hard, for they get no special pay and no incentive other than an extra half pint of milk per day. I believe the answer is that they take a pride in doing what they feel is a worthwhile job which is of military benefit, and, on their present project, of great benefit to the community as a whole. They are, after all, making a mark that will last for all time. The cynic would laugh at the suggestion of such altruistic motives, and certainly few tunnellers would give them as their reasons for working so well, but whilst one must admit that they match their hard work with equally hard play the fact remains that they possess a strong tradition for industry.

Tunnellers, more than any other tradesmen, tend to be conservative—ever reluctant to try a new method and highly suspicious of any new equipment. Great firmness and determination, mingled with the correct degree of tact, must be employed in the introduction of a new idea. That idea, however original, and however much in prototype form, must work first time, and it must immediately show a clear advantage over the old method. There is little time for modification adjustment or experiment, for the Tunnellers quickly lose confidence and after that has happened it is almost impossible to get them to try it again. They are also extremely superstitious and accidents at an early stage in the life of an unfamiliar machine will tend to put them off, even though that accident may not have been in any way directly connected with the use of the new equipment.

For the tunnellers in Gibraltar the emphasis is naturally on trade training, there being no other station where they may train or practice their craft. Therefore they will receive the bulk of their normal military training and duties at stations other than Gibraltar. They do, however, carry out their share of guard duties and parades, and although for special occasions they may need to concentrate a little harder on their drill and turnout than the other members of the Squadron, they set a high standard and are invariably a credit to their unit. At the last annual administrative inspection they won the Squadron inter troop competition for drill and room turnout. Similarly, Tunnelling Troop candidates for the junior NCOs cadres generally acquit themselves very well. Breaks for purely military duties, whilst perhaps mitigating against progress on the job, are nevertheless essential as a reminder to them that they are first and foremost soldiers and members of one of the "teeth arms".

Thus the Tunnellers have established a tradition for hard work whilst maintaining their trade skill and military efficiency. They have in two and a half years completed one major project and are well advanced on a second. With their skill and tenacity they have overcome all problems and limitations, and produced a unique link in Gibraltar's system of communication—which will be of great value to both the soldiers and the civilian alike. Many people will use these tunnels in their daily journeys, and will no doubt take them very much for granted; but how many will pause to consider the work involved, the element of danger to life and limb, the hours of toil in unpleasant and dirty conditions? How many will think of the men who drove them?

A Comparison of Labour and Output Using Two Alternative Methods of Mucking Out a 26 ft Wide Tunnel

(Based on One Shift)

Job	Using Decauville equipment, winches and a static "Chinaman" (*b*)	Using the spoil elevator
Shift boss	1	1
Eimco drivers	3	3
Tramming skips, and rail maintenance	5	Nil
Handling skips on "Chinaman"	2	Nil
Winch drivers	3	1 (*a*)
Dumper drivers	2	3 (*a*)
Total	16	8
Maximum possible output per shift	60 cu yds (*b*)	125 cu yds

(*a*) System can work at somewhat reduced output with only two dumper drivers and no winchman, ie right hand Eimco driver operates winch.

(*b*) These figures are hypothetical as this method was never in fact used during the enlarging operation.

Photo 1. A visit from the E-in-C. At the Little Bay portal of the pilot tunnel.
L to R Tunnelling Officer, Lieut-Col M. H. Lewis, Major A. Trimmer, Maj-General T. H. F. Foulkes, 2nd-Lieut S. H. Smith.

Tunnelling in Gibraltar 1.

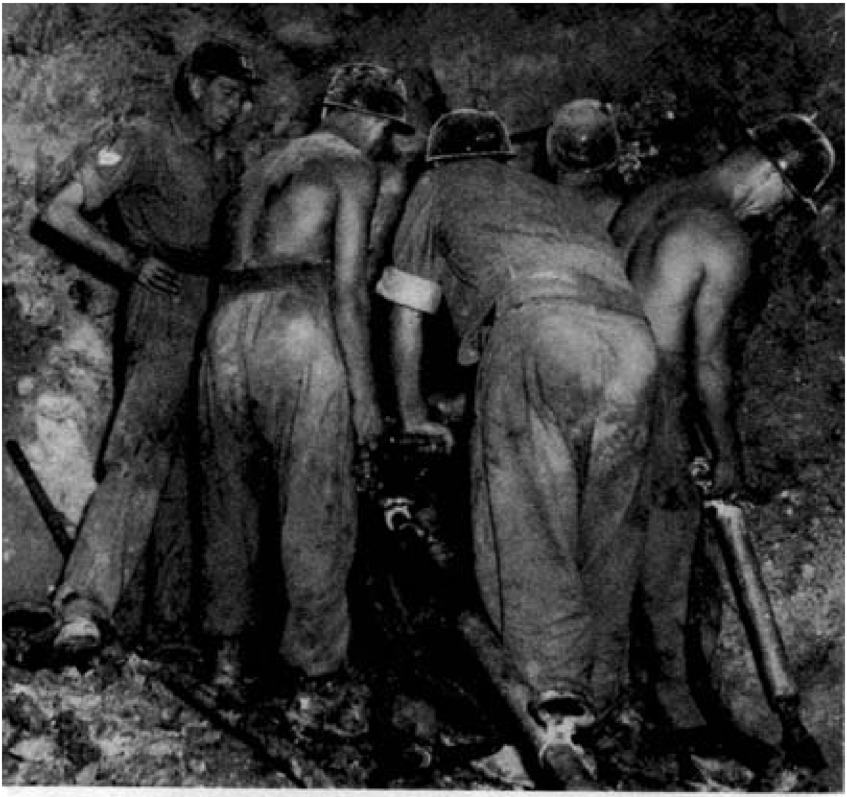


Photo 2. Drilling up. A Corporal watches his shift drill a four foot round in the Camp Bay 8 × 8 ft pilot heading.

Tunnelling in Gibraltar 2

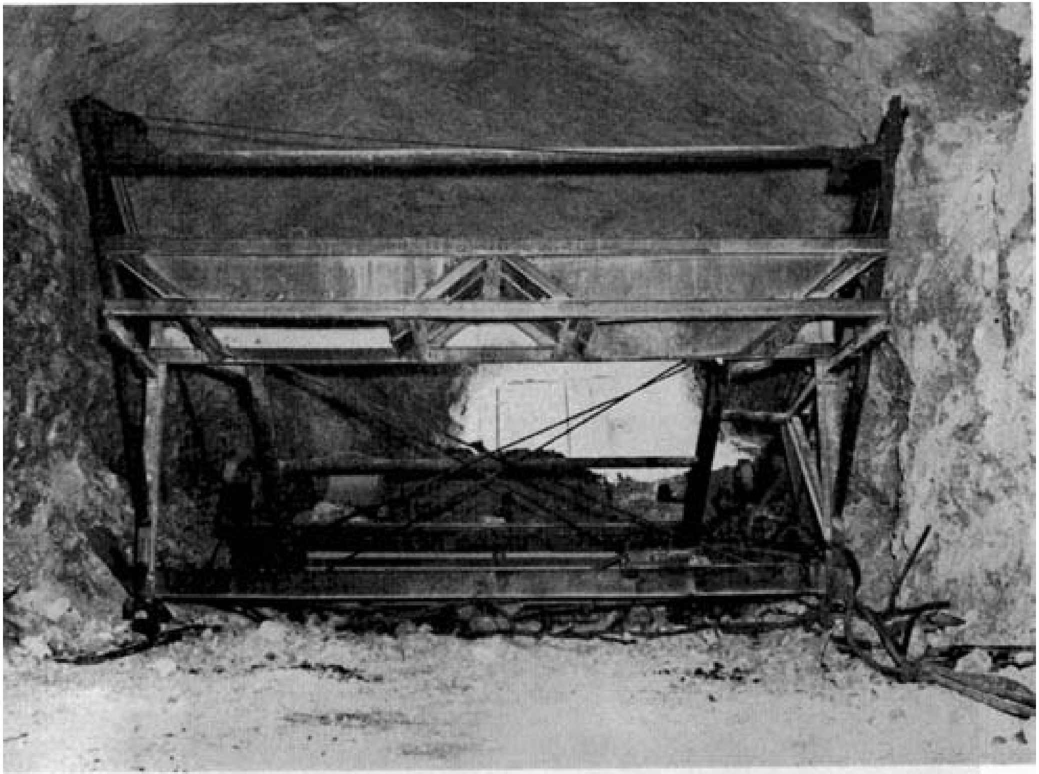


Photo 3. *Arrival at Europa.* The spoil elevator nears the Europa end of Keightley Way. This view clearly shows the two hoppers which guide the spoil into the dumpers.

Tunnelling in Gibraltar 3.

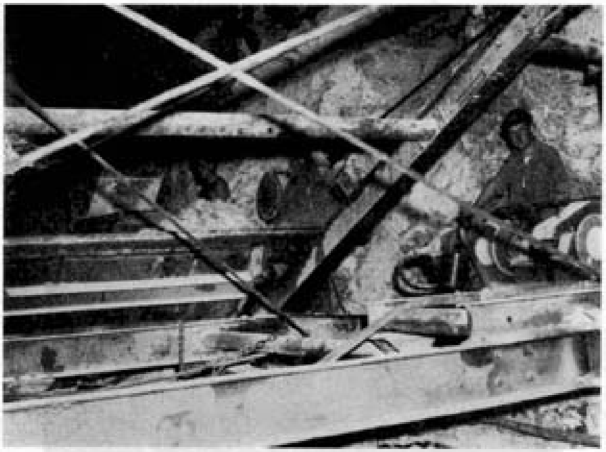


Photo 4. *Ready to hoist.* As the final Eimco shovel load is placed in the skip the winch driver stands by to lift the load in to the dumpers.

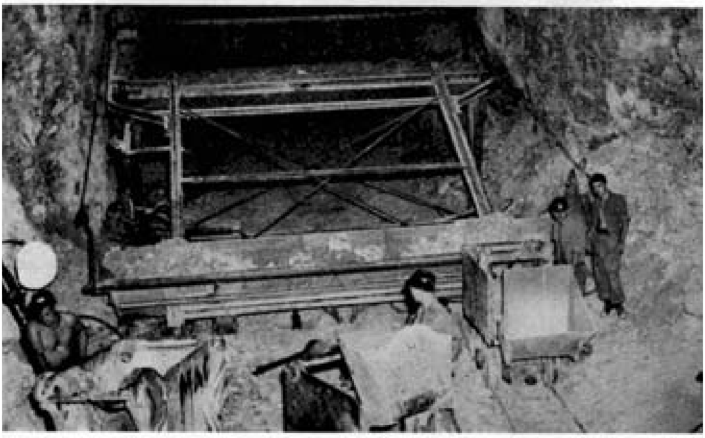


Photo 5. Another view of the spoil elevator in use. The right and left hand Eimcos are Type 21, the centre is the smaller 12B.

Tunnelling in Gibraltar 4 & 5

Photo 6. A photograph of the spoil elevator taken just after erection at Little Bay. In this view the skip is nearing the top of the ramp and about to tip over the hopper. The winch unit, which has two $7\frac{1}{2}$ hp compressed air motors and exerts a maximum pull of 16,000 lb can be seen in the bottom right corner of the photograph.

Tunnelling in Gibraltar 6

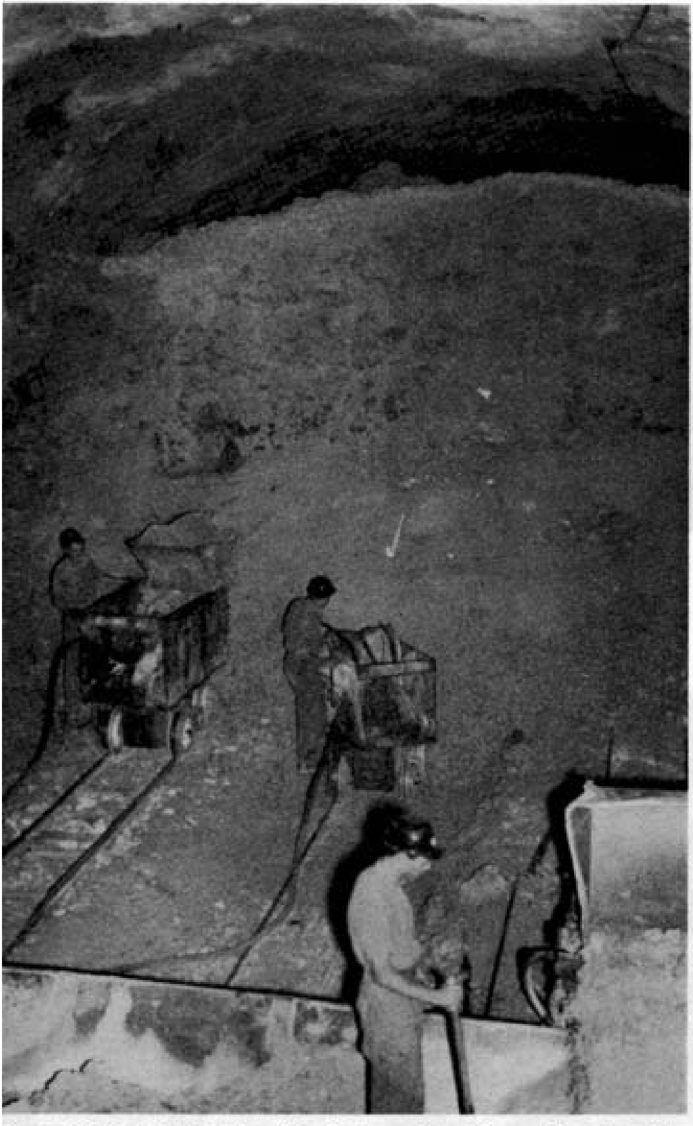


Photo 7. *Mucking out the slash.* Three Eimco loaders working at the muckpile produced from the slashing of Little Bay Tunnel. This picture gives an idea of the height of the muckpile and the narrow gap between the top of the pile and the crown of the tunnel. The 18 ft ladder type slide rail can be clearly seen under the left hand Eimco.

Photo 8. The Europa portal to Keightley's Way. Windmill Hill above.

Photo 9. Look, no rails! The new loading machine in use in Gibraltar for the first time.

Tunnelling in Gibraltar 8 & 9

Photo 10. His Excellency, the Governor and Commander-in-Chief Gibraltar, Lieut-General Sir Charles Keightley, GCB, GBE, DSO, formally opens Keightley's Way.

Photo 11. The drilling cage under construction in the CWO's workshop.

The Corps in a Changing World

By Lieut-Colonel G. H. McCutcheon RE

"There was once a man who was indispensable, but he is dead. His name was Adam."

Anon.

This article is intended to provoke. It is written at a time of great change, not only affecting Britain's role in Western defence but, to an even greater extent, her cold war tasks and the means and methods by which she proposes to carry them out. The political and military policies of the United Nations have come to be major factors, particularly in cold war affairs. The tasks which may fall to the British Army are also changing. The winds of change have blown so widely and so strongly as virtually to rule out any repetition of a four-year war in Kenya or a twelve-year operation in Malaya. The winds blow even faster now and the prospect for collective action is immeasurably greater. Only the very great may dare to go it alone.

It is these strategic considerations, of course, which nowadays bear so heavily on any deliberations related to the reshaping of the Army for its most likely tasks. To suggest a complete reshaping of the Army would involve a major study and would have to take account of inter-service considerations. It is intended, therefore, generally to limit the provocation to the Corps though some of the thoughts set out below will have obvious bearing on other arms and services.

Before beginning to examine some possible changes in the roles and functions of the Corps it will undoubtedly be helpful to set out the basic assumptions upon which these suggested changes are based.

Firstly it is assumed that, however irrelevant its result might be to the final outcome of a general war between East and West, the threat of nuclear war in north-west Europe will continue.

Secondly it is assumed that only in very special circumstances—and in very limited ways—will British forces be invited to form part of any United Nations force such as that employed in the Congo.

Thirdly it is assumed that, in those areas where British forces do become involved in direct support of British government policy, there will be a growing possibility of UN or other group intervention.

The fourth assumption is that the British Government will continue to be willing to meet all its military commitments under the terms of all existing treaties and regional defence agreements.

Lastly it is assumed that, in spite of all protestations of good-will, no significant progress will be made towards total disarmament within the next ten years. If such progress should be made—or we be invaded from outer space—then neither the foregoing assumptions nor indeed this article itself will have any significance.

There are two other tactical assumptions which greatly affect all considerations of the future shape both of the Army and the Corps. The first is that self-sufficiency will be a priority requirement within all units of the field army. The second is that speed into action will be increasingly important.

Accepting the foregoing assumptions then, let us look now, in strictly alphabetical order, at the existing areas of the Corps' activities and see what changes might be effected with the aim firstly of preparing it for its probable tasks and, secondly, of getting the maximum value, in Army terms, from the manpower provided.

Armoured Engineers

The requirement for armoured engineers is directly related to that for medium and heavy tank formations. The heavy tank philosophers are now heard no more. The production of a simple and effective platoon anti-tank guided missile suggests that the days of even the medium tank are numbered. The most insistent voices now are those who claim that on the nuclear battlefield the requirement for rapid concentration, heavy fire power and rapid dispersal can best be met by the helicopter. The tactical value of "sky cavalry" in cold war operations must await an assessment of American experience in Laos. Nevertheless there are many young cavalrymen nowadays who are more eager to slip into the pilot's seat than their fathers were to quit the saddle. Whatever the future brings, certainly the heavy and medium tanks will not remain. With their passing we must accept the heavily armoured engineer will also disappear. The saving of manpower here is small but the high quality will make it a very welcome addition primarily to the APC-mounted combat engineers and amphibious bridge troops. The career prospects of those involved will also be greatly enhanced.

Bands

There are three main centres of Corps activity, the RSME, the Training Brigade and BAOR. Each of these requires a measure of musical support and the existing two bands could be reorganized to provide a minor staff band for BAOR while still providing adequately for the needs of the RSME and Training Brigade.

Bomb Disposal

This small but important commitment is likely to continue for a number of years. One logical change would be to widen the area of Corps responsibility to include the disposal of all explosive charges found by British forces in operational areas. In recent years this interesting and challenging task has almost always been given to RAOC specialists with the Corps in distant support.

Combat Engineers

Combat Engineer Squadrons, whether engaged in general, limited or cold war operations should be bigger all-purpose squadrons, highly trained and capable of operating with either light or heavy-scale G 1098. Amongst their strength they should include a much wider variety of special skills to provide for those commitments which a planner can expect but never foresee. These might well include personnel trained as light aircraft and helicopter crews, one or two sections' worth of parachutists, a section's worth of under-water swimmers as well as smaller numbers of specialists with second trades as

Survey

Of all the military services that of survey has probably gone further towards joint-service collaboration than any other. An even closer integration is probably possible but there will always be the shoreline sharply defining the Navy's special field of interest.

As now organized field surveyors have a vital part to play in preparing for general war. Once it has begun, however, the pace of events will make the fulfilling of their traditional roles almost impossible. There is one very vital nuclear war function, however, which is now largely neglected which field survey units seem particularly well-suited to assume, that of recording and reporting enemy nuclear strikes. In the chaos and confusion of a nuclear engagement a commander will be deeply concerned to have as accurate a state as possible of enemy strikes. He will never be able to accept a ponderous bilingual processing of the information through host-nation civil defence channels. A highly mobile survey group operating as small observer parties and provided with a first-class communications system could be of inestimable value to him. It should be possible, with some reinforcement, for field survey units to train for this role while fulfilling their peacetime functions.

A likely first impression from the foregoing is that the suggestions amount almost to a proposal to disband the Corps. This would be quite wrong. The field army nowadays is chronically short of engineer support and a redistribution of available manpower is urgently needed to take account of probable requirements over the next fifteen to twenty years.

The Army generally needs to readjust its balance. Its manpower problem is largely of its own making; inter-arm and service rivalries, and a fair measure of traditionalism, have produced a situation in which the defence of arm and service interests has been pursued with a loyalty and vigour which was often blind to the wider interests of the Army and defence forces.

The existing condition of nuclear deadlock does give us, for the first time in history, a nearly absolute guarantee against another world war. The United Nations, however vulnerable to criticism, is continuing to add to its ability to act both politically and militarily in a widening field of operations. These two factors alone must, inevitably, have very considerable effects on the shape and functions of the British defence forces. In face of these and other factors it is plainly required of all of us in the Services that we should not only be willing to accept changes when they come, but that, by looking far enough ahead we should ourselves be able to anticipate the need for change and prepare ourselves accordingly. Far-sightedness and flexibility, surely, have never been lacking in the Corps.

The Unconventional Sapper

By Lieut-Colonel I. T. C. Wilson, mbe, mc, RE

Introduction

The traditional task of the Royal Engineers is to use their knowledge of engineering and training in independence of thought to overcome difficulties. They have been the experimental Corps of the Army, ready to try new ideas and to develop them to the stage where they can be handed over as a technique to someone else. In modern times, with the technical advances in the equipment of the fighting forces, the military engineer is no longer esteemed as an outstanding scientific character; there are several more technical corps. At the same time military engineers have never been in such demand in the front line of battle. As the equipment of the fighting troops becomes more complex and more mobile so they become more dependent on it, and the tendency is to hold the Sappers further forward to try to ensure that a fighting soldier and his logistical backing do not become separated. The quantity of engineers thus far forward in the order of Battle is often justified by stressing their value as combat troops, and in so many peacetime exercises the Sapper sections trail along behind the other troops, because it is difficult to bring in a Sapper problem, and act only as emergency infantry. The Corps of Royal Engineers must not come to be regarded merely as second class infantry nor, of course, must they withdraw from the battlefield and lose their claim to being classified an Arm. Without attempting to comment on organization, there must be trends in the development of the Army in which it is the natural bent of the Engineer to lead. There appears to be scope for this in the cold war.

Quotes from a US Army Publication. "In nations where the intensity level of insurgency is low, the role of force is deterrent and preparatory in nature. Forces should be urged to do what they can to assist the people through psychological operations and military civic action projects, particularly in remote and deprived areas and thus ameliorate some of the conditions which lead to subversion and insurgency."

"The Special Action Force is a specially trained, area-oriented, partially language-qualified, readyforce in a high state of operational readiness. Its members are highly motivated and prepared from a standpoint of training and psychology to work in remote areas with foreign personnel including primitive groups under conditions of relative hardship, danger, and austerity."

Extracts from speeches by Colonel R. L. Clutterbuck OBE, to US Army audiences at Fort Bragg, North Carolina, USA. "If you think that primitive peoples are better off without the basic benefits of civilization—such as medical attention, and the means to grow or buy enough food—then go and see for yourself. They will cluster around you with their sick, sore, starving and injured, and their love for you will depend on how far you can help them" (the Malayan aborigines) . . . "The two most valuable men in contacting local tribes are the medic and the engineer, the one to treat their ills, the other to open the way to some of the real advantages of civilization."

THE REQUIREMENT

In peace, the Armed Services fulfil the role of a National Insurance Policy, they are expensive to maintain, are generally regarded as a necessary evil and everyone hopes the situation will not come about when they are required. Their value to the nation is in their existence rather than their actions, in fact the more active they are, often the more embarrassing they are, and certainly the more costly they are. These facts are not to suggest that a soldier should live a life of idleness, he would make a poor insurance policy if he did so, but that the energy and zest for adventure that is in most soldiers be put to use in peace to help the national policy at the same time as a soldier trains for war. The natural tendency of the Armed Forces is to concentrate their efforts on preparing for what they foresee as being the pattern of the next war. However, with the modern deterrent of the nuclear weapon, the next war may never come. The next war could be lost just as effectively without firing a shot in anger if the peacetime policies of the Western Nations are not right or are not rightly implemented.

Perhaps the greatest advance in science that affects the largest number of people is the speed with which news can now travel around the world. Radio, television, newspapers and films are now reaching even the most primitive people, and are providing them with food for thought for the first time in their history. This is one of the main causes for the "wind of change" which is sweeping not only through Africa but also through all the under-developed countries on the right side of the iron curtain. The problem is to ensure that in the process of change and development the minds of the people are not contaminated by Communist influence, not so much because the principle of Communism is evil, but because in practice, Communism is pledged to rule the world. The battle for minds has been joined.

The process of development of a country is a slow one because it depends to a very large extent on the education of the inhabitants. This is essentially a civilian process. There are, however, two activities in which military assistance can be invaluable. One is what might be described as opening the road, the other is help in the face of a disaster caused by nature. Both these are obvious tasks for military engineers.

The use of military resources for the benefit of civilian communities is to seek to improve the living conditions of the local population and thereby to gain their loyalty, respect and support. Such projects, grouped together under a Military Civic Action Programme, may be carried out entirely by British troops or preferably by small parties of troops or individuals supervising working parties of local civilians or local forces. Typical of the tasks which could be undertaken are:—

(i) Construction of roads, bridges and airfields to open an area to the outside world thus enabling the benefits of trade and education to reach it.

(ii) Opening an area for cultivation by setting up saw mills and operating a forestry programme or developing a drainage or irrigation scheme.

(iii) Providing water supply and sanitary controls to a dwelling area.

(iv) General construction of community building projects.

(v) Organization of sea damage control and recovery operations in the face of a natural disaster.

The trend in the use of soldiers for similar tasks is already developing.

What is required is to be ahead of the demand, with troops psychologically and materially prepared to move at very little notice, and to work in remote areas under hardship conditions.

THE PROBLEMS

If soldiers are set aside for training for and are committed to these cold war tasks, there are two immediate questions which spring to mind. The first is where are the manpower resources from which they can be drawn? With the current problems of recruiting, a small regular army and the necessity to maintain garrisons at strategic points around the world, especially BAOR, can any men be spared for this type of task? The second question is how can this type of work be considered as training for war? In considering the second question, a possible solution is suggested for the first.

The type of skills that a soldier requires for the cold war task of civic action programmes is not so much intensive academic training (although the direction of tasks does require qualified engineers) but rather common sense, combined with a basic knowledge of engineering skills. In the majority of sites the engineer functions will involve pioneer work with local material and local equipment. Inprovization and the use of field expedients will be the rule. Individuals must be taught to develop determination tinged with the patience to take proper cognizance of the skills, prejudices and customs of the local work force. To be successful these troops must also be self-reliant and possess a sense of responsibility and personal integrity so that the value of a project is not marred by bad relations with the indigenous population. In addition to the training requirements for carrying out the work, there is the problem of access to the places of work. The troops concerned must be fully trained in all aspects of airportability both with long range transport aircraft, medium and short range fixed-wing aircraft and helicopters. They should know how to call for aerial resupply. It is suggested that they should be parachute-trained for access to small isolated sites. They require to be equally proficient in all aspects of sea transport including the use of rivers as supply routes.

Training would require all the basic Sapper skills with emphasis on improvization. Demolition training would require concentration on the economy of explosives and the skilful emplacement of charges, rather than the more usual Sapper answer of working out the formula and adding 50 per cent to make sure. Some instruction would be needed in the local manufacture of explosives. As a force might be operating in an area where hostile elements could be encountered, the essential military skills of fieldcraft, weapon training, map reading, patrolling, evasion, escape, survival and resistance to interrogation must also be taught thoroughly. The nature of the task also introduces the need for each sub-unit to be fully independent with long range wireless communications and well qualified medical orderlies.

Equipment required would need to be air-portable and preferably air-droppable, robust and simple to maintain. Some contradiction arises here that while use of equipment, especially plant, vastly increases the scope for carrying out tasks, dependence on it tends to inhibit the determination to overcome difficulties. The answer possibly lies in a formation of differently equipped units.

The above type of training and organization provides a force not only qualified for its peacetime mission but also for raiding, airborne and similar unconventional operations in war. Use of such a force could alleviate the problems arising out of the first question.

Use of Raiding Forces in War

Modern transport aircraft give to a Commander in war the ability to extend his influence to the rear of his enemy. A threat of an airborne operation will cause an enemy to waste much of his manpower in garrison duties.

If the threat is continually being emphasised by small raids, the drain on enemy manpower is likely to be greater. Therefore raids should be of value out of all proportion to the size of the raiding force, apart from the damage which can be inflicted to enemy installations. Should the raids include assassination targets of the enemy leaders and should this fact be published in peace, it might make some ambitious leaders of adolescent countries, for example in the Middle East, consider their actions very carefully before risking war. Of course, striking at the leaders is a game two can play, but it could be good for promotion. The idea may seem immoral, but is surely no more so than Napoleon directing the fire of his guns against Wellington at Waterloo, or in modern times mounting an air attack to devel a located enemy headquarters.

The main object of a raid is to destroy something, and this is an application of the engineer task of demolitions. A raid is only a slight extension of the traditional Sapper task of providing the assault demolition team. To accept such a task is a natural progression from the breaching of the Delhi gate, through the Sapper demolition teams who landed on D Day in Normandy ahead of the assault waves to blow the beach obstacles and the airborne Sapper raid on the Norwegian heavy water plant. Training in basic soldiering, use of weapons and demolitions and with a knowledge of engineering to guide the most effective placement of demolition charges makes a team of military engineers most suitable for small raids. For larger raiding parties, infantry might be required to seize and hold the objective while a Sapper demolition team fulfils its mission. This suggestion is not that the Sappers should usurp the Special Air Service whose task is to remain for long periods in enemy territory, but should be complementary to them and should be available for call by them to make a raid followed by evacuation.

Sapper raiding teams could be given preplanned operational tasks in Europe in our own lines, probably in connexion with the creation of an obstacle. They could be at a permanent state of readiness for emergencies including reinforcement of BAOR, possible by parachute, during a state of alert. Other tasks in global war could include raids behind the enemy lines or after the war is over, assistance to the population of a devastated area.

Airborne Operations

Airborne troops are the most versatile part of the strategic reserve. Use of air transport gives a speed of reaction not afforded by seaborne troops, even those already embarked on ships, with the additional advantage that the airborne soldier can train up to the last moment and does not face the deterioration associated with a long sea voyage. Aircraft with short take-off and landing performance can land on a hastily prepared airstrip which is within the capability of parachute forces to construct. This means that the initial objective for an airborne force need not be a port nor an airfield, which factor should give additional flexibility to planning.

However, the introduction of a force into a country carries with it logistical problems which can often only be solved by engineer work. In Kuwait, at the time of the crisis in 1961, the Oil Companies had the resources to carry this engineer load but this instance is the exception rather than the rule. Engineers will usually be required in the Strategic Reserve to act as an immediate follow up to assault troops to relieve the Brigade Engineers for their Brigade close support tasks and to give logistical support to the Expeditionary Force. The sequence of a typical operation might take the following lines with emphasis being given to the engineer aspect:—

(i) Parachute assault on certain specified objectives including an area suitable for an airstrip;

(ii) initial construction of an airstrip by engineers of the Parachute Brigade;

(iii) reinforcement by parachute or airland of more engineers to take over the airstrip and build it into an airhead, and to establish installations such as a petroleum depot;

(iv) air land of a second or subsequent Brigade to reinforce the Expeditionary Force, together with the logistical backing for the maintenance of the Force.

This would be another highly suitable field for the employment of suitably trained engineers of the Strategic Reserve.

Conclusion

The suggestion is that the Corps of Royal Engineers should once again lead the trend of development of the Army by establishing a unit or units specially trained to take an active part in the cold war, for which Engineers as a whole, are very well qualified to be of great value. The commitment of troops to such an organization would not be to the detriment of the Army's preparedness for war, either limited or global, because there are a number of equally valuable tasks in these conditions which the organization could perform. Employment in this manner would give a full, exciting and adventurous life with ample opportunity for character development which should benefit individuals and the Corps as a whole.

The Movement Control Service in Germany

By Colonel R. F. Parker, MBE, RE

"What do you know about this business?" the King said to Alice.
"Nothing" said Alice.
"Nothing whatever?" persisted the King.
"Nothing whatever" said Alice.

"Begin at the beginning" the King said gravely, "and go on till you come to the end; then stop"

Alice in Wonderland

Introduction

Since the last article in the *Journal* on the subject of Movements (The Employment of Regular Sapper Officers in Movements by Lieut-Colonel D. E. Thackeray in December 1959), there have been policy decisions which make the Engineer-in-Chief responsible for the entire manning of the Movement Control Service, both officers and other ranks. In particular the Army Council in March 1962 confirmed the need for the Movement Control Service to operate in the long term at optimum efficiency and decided that it should be manned in the normal way by regular officers of the Royal Engineers. They also decided that a proportion of Q (Movement) staff appointments (ie those that deal mainly with executive movement work) should be re-allocated to the Royal Engineers. These appointments range from SO III (Movements) to Colonel (Movements) of which there are two appointments in the War Office, so that there is a balanced career structure.

The training of officers for Movements and Transportation appointments is being combined in order to increase flexibility in the deployment of officers and to improve expertise. For example, the long Transportation course has been redesignated the Long Movements and Transportation course and about two months of the course are at present devoted to movements subjects.

It will be some years before the Corps will be able to begin providing regular officers who have completed their normal young officer training and regimental duty. Until then, Extended Service officers will continue to provide a large proportion of the numbers required: these Extended Service Movement Control officers are considered in competition with regular officers for temporary promotion in senior appointments within Movements. They are the mainstay of the Movement Control Service.

Consequently the Movement Control Service and Movements Staff appointments are of more interest to Sapper officers than hitherto. I therefore commend Colonel Dennis Thackeray's article anew, confirm that a Movements appointment is a most interesting, rewarding and certainly a very "live" one, and I propose following his article up here with some factual notes on Movements in the British Army of the Rhine.

Organization in BAOR

As is usual when explaining anything to do with BAOR, it is necessary to start off by explaining a BAOR peculiarity. One peculiarity is an experimental development on the staff which has recently been initiated: the staff functions of Transportation in HQ BAOR, formerly carried out by the OC and 2IC of the Transportation Inspectorate RE in their roles of SO1 RE (Tn) and SO2 RE (Tn) on the staff of the Chief Engineer, have been combined with the (Q) Movements staff. The AQMG (M) has become the Assistant Director Movements and Transportation and one of his three Deputy Assistant Directors (DAD) Movements is now DAD Movements and Transportation. Similarly in Berlin, the SO 3 (Movements) on the staff of the Berlin Infantry Brigade Group HQ is now DAD Movements and Transportation in order that the Commander in Berlin can have direct advice on Transportation matters and a more direct financial and operating control of railways and WD railstock matters there. These new appointments, of course, fit in well with the policy of combined movements and transportation training.

In HQ BAOR, the staff under the Colonel Q (Movements), who is head of one of the main staff branches and as such deals directly with the Chief of Staff, is now entirely Sapper manned except for the two MS appointments on the Plans side. Apart from its normal staff role, it exercises functional and technical control over the Movement Control Squadron RE and administers the Squadron so far as establishments, postings, confidential reports etc are concerned. The only other executive staff appointments in BAOR are the one in Berlin mentioned above and the SO1 (Movements) at the Advanced Base: the latter also has the role of Port Commandant of Antwerp and the other channel ports used from time to time for military movement.

Movement Control Squadron, RE (BAOR)

This is an inappropriate title. The Squadron consists of troops and sections deployed over 400 miles from Antwerp to Berlin, each troop or section being administered in varying degrees by local units. The three main troops, which between them cover that part of the Federal Republic of Germany in which BAOR is stationed, are each commanded by a major: he is the adviser on movements to the formation and unit commanders in his area, as well as being responsible for the control of movement in his area and being the liaison link with the German civil transport and road authorities. Nevertheless the Squadron is very much a "unit" with an "*esprit de unit*", and one troop can rarely operate in isolation from the others. The troops in their turn are generally widely scattered with small detachments consisting of two or three soldiers and civilian staff. This wide deployment poses problems of administration and welfare. All ranks have a job of work which has to be done, and the business of fitting in leave, courses, military and recreational training is a very great problem which is made even more difficult when, as is inevitable at times, the Squadron is below full strength. The big advantage, and one which is the main factor in maintaining a good morale and sense of duty, is the fact that all ranks have an active and necessary task of serving others and can see the result of their work.

The Other Ranks of the Squadron are, of course, all regular soldiers and all clerks RE, a large proportion of them being warrant officers and senior NCOs. There are also a number of attached ERE personnel, including five

RAPC officers required for currency changing at air trooping terminals. The local civilian element is large, and many of these have served British Army movements for over ten years and are extremely valuable members of the unit. There are eight regular Sapper officers employed either in the Squadron or on Sapper designated staff appointments: two lieutenant-colonels and six majors.

Functions

The function of the Movement Control Squadron, basically, is the executive control of military personnel and freight movement for BAOR including the Advanced Base (British Forces) in Belgium and Berlin. The civil movement resources are very good. There are the great ports of Antwerp and Rotterdam, the minor Channel ports, the Rhine ports and the North Sea ports. The rail and canal network is one of the densest in the world and the road network is equally extensive. The number of airports is adequate for peace time. There is a growing cross-channel air service for freight, and the "roll on, roll off" vehicle ferries operate four days a week between Tilbury and Antwerp and Rotterdam. The military movement resources, general transport and tank transporter companies, WD rail stock including a substantial number of war flats are more than adequate for peace time. Consequently there is plenty of choice of transport agency for the normal movement of personnel and freight.

I propose to touch only on those aspects of the Movement Control Service in Germany which are of particular interest or are peculiar to BAOR.

The first point is to remember that British Forces Germany are a guest force, and that our military movement and use of routes in Europe are subject to the Host Nation laws and decisions. We are dependent on the co-operation of the Host Nations, mainly Germany, France, Belgium and Holland. They are all extremely helpful, but require good notice of moves through their countries. We negotiate tariffs for military personnel and freight on their railways, documents for frontier crossings including customs forms, and we are, of course, subject to their traffic laws. The routine movement within the area of the Federal Republic in which British Forces are stationed and routine movement to and from the advanced base in Belgium works smoothly and easily. But unit moves by road or rail through the channel ports or to training areas in other parts of Germany, France, Denmark, Belgium need a lot of planning well in advance in conjunction with the Nations concerned.

Unit moves, either normal arms plot changes of station or training moves, which include moves by LCT and air to the Hebrides, are a big commitment. Fortunately it has now been accepted that unit moves between UK and BAOR will normally be by *ad hoc* air charter flights, outside routine air trooping schedules, to and from appropriate airfields in UK and Germany. The main body of a regiment/battalion is moved in a five-day period, probably in two planes per day each plane carrying sixty to ninety passengers. The last major move of this nature was carried out most successfully in June and consisted of a three-way move involving some 2,000 soldiers and their families. The planes loaded the Royal Fusiliers, moving from Colchester to Osnabruck, at Stanstead in Essex and landed them at the RAF station Gutersloh; here they loaded the Prince of Wales Regiment from Wuppertal and flew them to the RAF station at Gatow in Berlin. The Durham Light

Infantry, moving from Berlin to Barnard Castle but most of them proceeding on leave first, embarked at Gatow RAF station in Berlin and were flown to Newcastle.

Air Trooping

Air trooping between the UK and Germany on which some 10,000 passengers travel each way each month, has posed some interesting problems on the organizational side. The air trooping service is operated by British United Airways on five days in the week from the RAF airfields at Wildenrath and Gutersloh and the civil airports of Dusseldorf and Hannover, to Gatwick and Manchester in the UK. Duty travel is fairly consistent over the year apart from TA sub-units and parties in the summer, but there are large leave travel peaks in the summer and at Christmas. Fundamentally, we are trying to do two things which are incompatible: the first is to fill each aircraft completely, and the second is to allow everyone, particularly the leave men, to travel when they want to.

The former system of bidding for and allocation of seats, which was as unsatisfactory for the customers as it was for the Movements staffs, has now been abolished. The War Office/Air Ministry have agreed to operate a fixed schedule of thirty flights a week: this copes with the traffic requirements in normal months, and permits a system of advanced booking by units direct to their appropriate MC Troop. We have visited both local and head offices of BEA to study their commercial methods of booking and have applied, as far as practical and economical, some of their techniques. However, there are many complications and military and financial factors which bedevil what might appear on the surface to be a not too difficult problem: reservation of seats for late duty bids, party travel (eg bands, unit advance parties, sports teams, block leave parties), suitably timed flights for families with young children, peak travel periods and the justification for extra flights, fitting in return dates with leave requirements and so on. Under the new system units book direct with MC troop traffic offices, with a master traffic office exercising over-all control and information on all flight bookings four months ahead.

One of the essential requirements for efficient control of movement is good communications particularly when dealing with short range air flights. The "Movements" communications in BAOR are a source of envy to many. Generally the communications are between the traffic offices located at Troop HQs and HQ BAOR, and to the Joint Services Combined Booking Centre in London. These are all tied by direct military telephone lines: in addition we use Telex, and teleprinters. The MC sections and offices dealing with rail movement have telephone extensions on the BASA (German railways) telephone network.

Road movement is of interest because BAOR enjoy a special degree of freedom of road movement in Germany by virtue of an agreement that was made some eight years ago with the Federal Ministry of Transport. Under the terms of this agreement, the maximum dimensions defining an "out-of-gauge" vehicle, for which a movement licence has to be obtained before it can use the roads, are appreciably greater than those laid down for other road users: convoys of less than forty vehicles can move without a licence except on autobahns: and we can deal direct with the civil authorities, who are the ultimate authority for road movement, through the Land Police Advisers of the Joint Services Liaison Organization. Our relations with the lande authorities and the civil police are very good and they are most co-operative. It is therefore important that units abide by the rules for obtaining licences for convoys and out-of-gauge vehicles and obey the national traffic laws. The procedures and dimensions in different countries vary; a fact which does not make for simplicity.

Berlin Travel

Berlin travel is unique and politically sensitive. All surface travel is checked by the Russians, at two checkpoints for road transport, one at each end of the autobahn, and at one checkpoint, at Marienborn 5 miles inside the Eastern Zone of Germany, for rail transport. There are three air corridors to West Berlin, and the control of air travel is one of air traffic control, the individual or the freight carried not being subject to any physical check by the Russians and not therefore requiring any special documentation. The special documentation for surface travel has to be accurate and meticulously correct; the Russian soldiers can check only by comparison with examples or cross checking between documents, they cannot use their judgement as they cannot read English. A minor incident over incorrect documentation always presents an opportunity for escalation into a major political incident. So the rigid interpretation of the rules by the Movement Control Service, which is not always appreciated by exasperated travellers with dog-eared identity cards, is very necessary.

Each of the occupying powers in Berlin, the USA, France and ourselves, run regular military passenger trains. The British train runs every day in the year (except Christmas day) in each direction: this is a political requirement and is the most flagrant contradiction of the principle of full utilization! However, it is paid for by the Berlin Budget and not by the British taxpayer! The passenger coaches are Deutsche Bundesbahn stock, but the dining car and the staff coach, which carries the military train staff and guard and their communications, are WD stock. The train starts off at Brunswick with Deutsche Bundesbahn engine and crew; at Helmstedt on the zonal frontier an East German engine and crew (a well indoctrinated crew!) take over and take the train on to Charlottenburg in Berlin, stopping at Marienborn where the OC Train, the Train Conducting Warrant Officer (TCWO) and interpreter dismount and present the train and passenger documents to the Russians. The TCWOs have a most responsible task in such a politically sensitive area. They need to be firm, tactful, right on top of their jobs and absolutely reliable. A freight train runs to Berlin once every three weeks; it is marshalled near Hannover, loaded vans being despatched from depots in the UK, in BAOR and the Advanced Base (the most important being vans from Carlsberg breweries!) to reach the marshalling yard by the due date. There a guard joins the train and travels in a WD owned fitted guards van with radio communication. These trains are the only regular British military trains now operating in Germany, though over a year about eighty special military trains are run by us, as well as numerous rail moves of armour. The latter, as far as possible, is moved by road in order to avoid costs.

The War Office have recently agreed for an experimental period a contract for the delivery of "Red Star" Ordnance stores direct by road from COD Chilwell to 15 ABOD at Viersen, near Monchen Gladbach. The service operates three times a week. The contractor provides a 15-ton capacity vehicle at Chilwell. It leaves Chilwell at 0800 hrs on Day 1, crosses from Tilbury to Antwerp on the "roll on, roll off" ferry operated by the Steam Navigation Company on the night of Day 1/Day 2 and arrives at 15 ABOD at 1500 hrs on Day 2. This is an efficient and surprisingly inexpensive method of freight movement, and has the great advantage that weight and volume of packing materials can be reduced as no handling of the stores is involved *en route*. A great contrast to the method of moving MFO by the cross channel air bridge: a method involving a large number of transhipments between road, rail and air transport.

Liaison

I have already mentioned the close liaison necessary with the Host Nations: this is particularly necessary, of course, in war planning. We also have a very happy and close liaison with the 594th Transportation Group (Movement Control) of the United States Army. This group is organized into five regions covering the USAREUR communications zone in France and Germany up to the Seventh Army rear boundary. Their third region, commanded, incidentally, by a lieut-colonel who served in the British Army during the early years of the last war, is contiguous with our area and has its HQ at Frankfurt. They are extremely co-operative: we are sometimes staggered by the size of their staffs and organization: and by the degree of their control over movement. Their procedures for road movement are more complicated, as they have not the same degree of freedom of movement as we have by virtue of our agreement with the Germans which I mentioned earlier. This co-operation extends on occasions to an exchange movement (under secure cover!) of Bourbon and Scotch!

There is, of course, a very close liaison at all levels between RAF and Army movements, particularly on the air trooping side. At Gutersloh RAF station, the movement control unit at the airfield is an entirely joint unit, commanded by a squadron leader, with a MCS Captain as his second in command. At the other air trooping terminals, RAF and Army rank and file are exchanged. There are certain limitations to this exchange, because the RAF personnel are trained to load freight aircraft and prepare aircraft documents whereas soldiers are not.

For liaison with the Deutsche Bundesbahn a railway liaison officer with a small civilian staff is attached to the DB Direktion HQ at Hannover. He is the link between the DB and the British Forces and the Canadians and performs an extremely useful and busy function. He is part of the army organization, being responsible to the Colonel Q (Movements) at HQ BAOR, but his impartiality is ensured by the fact that he is an ex-fighter pilot of the RAF!

We assist the Canadian Infantry Brigade Group in many matters and keep a close liaison with their Brigade RASC officer who is their senior movements officer.

Army Emergency Reserve

No account of the Movement Control Service in BAOR would be complete without a reference to the AER (MC and TN). The first stages of mobilization and/or alert measures, inevitably involve a formidable amount of movement, including reinforcements from the UK and deployment of stocks and units. These tasks cannot possibly be controlled by the peace time MC Squadron in BAOR for more than a few days, and we therefore have to rely on the early arrival of MC reinforcements. These include two units of the AER, one of which provides British Liaison Officers with the various national movement agencies in Germany, Belgium, Holland and France. Both units send a proportion of their officers and other ranks to train in BAOR each year, so that they can train effectively for their war time role and get to know the procedures used and the personalities in the NATO Allied HQs. They are an exceptionally keen body of men and include some very high standing executives and directors in the British Railways Board and other travel organizations: and, of course, between them bring a large amount of expertise in movements to bear on the tasks. Many of them know each other and know serving MC officers—a very useful factor in their type of employment. This comradeship and exchange of views is fostered by the Movement Control Officers Club, a flourishing organization with a wide range of serving and past MC officers—including a growing number of regular officers—many drawn from civil transport and travel organizations. Their main club function is denoted by their well known cry—"The Second Tuesday at the Albert".

The Future

I would like to digress from BAOR and briefly look at the future of the Movement Control Service. Is it going to remain a Corps responsibility? What has it to do with engineering? Where will it fit into the rationalization of the Services? These are all very relevant questions today, when the integration of the Armed Services and the rationalization of the services in the Army are being studied and reviewed, and they certainly will affect the future of the Corps to some extent. I believe that the amalgamation of the Movement Control Service with the Transportation side of the Corps is a good "shot-in-the-arm" for Transportation, because there is a need for flexibility. Our small regular army cannot afford specialist troops unless there is a real need for them in cold war operations before reservist forces are mobilized: viewed in this light, it is questionable whether there is sufficient justification for railway operating and maintenance units in the peace time army, unless the majority of the personnel can be used in a secondary role, and thereby achieve a degree of flexibility. Again is a Transportation Corps, on the lines of the US Army Transportation Corps required? The latter, formed during the last war when money was no object and manpower not a limiting factor, is not an unqualified success. There is a distinct difference between the two functions of "Management" and "Operating".

"Management" is the staff action involved in co-ordinating agencies to execute a common transport task: with it goes the requirements for an executive control by a movement control agency situated at nodal or interchange points. "Operating" is the technical functioning of each individual transport agency and varies from the simple business of driving a lorry to the complex operation of a jet aircraft or an inter-planetary space ship. The various transport agencies, road, rail, ship, air, have very little in common with each other as regards operation. I do not believe it is a sound proposition purposely to mix up the management and movement control function on the one side with the function of all or some of the operating agencies on the other side into one Transportation Corps. I would suggest that the management and movement control (ie Movement Staff and the Movement Control Service) be kept clearly as a separate function, but for the purpose of training and of ensuring flexibility of personnel, it should be combined with another related function; eg Transportation, RE or RASC transport or Provost traffic control. From the Corps point of view, I believe we should try to keep it with Transportation, as in fact is at present being done.

Conclusions

An appointment in "Movements" can lead to a most interesting and varied tour of duty; so, in the words of Colonel Dennis Thackeray, do not be despondent if opportunity takes this particular turn in the career planner's maze. The size of the Movement Control Service in peace is very small, but it has a sound backing for mobilization in the AER. It is of particular interest at present in view of the trends and recommendations of rationalization and integration within the Armed Services.

Nuclear Training Within the RSME

By D. R. Trotman, Esq, BSc, MSc(Eng), AMBrit IRE

Lecturer in Nuclear Engineering, Royal School of Military Engineering, Chatham

Technical training dealing with atomic energy can be concerned with both nuclear warfare and the controlling of power in nuclear reactors. Both are important aspects of this rapidly-developing technology, and the role and responsibilities of the Royal Engineers are such that nuclear reactors must now become increasingly evident as part of their technical training.

At the RSME Chatham, officers attend Long Engineering Courses, leading to the qualifications of AMICE or AMIMechE. It is, however, the E and M officers who are, and always will be, concerned mostly with nuclear power generation and consequently they receive the greater portion of the nuclear instruction. The civil engineering courses are given sufficient basic reactor engineering instruction to enable them to "understand and think nuclear".

The course given to E and M officers consists of six weeks instruction spread out over a twelve-week span to give ample time for private study. The first party of officers who attended this course suffered a six-week concentration of effort; quite rightly they complained (as did the lecturers) that "non-stop nuclear" was very exacting!

The training is divided into three main parts. Theoretical instruction, practical training, economic/logistic exercises and examinations and student lecturettes, as part of the final week.

Theoretical training. The theoretical introduction covers a wide field and comprises some eighty 45-minute lectures, spread out over eight weeks. The term "introduction" may seem something of an anomaly, particularly to the student who is grappling with it and, indeed, very little further theoretical training is given beyond that point. Nevertheless, at least five of the six subjects taught could *each* be expanded to eighty periods if required, so that as far as the depth of subject is concerned it is only relatively elementary.

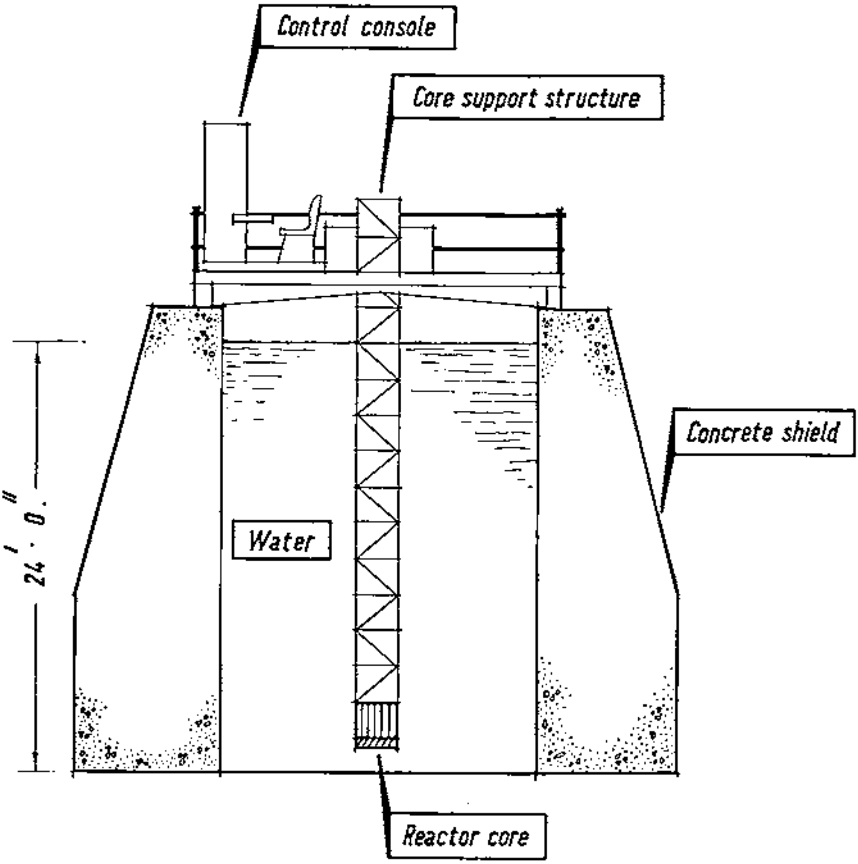


Fig. 1. A "swimming pool" reactor is perhaps the simplest of the research reactors. The reactor core is cooled by ordinary water, and is readily viewed from the surface.

After the first lectures, in which the student encounters atomic structure, isotopes, radioactivity, and fission reactions, the question of health and safety is next considered. This subject is of considerable importance, not only in reactors but even more so in the warfare aspect. Thus the subject deals with maximum permissible doses of radiation, methods of protection, contamination control, design and forward planning. It is during the Health lectures that those mysterious units, the RAD, REM, RBE, ROENTGEN are introduced, the so-called tolerance level of which seems to be in constant dispute.

The main object of this nuclear course is to produce officers capable of operating and controlling a nuclear reactor, and so the principal portion of the theoretical training is devoted to control, instrumentation and engineering, some forty periods in all. As an introduction to the instrumentation, a few lectures on electronics are given, leading to the relatively straightforward reactor control channels and associated safety circuits and interlocks. The engineering aspect covers a wide selection of reactor systems, such as the MAGNOX, PWR, APPR and mobile reactors, research reactors and the nuclear energy depot concept. In addition the component parts, such as fuel, coolant, moderator, and heat exchangers, are covered in detail. Aspects of radioactive waste disposal and advanced reactor concepts, such as magneto hydro dynamic generation, serve to round off the engineering lectures.

To complete the theoretical training, several lectures on reactor theory are given, dealing with such subjects as the life cycle of thermal neutrons, reactivity, neutron diffusion and reactor kinetics. Where possible, a non-mathematical approach is given, bearing in mind that the officers on the course are being trained for operation and control, rather than design.

Practical training. It is with this background knowledge that the officers pass to the second part of their course, namely, practical training. For this, they leave the confines of the RSME, and are attached to the Atomic Weapons Research Establishment at Aldermaston, and come under the auspices of the Army Element there. Despite the title of the establishment, the course is in no way concerned with weapons, and spends much of its time working on the "swimming pool" reactor "Herald" and the lower power version "Horace". It is here that the officers are allowed to operate and perform experiments with these reactors, taking some ten days in all. The Reactor School at Harwell is also used for part of the training, in particular for heat transfer experiments and the Reactor Simulator. Laboratory work, dealing with the fundamental properties of alpha and beta particles, gamma rays and neutrons, is also carried out. The first course performed this laboratory work at the Royal Military College of Science, and the second course are visiting the Royal Naval College at Greenwich. Both colleges have well equipped laboratories for this level of training, and instruction in these subjects is essential in order to maintain a well-balanced course. In all, the practical training with supporting lectures lasts three weeks. This includes a day visit to Winfrith Heath Atomic Energy Establishment, to see the large number of experimental reactors there.

Completion of the course. For the sixth and final week, the course returns to the RSME. Here the word "examinations" rears its ugly head, and the students are set three separate papers on Basic and Health Physics, Electronics and Control, Engineering and Reactor Physics. In addition, each student presents a 30-minute lecture on a nuclear subject. This latter item is the result of the student being given a text book on a single nuclear subject, eg, reactor shielding, and from it prepare his lecture. Thus, this is by way of an investment for the future, because we then have one qualified nuclear engineer officer with special knowledge of reactor shielding. Other subjects being given for special study include reactor heat transfer, steam cycles, radioactive waste disposal, instrumentation, and control of hazards.

There are obviously many situations, either in peace or limited war, when nuclear power is a favourable means of producing electricity. Conversely, fossil fuel systems may be more favourable, the deciding factors being relative fuel costs, logistical situation, and size of plant. The pros and cons of the nuclear versus fossil fuel systems are evaluated by the course in the form of an exercise for a number of different situations, such as Christmas Island, Gibraltar or Cyprus. Factors such as fuel cost, electrical requirement, capital cost and interest rate are taken into account. For a limited war situation the cost is not all important and the main factor becomes one of logistics, so that the two possible applications of nuclear power are not alike for those reasons.

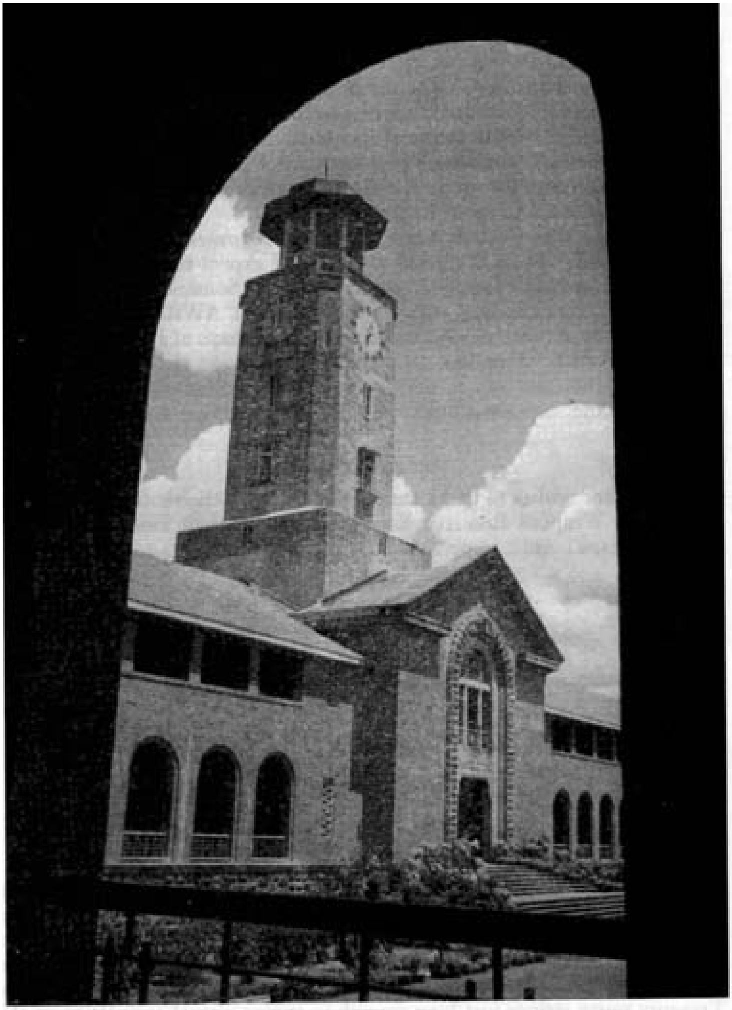


Photo 1. The clock-tower and main entrance of the Headquarters Building seen through an archway of the Transportation Wing.

Where India Engineer Officers are Trained 1

Photo 2. The Headquarters Building and the approach road from Dapodi.

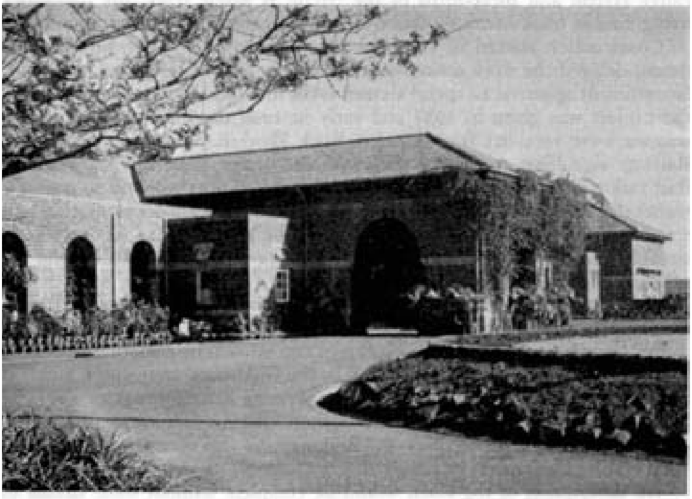


Photo 3. The Headquarters Mess showing the main entrance and porch on which bougainvillea may be seen.

Where India Engineer Officers are Trained 2 & 3

Photo 4. The Assembly Hall, seen from the old Nasik Road, is used for addresses, lectures and occasionally for theatrical productions.

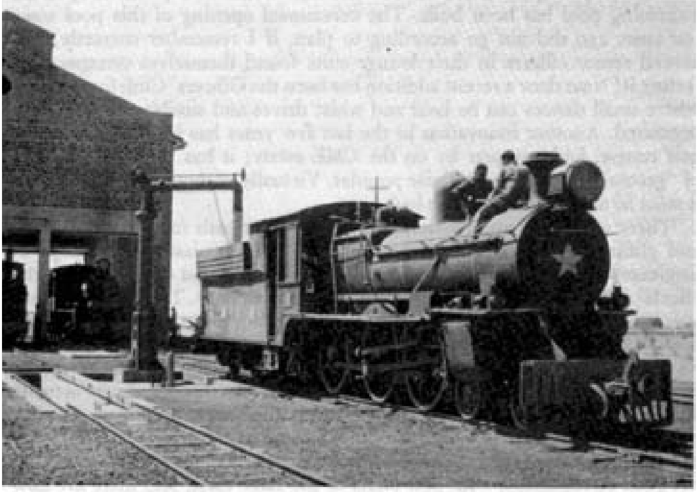


Photo 5. Fitters at work on one of the four steam engines of the CME Railway. This old 4-6-0 once ran on the South Indian Railway.

Where India Engineer Officers are Trained 4 & 5

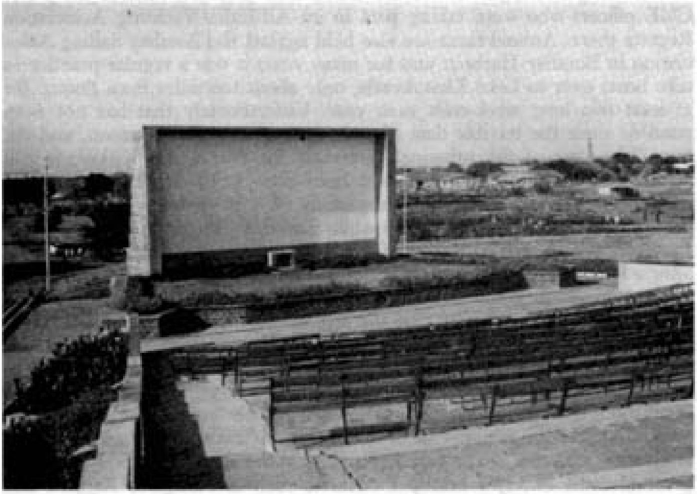


Photo 6. The open air cinema has a wide-vision screen and is flanked by beds of bright red cannas and other flowers.

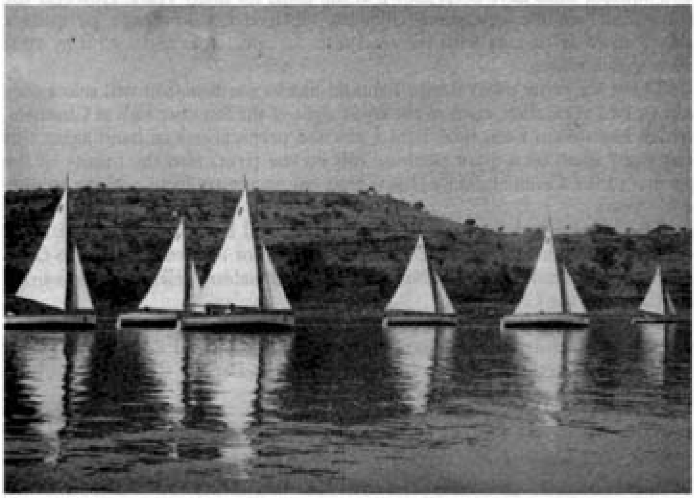


Photo 7. "Wagtails" of the CME Sailing Club competing in a race some years ago on Lake Kharakvasla.

Where India Engineer Officers are Trained 6 & 7

Other nuclear instruction. As already mentioned, long civil courses receive lectures on nuclear engineering, lasting up to one week, carried out entirely within the RSME. It is also proposed that YOs should receive a few nuclear lectures, primarily to introduce them to the subject. For senior officers, the Senior Officers Engineer Planning Course, held at the RSME once a year, had one day of nuclear instruction for the first time this year. This was well received, and the course may be modified next year to include some nuclear tactical problems.

So far all instruction given at the RSME has concerned officers only, but obviously training must also be extended to other ranks. This is involving a reassessment of the trade training, including new trades such as say, Clerk of Works (Nuclear), who would become Reactor Superintendents should the Royal Engineers be fortunate enough to possess reactors of their own, in keeping with the US Corps of Engineers.

Conclusion. It is clear that the training is at present being given to the select few, and even in five years we can only expect twenty to twenty-five E and M officers to be trained to these standards. Some of these officers may receive additional training elsewhere, such as at AWRE, CEGB nuclear power stations, or with nuclear consortia, and perhaps at Fort Belvoir in the USA. At present, we in this country lean heavily on the USA for military reactor concepts, and only by persevering in our nuclear engineering training instruction and experimentation can we hope to give something back in return.

ACKNOWLEDGMENT

The author wishes to thank the Atomic Power Construction Co Ltd, and the Atomic Weapons Research Establishment, for their kind permission to publish Photos 1 and 2 respectively.

Where India's Engineer Officers are Trained

By "BANGALORE-WALA"

THE Indian equivalent of our RSME is their College of Military Engineering, located at Dapodi a suburb of Poona, not far from the depot of the Bombay Engineer Group (formerly the Royal Bombay Sappers and Miners) in neighbouring Kirkee. Built during the early years of Indian independence, it has benefitted from the new national fervour that fortunately loosened the Treasury purse strings just long enough to ensure virtual completion of this bold and imaginative concept of large and imposing buildings, carefully sited on a spacious estate of 4,000 acres. As will be evident from subsequent paragraphs, the CME is in many respects like Chatham, Shrivenham, Hermitage and Longmoor rolled into one. After serving on the staff there in its early days, I was most fortunate to have the opportunity of revisiting the

College in the spring of 1963 when I was able to see many completed buildings and projects that had scarcely been initiated ten years ago. The CME cannot fail to impress the visitor and the Indians are justifiably very proud of it as the Centre of their Corps of Engineers.

Prior to the Second World War no such centre existed. Officers were trained in Britain and in civil universities in India while Other Ranks were trained at one of the three Sappers and Miners depots. However, in order to train military engineers for South East Asia Command the Indian SME was established at Roorkee in September 1943. It was alongside the civil Thomason Engineering College and in fact used many of the latter's facilities, such as buildings, equipment and lecturing staff.

At the end of the war, with the expansion of the Thomason College into a university, the SME was moved to its present site near Poona, and the first course started in February 1948. At that time the school was housed in temporary hutted accommodation, a wartime camp built a few years before for the United States Army, but considerable expansion and new construction had already been planned.

With the coming of Independence it was necessary to provide education for a technical engineering degree, not only to experienced officers of the new Corps of Engineers but also to the large number of young officers who would be joining. Thus regular Degree Engineering courses for Engineer officers were started in 1948; each of these lasted about two and a half years. Soon, Degree courses for EME and for Signals officers followed and about 1950 the school was rightly renamed the College of Military Engineering. Permanent buildings were required and the whole construction project was divided into three main phases, during the first two of which many of the temporary buildings would continue to be used, pending completion of new living quarters for the students, an officers' mess and other buildings. Amongst the first of the new buildings to be taken into use were the Field Engineering Wing and Electrical and Mechanical Wing, both of single storey construction and square in shape round a large internal courtyard incorporating fountains and gardens. Lecture rooms and offices were wonderfully spacious and well equipped, and model rooms and equipment displays ingeniously arranged, while everywhere wide verandahs and high ceilings gave an impression of quiet and coolness.

The project was a vast one and included an entirely new road system, the planting of hundreds of trees and flowering shrubs, the construction of playing fields and other recreational facilities, quite apart from administrative and instructional buildings, barracks, students' quarters, married quarters for all ranks, schools, canteens etc., etc. Dry bridging gaps had to be prepared and a huge amount of wet and dry bridging equipment, machinery, plant and laboratory equipment positioned and brought into use. In addition a self-contained training railway had to be constructed from scratch.

All this has taken time, but the completed college is a magnificent place. It lies between the twin flat-topped Dighi hills, a couple of miles to the east, and the main Poona-Bombay road to the west, while its southern boundary is the Mula River, which of course provides certain facilities for bridging and rafting. The setting is a noble one and the distant view of hills forming an arc to the south and west is pleasing to the eye.

Looking from the Poona-Bombay road or railway where they cross the Mula, the long double-storeyed Headquarters Building, with its tall central clock tower, can be seen on the top of gently rising ground as it looks out south-westwards to the main entrance gates in Dapodi village; it is a feature of the Poona area. Not only does it house the Headquarters offices in the central portion, including the Commandant's and Deputy Commandant's, both upstairs now, though originally on the ground floor, but also the large Civil Engineering Wing with its Construction, Survey, Soils, Roads and Airfields and other schools and also the much smaller Transportation Wing.

Behind, and to one side of, this imposing pile is a small square house that looks somewhat incongruous, but is nevertheless rather ingenious, for it demonstrates all types of building construction and the many technical terms used. Names are displayed and students can see at a glance Flemish bond here, English bond there, what the soffit of an arch is and many other things besides.

Nearby also is the Assembly Hall used for important lectures to all students and members of the staff, and similar functions. This fronts on to the former Poona–Nasik road that has now become an internal road only, the whole estate being by-passed by a new highway to the west that links up with the old road further north.

That apparently essential feature of all British-inspired road layouts, the roundabout, can be seen at a number of road junctions, and the Royal Engineers' influence is clearly reflected in one or two of the road names, such as Brompton Lane, which, incidentally, are painted now in the English language only. Nevertheless I was struck by the very recent Americanisms that seem to have crept in; for instance the CME "Campus" and the "Faculties" of Engineering and of Combat Engineering. The last named has a headquarters controlling two wings, the Field Engineering Wing and the Tactics Wing and is commanded by a Colonel. The other faculty controls the Civil Engineering and E & M Wings. Besides the Transportation Wing, already mentioned, there is an Administration Wing whose functions are obvious, and the Military Engineer Experimental Wing, dealing with research that has Soils and General Engineering Sections.

At any one time there are probably about 300 student officers in residence, three-quarters of whom are on YO's Degree Engineering Courses, of which there are different kinds for Engineer, EME and Signals students. Other Engineer YO's will be on a nine months' Field Engineering and Bridging Course; they must attend this on first commissioning and prior to being posted to a unit. About eighteen months later they are back at the CME to take their degree course.

Apart from these there are the normal periodic Field Engineering and Bridging Courses for Unit Commanders, Commanders Engineer, All Arms Courses in field works, Plant and Workshops Courses, short Transportation Courses, etc.

Between 150 and 200 JCOs and ORs are also in residence at any one time, engaged on JCO/NCO Instructors' courses, various works courses for overseers, draughtsmen, mechanists and others, certain transportation and other specialist trades courses beyond the scope of the three Engineer Groups.

There are no Long Transportation Courses such as we have, nor any of the other long courses that involve attachment to civil firms. Advanced survey is not taught at the CME. Advanced bridging training, however, is given in tidal waters at Marve, on the sea coast not far north of Bombay, while port and IWT training of a somewhat limited kind is carried out at Bombay itself.

A very large proportion of the instructional staff at the CME are civilians, there being a number of professors who teach academic subjects such as mathematics, the theory of structures and civil engineering and E & M subjects. There are also civilian scientists employed in the various experimental and testing departments. Other civilian instructors are in the workshops and elsewhere.

The CME Railway was of particular interest to me, and I was able to ride round the 8-mile circuit in a special train. When the Commandant advised me the evening before not to have any breakfast before joining him at the station at 8.15 a.m. as we should get it on the train, I laughingly replied, that I had eaten eggs and bacon cooked "on the shovel" before now, at Longmoor. Imagine my surprise, therefore, when we boarded the last coach of the pale blue painted special train to find a long table laid for breakfast and a turbanned mess-bearer asking how we wished our eggs and bacon to be cooked! There were also cereals, toast and marmalade and coffee and I ate one of the best breakfasts ever served to me during my Indian visit, punctuated with several visits to the rear observation platform where I returned the salutes of pointsmen and others of the Railway Unit that operated the line, as we trundled round. I later inspected the engine shed with its inspection pits etc and was struck by the fantastic cleanliness of the place, which of course has not been used to any great extent yet. In any case Kirkee weather, unlike that at Longmoor, permits locomotives to be cleaned and repaired in the open for three-quarters of the year!

Unlike our own Longmoor Military Railway, the CME Railwy is not connected to the main line at all, the gauges being quite different. It is a metre gauge system and three-fifths of the circuit is single track, the remainder being double track (work on this was still not completed when I saw it).

Construction started in 1952 but a severe shortage of sleepers (and of funds) delayed the work seriously after about a mile of track had been laid. Government approval to spend sixteen lakhs of rupees (£120,000 approx) on the project was given in 1955 and early in 1959 the first locomotives and wagons were received from Golden Rock Workshops in Southern India. Railway signalling equipment followed and today there are six stations, four rather ancient steam locomotives, all of different types (and so posing a wonderful spare parts problem) and about a dozen miscellaneous coaches and wagons, besides a much-used railway jeep and a Wickham car. At one place a sizeable nullah is crossed, one track being supported by a TS Bailey and the other by a UCRB span.

The Transportation Wing has quite an elaborate model room in the main Headquarters Building and in the basement there is a very extensive model railway layout used for training blockmen and other transportation trades.

In India, "TN" has got "becalmed in the Doldrums' so to speak and it is not clear to what extent military railway operating and maintenance might be necessary, say in Assam, should the Chinese threat again materialize. IWT, could come into its own again on the Brahmaputra and even Docks Operating (as it is still called) might be required.

No description of the CME would be complete without some details of the very spacious Officers Mess, all on the one floor. The lofty dining hall can seat 275 officers at a time; its design is very simple and the only decoration is provided by the splendid silver trophies, of which there is already quite a wonderful collection for use on special occasions, and by the regimental pagris and cummerbands of the bearers waiting on their masters and flitting to and fro silently across the polished stone floor. The main hall has two large oil paintings of Lieut-General Sir Harold Williams, the first Colonel Commandant of the Corps of Engineers who had commanded the SME at Roorkee both during and after the war, following on Brigadier C. G. Martin, VC who was the first Commandant, and of General Srinagesh, the first Indian Colonel Commandant of the Corps. Both these pictures are really magnificent and I was told that two more, of Generals Kochhar, who is another Colonel Commandant, and Harkirat Singh, the present E-in-C, will be added shortly. Considering the short time since they were started, the Mess gardens have progressed most remarkably and despite the water shortage mentioned later were gay and colourful with cannas and bougainvillea, etc. This mess of course is the Corps Headquarters Mess, and, being a new institution, it has had to compete in popularity with the far older and more historical messes of the three former Sappers and Miners Groups. Having recently visited two of these and seen how superbly they are kept and how progressive they are in blending new ideas and improvements with the old traditions and layout, I would say that the CME Mess has an 'uphill fight'. The Group Spirit, so well known to many British officers, is still amazingly strong and the new *esprit de corps* has not been entirely successful as yet in its bid to 'take over'. There is no question of destroying the old but only of making it subservient to the new.

I was interested to see how quickly trees and shrubs had grown up, not only in the gardens of the principal Group IV and Group V officers' married quarters, but along the road that separates them from the sports ground where cricket is played and on the far side of which a pleasant open air swimming pool has been built. The ceremonial opening of this pool some ten years ago did not go according to plan, if I remember correctly, and several senior officers in their lounge suits found themselves unexpectedly testing it! Next door a recent addition has been the Officers' Club for families, where small dances can be held and whist drives and similar club activities organized. Another innovation in the last few years has been the nine-hole golf course, laid out near by on the CME estate; it has "browns" instead of "greens" and is proving quite popular. Virtually without an inch of shade it must be as good as a Turkish bath!

There are sports and pastimes for all tastes, squash racquets, volleyball and gliding are but a few, and clubs for the enthusiasts. The Corps of Engineers Sailing Club is a particularly thriving one that owes much to the efforts of British officers in establishing it in its early days. The clubhouse still stands on the former well shaft with its race control tower at the top of what used to be the bullock ramp, but the old bamboo and chattai roof has given way to a much more sophisticated and lasting structure. Because of the fickleness of the wind just there, I understand that races are now usually started half a mile or more downstream near the Kirkee Ordnance Factory but finish at the clubhouse. The original fleet of Dublin Bay Wagtails, some of which came from the long-since defunct Royal Connaught Club at Poona, has been strengthened with new boats of the same class, and there are now brightly painted CBKs as well. Incidentally, the CME club has successfully "exported" both classes to its comparatively new sister club, the Defence

Services Sailing Club at New Delhi where I also enjoyed a pleasant evening's sail on the Jumma, just above the Okhla lock gates. At Madras too I met CME officers who were taking part in an All-India Yachting Association Regatta there. Annual races are also held against the Bombay Sailing Association in Bombay Harbour and for many years it was a regular practice to take boats over to Lake Kharakvasla, only about ten miles from Poona, for at least two long week-ends each year. Unfortunately that has not been possible since the terrible dam disaster during the 1960 monsoon, and the huge lake, one of the principal reservoirs for Poona and Kirkee, is still almost dry. Only minor repairs had been done to the big breaches and I understood that, pending the completion of a governmental inquiry, no rebuilding would take place. Meanwhile (and this was one of the first things I noticed when I arrived at the CME in the middle of the night, hot and dirty after a long train journey) there is quite severe water rationing. Needless to say, this made the whole place look more dried-up than usual for the end of March. I got the impression that the lack of the Kharakvasla Regatta, combined with the extra burden on training caused by recent events on the Indo-Chinese border and the transfer of some of the "main stays" is beginning to have a slightly adverse effect on the club, but even the most successful institutions must have their "downs" as well as their "ups".

This expression reminds me of the organized "hikes" there used to be for students some years ago on certain Sundays in the monsoon period, when the great Maratha Shivaji's hilltop fortresses, such as Sinhgarh, Rajgarh and Porundhar were "reconquered". I think this practice, which was both instructive and physically beneficial, has been curtailed in recent years, and one did not hear accounts of the hikes in the mess as in the old days.

In a country still free from television, the "talkies" are as popular as ever and outdoor films have been shown at the CME for many years. However the somewhat "ad hoc arrangements" were replaced not long ago by quite a smart open-air cinema with terraced seats for spectators and a 40 ft by 20 ft wide-vision screen.

There are many other things I should like to mention, but will select only one or two at random, such as the equivalent of the Summer Ball at Chatham, which has always been held (and I saw the preparations in hand again this last year) afloat on a giant pontoon raft on the river; also the beauty of the garden of the Commandant's House that has grown up from nothing in only a few years.

The Indian version of our Institution of Royal Engineers, the Institution of Military Engineers, however, is not based on or located near to the CME but at Army Headquarters in New Delhi. Nevertheless their quarterly journal is printed on the CME press.

The Indian CME is a magnificent centre of military engineer learning and worthy of a salute of appreciation from us in the Royal Engineers "everywhere", or "Sarvatra", which is the Hindi equivalent of "Ubique" and the motto of the Engineers in India.

Critical Path Planning and Scheduling

By MAJOR H. P. MUNRO, RE(TA), BSc(Eng), AMIMechE, AMIChemE

INTRODUCTION

CRITICAL path planning and scheduling (CPPS) has been introduced by many companies, particularly those in the construction industry, as it is a very successful tool both for Engineering Planning and Scheduling as well as for Management. This article is intended as a "layman's guide" to show how it functions and its application to a small engineering project.

DEFINITIONS

The following terms are used in CPPS.

Job. The smallest practical part into which a task may be divided. Each job is denoted by an arrow in an arrow diagram.

Arrow diagram. A completed plan of a task showing sequence of jobs.

Critical path. Is the sequence of arrows, which make up a continuous path (or paths) throughout the arrow diagram, which determine the overall time required for the task.

Elapsed time. The duration of a job in time units.

Node. Junctions of arrows (ie jobs) on an arrow diagram.

Restraint. A factor which imposes a limitation on the starting (or finishing) of a job.

Network. An arrow diagram with all the nodes numbered and all arrows given elapsed times.

Earliest Start (*ES*). The earliest time a job can be started.

Earliest Completion (*EC*). The earliest time a job can be completed.

Latest Start (*LS*). The latest time a job can be started so as not to delay the overall task completion time.

Latest Completion (*LC*). The latest time a job can be completed so as not to delay the overall task completion time.

Total Float (*TF*). The amount of time a job can be shifted without necessarily affecting the overall task completion date.

Free Float (*FF*). The amount of time a job can be shifted without affecting any *subsequent job.*

ARROW DIAGRAMS

Planning

The basic planning of CPPS is done by an arrow diagram which is akin to a works table.

Jobs are expressed by arrows thus ——→, but before an arrow can be drawn the following six factors must be known about each job.

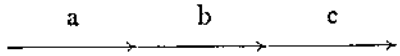
(i) What factors control the start of it?
(ii) What job immediately precedes it?
(iii) What job immediately follows it?
(iv) What other job (or jobs) can be done concurrently with it?
(v) What factors control the completion of it?

And lastly for scheduling only:

(vi) What is the elapsed time of the job?

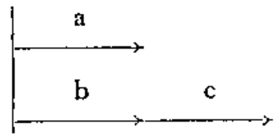
Having obtained the answers to the first five factors listed above it is possible to draw an arrow diagram. As an example consider the following cases:

(*a*)



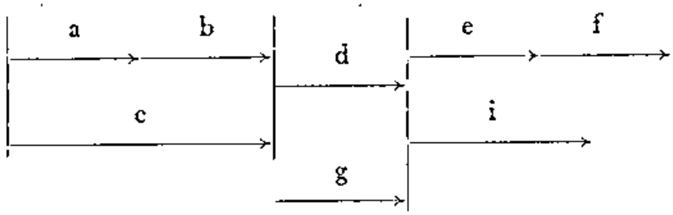
This means job "c" can only be started when "b" is finished, which in turn can only start when "a" is finished.

(*b*)



This would mean job "c" can only be started when "b" is complete but jobs "a" and "b" can be done concurrently.

(*c*)



This means the following:—

(i) Job "b" must follow job "a" but it can be done concurrently with job "c".

(ii) Job "a" and "c" can be started concurrently.

(iii) Job "d" can only be started when both jobs "b" and "c" are complete.

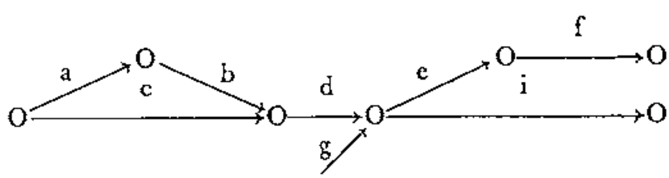
(iv) Job "g" can be done at any time but must be completed by the time job "d" is completed.

(v) Jobs "e" and "i" can both start when "d" and "g" are complete and can be done concurrently.

(vi) Job "f" must follow "e", but the completion of jobs "f" and "i" are not correlated.

The above example (*c*) could be drawn like this:—

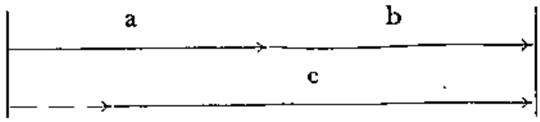
(*d*)



Both types of diagram are correct but the first type is more like a works table in appearance and is more easy to draw on a drawing board.

Dummy arrows — — — → are used logically to complete a plan. Suppose in example (*c*) job "c" could not start until job "a" had progressed a certain amount (eg as in building a road, the work on each stage of construction is often echeloned), then this could be expressed thus

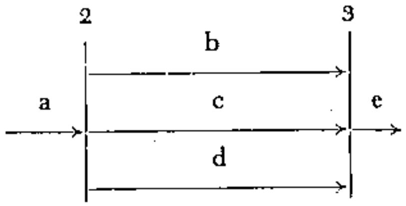
(*e*)



and when scheduling (see later) was done this dummy arrow would be given an elapsed time.

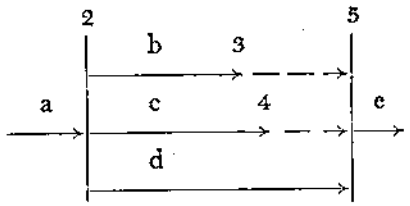
Similarly if two (or more jobs) have to be done between the same nodes, it would be impossible to differentiate between them without dummy arrows

(*f*)



should be drawn as

(g)



(alternatively the dummy arrows can precede the job)

In the latter case job "b" can be defined as step 2–3, job "c" as 2–4 and job "d" as 2–5. This would have been impossible in the first diagram, but the dummy arrows would not be given an elapsed time when scheduling unless echeloning was specifically required.

Scheduling

CPPS separates planning from scheduling. Initially the sequence of jobs is planned on an arrow diagram and when this is complete scheduling can start.

Whilst it can be said that a job priority list plans and a works table schedules, an arrow diagram gives a much clearer over all picture and can show much more information.

Scheduling is done in the following manner.

(i) Number the beginning and ends (ie nodes) of each arrow.

(ii) The number at the beginning of an arrow must be less than the number at the end and the first node must be numbered 1 and not 0. It is desirable for computer computation that all arrows are numbered correctly. If the numbering of a certain node is omitted in error and subsequently discovered then the diagram may have to be renumbered again (correctly) throughout.

(iii) The elapsed time of each job must be ascertained and written below the arrow (using the same time units throughout).

Having completed the above information for the arrow diagram (it is now called a "Network") the input information for either computer or manual computation can now be prepared by drawing up a schedule in columns headed thus: Step (numbered consecutively starting from 1); I Node (the node at which an arrow starts); J Node (the node at which an arrow ends); Elapsed time (duration of job); Job Description (or Job serial number).

The above schedule must be completed in the numerical order of "I" nodes, and when several jobs start with the same I node then list these in order of the "J" nodes.

An example of this is shown in Appendix D.

It is pointed out, however, that before this schedule can be evaluated on a computer, a computer programme code has to be written for that computer.

If a computer is not available, it is possible to complete the scheduling manually. This is laborious and takes a long time say, 12–16 hours for what a computer could do accurately in 40 minutes. Manual computation is described in Appendix A.

Both manual and computer evaluation will give the following information for each step listed in the input data:—

Step; "I" Node; "J" Node; Elapsed Time; Earliest Start; Earliest Completion; Latest Start; Latest Completion; Total Float; Free Float.

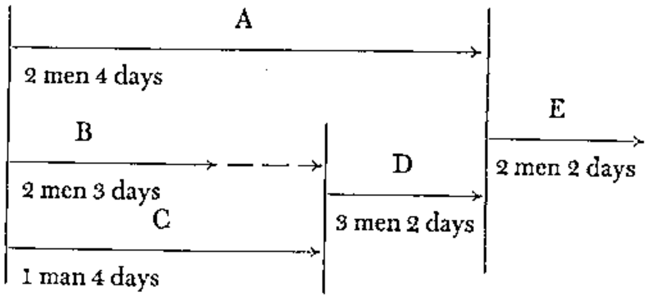
Restraints

So far no mention has been made of the labour force required (or available) to do the job in the given elapsed time. A computer can evaluate the schedule for a given labour force if the requisite input information (ie the number and type of each craft required for each job, and number of each type available) is supplied.

Manual evaluation involves keeping a progressive check on all the jobs deploying the labour in accordance with the planned sequence. This will highlight the bottle-necks and show where extra labour could be gainfully employed. This becomes very complicated for manual computation if more than say, three or four crafts are required.

Suppose a network is as under

(*h*)



By inspection it can be seen that the minimum time for the complete task is eight days (Jobs, C, D, E).

If three men are available how long will it take, and, if it is more than eight days, how many men are wanted to do it in eight days?

Case 1. *Three men available.*

	Days:	1	2	3	4	5	6	7	8	9	10	11
Men	1.	C	C	C	C	D	D	A	A	A	E	E
	2.	B	B	B	A	D	D	A	A	A	E	E
	3.	B	B	B	A	D	D					

Answer: eleven days with one man spare after six days. (Note: there are other ways to schedule this, but the shortest time is always eleven days).

Case 2. To do it in eight days.

	Days:	1	2	3	4	5	6	7	8
Men	1.	A	A	A	A	D	D	E	E
	2.	A	A	A	A	D	D	E	E
	3.	C	C	C	C	D	D		
	4.	B	B	B					
	5.	B	B	B					

This requires five men for three days, falling to three for a further three days and finally two for the last two days.

Thus if it is required to do the job in eight days, two extra men are required initially, and this assumes that only one craft is involved.

Example

As an example to illustrate the foregoing, a project involving the construction of a small power station containing two diesel driven alternators has been evaluated using CPPS.

The jobs (which for the purposes of the exercise have been curtailed in certain instances) are listed in Appendix B and include details such as finalizing plans, purchase and delivery of equipment as well as the actual site construction work. No attempt has been made to impose any labour restraints but physical erection restraints have been enumerated below the job list.

The network is given in Appendix C, computer input information in Appendix D and the manual computation in Appendix E.

It will be seen that the shortest time for the project completion is twenty-seven weeks. This could be reduced by three weeks if

(i) The design and construction of foundations (including curing) could be reduced by three weeks.

(ii) Structure delivery was one week early (this could be kept to the same delivery elapsed time if the design elapsed time was shortened one week—see (i) above).

The above two changes would result in the alternators being able to be installed on their fully cured foundations immediately on receipt. Secondly there would be no delay as a result of the ancilliary equipment not being complete. However, it would result in a very tight schedule.

Conclusion

As can be seen CPPS has many advantages over the older, more conventional, types of planning and scheduling. The more important advantages are:—

(*a*) It separates planning and scheduling into two separate operations.

(*b*) It is susceptible to computer application although manual computation, although laborious, is not difficult.

(*c*) It gives an immediate answer to the effect of delays and which are the critical jobs on the schedule.

(*d*) It indicates the interdependence between jobs, hence it consequently fixes responsibility for job completion times and increases co-operation.

(*e*) It can easily incorporate the time required for planning completion and for the ordering and delivery of equipment.

(*f*) When based on computer evaluation, revisions can easily be quickly worked out in view of revised estimates (eg late deliveries, etc).

(g) It can indicate which jobs are worth using a "crash programme" to reduce the overall task time.

Lastly it is pointed out that CPPS is not a "cure-all" to ensure success. It can be likened to a mathematical audit of a schedule to deduce the best possible one. However, ultimately, the human element, as it always is so, will be the final factor to ensure completion on time.

Acknowledgment

Acknowledgment is due to Mauchly Associates (England) Ltd for permission to publish this article as their parent company initially developed CPPS for commercial use.

Appendix "A"

Manual Computation

Definitions

I Node is the node at which a job starts.

J Node is the node at which a job finishes.

A is the earliest time a node (either I or J) can be reached.

Z is the latest time a node (either I or J) can be reached without extending the earliest completion time.

Method

(*a*). Lists all steps as for computer evaluation, in the ascending order of I nodes, with respective elapsed times, ie for each step J is greater than I.

(*b*). Make a separate list of all nodes in the network and then calculate the A of each node by

(i) Initially set all As to zero.

(ii) Taking the first step find the A of its I node by inspection of the network.

(iii) To this value add the elapsed time of the job to give an A for its J node. Repeat for any other step finishing at the same J node. The highest value of A thus obtained is the correct A of this J node.

(iv) Repeat for all other steps and nodes.

(*c*). Similarly calculate the Z of each node by

(i) Initially setting all Zs to the highest A obtained from (*b*) above.

(ii) Taking the last step find the Z of its J node (ie highest A value).

(iii) Subtract the elapsed time to give a Z for its I node. Repeat for any other step starting at the same I node. The smallest value of Z thus obtained is the correct Z for this I node.

(iv) Repeat for all other steps and nodes.

(*d*). Then compute for each step, the following information:—

(i) Earliest start = A of I node.

(ii) Earliest completion = ES + elapsed time of job.

(iii) Latest completion = Z of J node.

(iv) Latest start = LC—elapsed time of job.

(v) Total Float = LS—ES or LC—EC.

(vi) Free Float = A of J node—EC or subtract the EC of that job from the ES of subsequent job.

It will be seen that all nodes which have the same A and Z values are on the critical path and all steps which have a total float equal to zero form the critical path.

JOB LIST FOR EXAMPLE *Appendix "B"*

Serial No	Job	Elapsed time (weeks)
1	Finalize layout and equipment specification	2
2	Order two diesel driven alternators (ie receive tenders and place order)	4
3	Delivery of alternators	12
4	Installation of alternators	2
5	Design of foundations and structure	3
6	Purchase of structure	3
7	Delivery of structure	4
8	Erection of structure	3
9	Construction of foundations	8
10	Purchase of transformer	3
11	Delivery of transformer	8
12	Installation of transformer	3
13	Design of instrumentation	2
14	Purchase of Instruments	3
15	Delivery of Instruments	7
16	Installation of Instruments	4
17	Install lighting	2
18	Install plumbing	3
19	Painting structure	2
20	Painting equipment	2
21	Purchase of starting equipment and fuel tank	3
22	Delivery of starting equipment and fuel tank	8
23	Installation of starting equipment and fuel tank	4
24	Installation of cooling water	3
25	Fuel delivery arrangements	1
26	Testing	1

RESTRAINTS

(*a*) Foundation design; instrument design; purchase of starting equipment and fuel tanks cannot be started until the alternator order is completed.

(*b*) Foundations will require four weeks' curing before the alternator installation is started. Likewise they will require one week's curing before the structure installation is started.

(*c*) Instrument installation can commence five weeks after commencement of instrument delivery has started, but it will require two weeks to complete after the delivery is completed.

(*d*) Erection of structure cannot be started until the delivery is completed (subject to (*b*) above).

(*e*) Lighting and plumbing can be installed when the structure is complete.

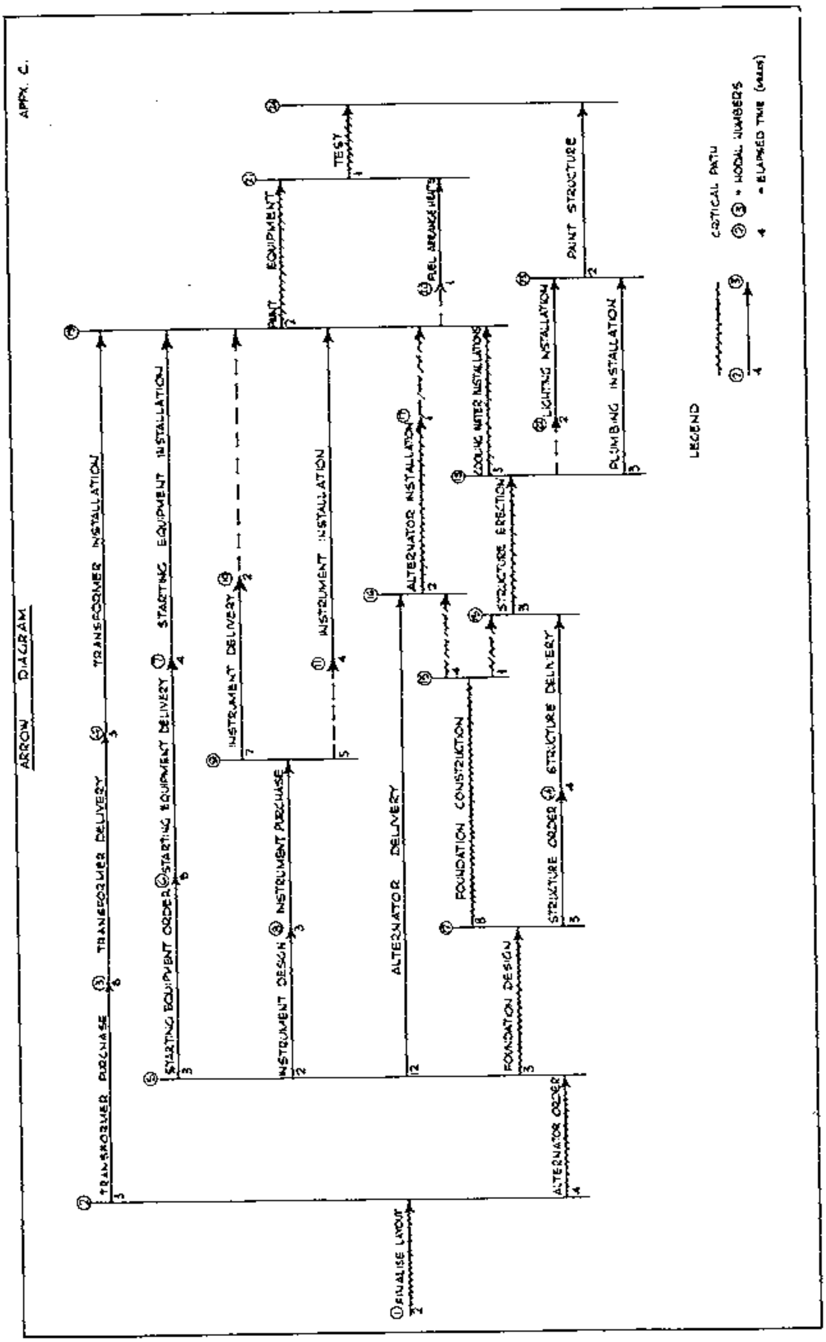
(*f*) Painting of the structure can commence when the lighting and plumbing are completed.

(*g*) Cooling water installation will require one week's work after the alternators are installed, but it can start when the structure is complete.

(*h*) Transformer/alternator connexions will require one week's work after the alternators are installed.

(*i*) Fuel arrangements require one week's notice which can be given once the cooling water is installed.

(*j*) Equipment painting can be done when all equipment has been installed, but must be completed before testing is started.



APPX. C.
ARROW DIAGRAM
FINALISE LAYOUT
TRANSFORMER PURCHASE
TRANSFORMER DELIVERY
TRANSFORMER INSTALLATION
STARTING EQUIPMENT ORDER
STARTING EQUIPMENT DELIVERY
STARTING EQUIPMENT INSTALLATION
INSTRUMENT DESIGN
INSTRUMENT PURCHASE
INSTRUMENT DELIVERY
INSTRUMENT INSTALLATION
ALTERNATOR ORDER
ALTERNATOR DELIVERY
ALTERNATOR INSTALLATION
FOUNDATION DESIGN
FOUNDATION CONSTRUCTION
STRUCTURE ORDER
STRUCTURE DELIVERY
STRUCTURE ERECTION
COOLING WATER INSTALLATION
LIGHTING INSTALLATION
PLUMBING INSTALLATION
PAINT STRUCTURE
PAINT EQUIPMENT
FUEL ARRANGEMENTS
TEST
LEGEND
CRITICAL PATH
= NODAL NUMBERS
4 = ELAPSED TIME (WEEKS)

Appendix "D"

Computer Input Information

Step	I	J	Elapsed time	Job Serial No
1	1	2	2	1
2	2	3	3	10
3	2	5	4	2
4	3	4	8	11
5	4	19	3	12
6	5	6	3	21
7	5	8	2	13
8	5	12	3	5
9	5	16	12	3
10	6	7	8	22
11	7	19	4	23
12	8	9	3	14
13	9	10	7	15
14	9	11	5	D
15	10	19	2	D
16	11	19	4	16
17	12	13	8	9
18	12	14	3	6
19	13	15	1	D
20	13	16	4	D
21	14	15	4	7
22	15	18	3	8
23	16	17	2	4
24	17	19	1	D
25	18	19	3	24
26	18	23	3	18
27	19	21	2	20
28	20	21	1	25
29	21	24	1	26
30	22	23	2	17
31	23	24	2	19

Note D = dummy due to a restraint.

Appendix "E"

Example—Output Data

Step	I	J	Elapsed time	ES	EC	LS	LC	TF	FF	Job No
1	1	2	2	0	2	0	2	0	0	1
2	2	3	3	2	5	10	13	8	0	10
3	2	5	4	2	6	2	6	0	0	2
4	3	4	8	5	13	13	21	8	0	11
5	4	19	3	13	16	21	24	8	8	12
6	5	6	3	6	9	9	12	3	0	21
7	5	8	2	6	8	10	12	4	0	13
8	5	12	3	6	9	6	9	0	0	5
9	5	16	12	6	18	9	21	3	3	3
10	6	7	8	9	17	12	20	3	0	22
11	7	19	4	17	21	20	24	3	3	23
12	8	9	3	8	11	12	15	4	0	14
13	9	10	7	11	18	15	22	4	0	15
14	9	11	5	11	16	15	20	4	0	Dummy
15	10	19	2	18	20	22	24	4	4	Dummy
16	11	19	4	16	20	20	24	4	4	16
17	12	13	8	9	17	9	17	0	0	9
18	12	14	3	9	12	11	14	2	0	6
19	13	15	1	17	18	17	18	0	0	Dummy
20	13	16	4	17	21	17	21	0	0	Dummy
21	14	15	4	12	16	14	18	2	2	7
22	15	18	3	18	21	18	21	0	0	8
23	16	17	2	21	23	21	23	0	0	4
24	17	19	1	23	24	23	24	0	0	Dummy
25	18	19	3	21	24	21	24	0	0	24
26	18	23	3	21	24	22	25	1	0	18
27	19	21	2	24	26	24	26	0	0	20
28	20	21	1	24	25	25	26	1	1	25
29	21	24	1	26	27	26	27	0	0	26
30	22	23	2	21	23	23	25	2	1	17
31	23	24	2	24	26	25	27	1	1	19

Notes. (*a*) All the above would be the output from either a computer or as a result of manual computation.

(*b*) The following data would have to be manually computed first, before the above can be done manually, but it would not be necessary if a computer were used.

Node	A	Z	Node	A	Z
1	0	0	13	17	17
2	2	2	14	12	14
3	5	13	15	18	18
4	13	21	16	21	21
5	6	6	17	23	23
6	9	12	18	21	21
7	17	20	19	24	24
8	8	12	20	24	25
9	11	15	21	26	26
10	18	22	22	21	23
11	16	20	23	24	25
12	9	9	24	27	27

By inspection it can be seen that (*a*) the critical path is through the following steps 1, 3, 8, 17, 19, 20, 22, 23, 24, 25, 28 and 29.

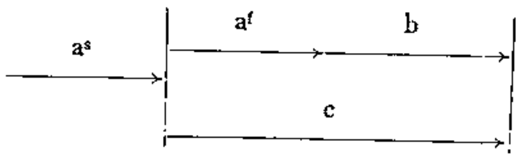
(*b*) The following nodal points are on the critical path 1, 2, 5, 12, 13, 15, 16, 17, 18, 19, 21, 24.

Note by Engineer Planning School, Royal School of Military Engineering, Chatham

Various planning techniques, basically similar to the Critical Path Method taught at the RSME, have been developed simultaneously and to fit a wide variety of different situations. It is not surprising, therefore, that differing conventions and nomenclature are met with. Those who have been instructed in these new techniques at the RSME, or have read our hand-out notes, will see at once that Major Munro's article differs from our teaching in some respects. This is not to say that his method is necessarily wrong—it is just differently presented.

There are, however, a few points in his article with which we do not agree, and which it is best to mention here. They are:—

(*a*) Dummy arrows should not be given "elapsed time" (ie durations) as we feel this is a contradiction. Instead, the case given in diagram (*e*) should be shown by splitting activity "a" into two parts thus:—



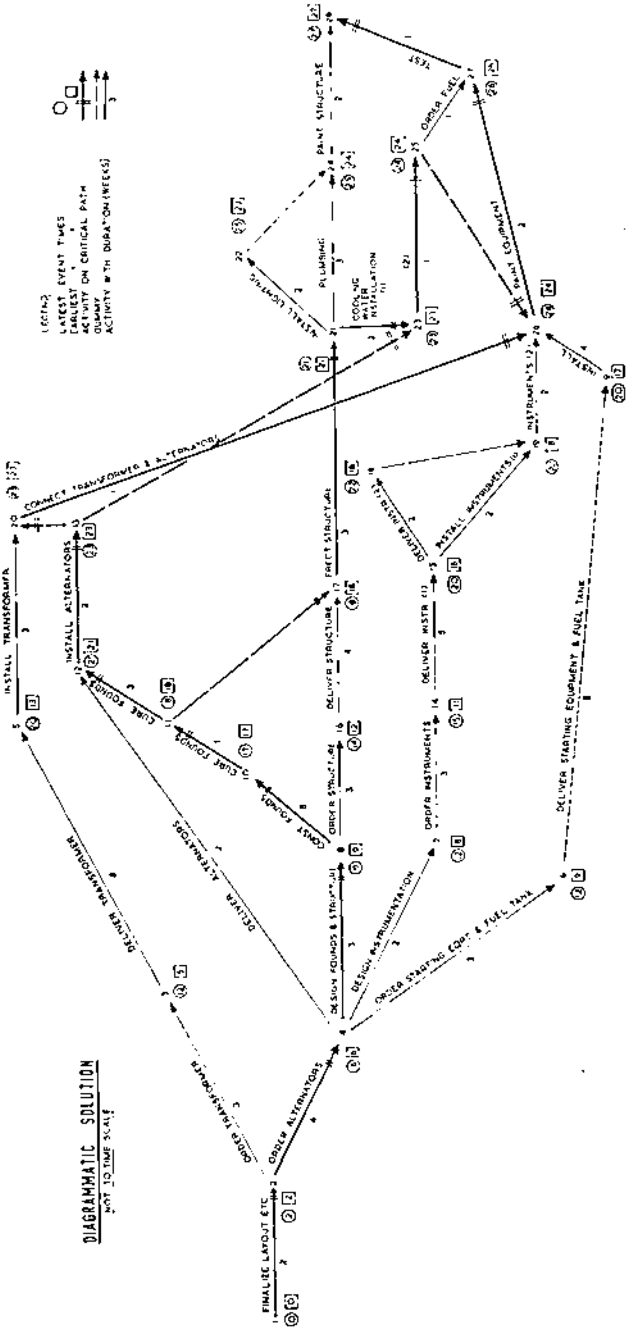
(*b*) Numbering of nodes (events), although normally done, is not essential for plans produced entirely on the arrow diagram, ie, without tabulation. Not all computer programmes require numbering in strict sequence.

(*c*) The system of tabulation recommended is merely using the planner as if he were a computer. For projects of moderate complexity the arrow diagram itself can be developed to give the critical path, total time required, etc, without the use of a computer and without tabulation. For example the project given in the article was analysed here with the result shown in the annexure following these notes. This arrow diagram, in the form familiar to recent students at the RSME, took about one and a half hours to produce. It gives all the information that can be derived from Appendices C, D and E of the article except for float times; these would become evident when the next step of producing the programme is carried out. For a project of this size, or even for one with several times as many "activities", it is obviously quicker and cheaper to calculate on the arrow diagram the earliest and latest event times, and hence the critical path, than it would be to prepare data and programmes for a computer.

An article giving the orthodox RSME approach to this interesting technique will be published shortly, probably in the next edition of this Journal. Of course there is a lot more to the business of planning than can be covered in one article; but those who have successfully absorbed Major Munro's most interesting article will have gained an understanding of some of the basic principles of Critical Path Planning.

N.R.S.

I agree that there are several different forms of presentation of this basic technique. Timings, my calculations, ie Appendix "E" (from memory) took about 45 minutes after completing the network. H.P.M.


DIAGRAMMATIC SOLUTION
NOT TO TIME SCALE
LEGEND
LATEST EVENT TIMES
EARLIEST
ACTIVITY ON CRITICAL PATH
DUMMY
ACTIVITY WITH DURATION (WEEKS)
FINALIZE LAYOUT ETC.
ORDER ALTERNATORS
ORDER TRANSFORMER
DELIVER TRANSFORMER
DELIVER ALTERNATORS
INSTALL TRANSFORMER
INSTALL ALTERNATORS
CONNECT TRANSFORMER & ALTERNATORS
DESIGN FOUNDS & STRUCTURE
DESIGN INSTRUMENTATION
ORDER STARTING EQPT & FUEL TANK
CONST FOUNDS
CURE FOUNDS
ORDER STRUCTURE
DELIVER STRUCTURE
ERECT STRUCTURE
ORDER INSTRUMENTS
DELIVER INSTR
DELIVER INSTR
INSTALL INSTRUMENTS
INSTRUMENTS
DELIVER STARTING EQUIPMENT & FUEL TANK
INSTALL
INSTALL LIGHTING
PLUMBING
COOLING WATER INSTALLATION
PAINT STRUCTURE
PAINT EQUIPMENT
ORDER FUEL
TEST

Presentation of Portrait of Lieut-General Sir Giffard Le Q Martel to the RE Officers' Mess, MEXE

A portrait, commissioned by the Corps Committee, of the late Lieut-General Sir Giffard Le Q Martel, KCB, KBE, DSO, MC, Colonel Commandant RE, painted by the Honorable George Bruce, RP was unveiled in the RE Officers' Mess, The Military Engineering Experimental Establishment, Christchurch on 3 October 1963 by Lieut-General Sir John Cowley, KBE, CB, Colonel Commandant, RE.

The present Military Engineering Establishment had its origin in the Experimental Bridging Company, RE set up at Christchurch under the command of Major Martel in February 1919. Martel had been Brigade Major of the Tank Brigade, commanded by another famous Sapper, Sir Hugh Elles, raised in the First World War, and his connexion with tanks continued through the Second World War when he was appointed Commander, Royal Armoured Corps. He was closely connected with the mechanization of Field Companies; he designed tracked vehicles for engineer work; the infantry carrier was the outcome of his inventiveness. He designed the Box Girder Bridge, known as the "Martel" Bridge, which was the forerunner of the "Bailey" Bridge. For his services and inventions he was awarded a very substantial sum by the Government, the whole of which he donated to the RE Benevolent Fund. He was a great boxer, being the Inter-Service Welterweight Champion in 1912–13 and again in 1921–22—a most remarkable achievement; he hunted, played polo and he was fond of shooting. He lost an eye as a result of injuries received during an air-raid on London. He died in 1958 and Her Majesty the Queen was represented at his memorial service, held in the Chapel of the Royal Military Academy, Sandhurst—a final honour and tribute to a most outstanding Sapper officer.

Amongst those present at the unveiling of his portrait, besides Lieut-General Sir John and Lady Cowley, were General Sir Charles and Lady Jones, Sir Donald and Lady Bailey, Major-General and Mrs T. H. Foulkes, Major-General G. W. Duke, Major-General and Mrs. G. N. Tuck, Brigadier and Mrs G. R. McMeekan, Brigadier and Mrs H. H. Bateman, Brigadier and Mrs L. R. E. Fayle, Brigadier S. G. Galpin, Brigadier and Mrs G. C. Richards, Brigadier and Mrs H. A. T. Jarrett-Kerr, Brigadier J. R. G. Finch, Colonel G. H. Hunt and Brigadier G. T. A. Armitage, representing the Royal Armoured Corps, and Mrs Armitage.

General Martel's successors at Christchurch have been:—

Officers Commanding, Experimental Bridging Company Royal Engineers

February 1919–January 1921	Major G. Le Q. Martel, DSO, MC, RE
January 1921–January 1923	Major A. V. T. Wakely, MC, RE
January 1923–August 1925	Major H. H. Bateman, DSO, MC, RE

Superintendents, Experimental Bridging Establishment

August 1925–November 1926	Major H. H. Bateman, DSO, MC, RE
November 1926–November 1930	Captain R. D. Davies, RE
November 1930–November 1932	Major J. B. H. Doyle, OBE, RE
November 1932–November 1936	Captain S. G. Galpin, RE
November 1936–September 1941	Major S. A. Stewart, RE
September 1941–January 1944	Lieut-Colonel G. H. Hunt, MC, RE

Chief Superintendent, Experimental Bridging Establishment

January 1944–March 1946	Colonel G. H. Hunt, MC

Chief Superintendents, Military Engineering Experimental Establishment

March 1946–April 1950	Brigadier G. R. McMeekan, DSO, OBE
April 1950–July 1953	Brigadier Sir Millis R. Jefferis, KBE, MC
July 1953–April 1956	Brigadier L. R. E. Fayle, DSO, OBE

Directors, Military Engineering Experimental Establishment

April 1956–December 1956	Brigadier L. R. E. Fayle, DSO, OBE
January 1957–September 1962	Sir Donald C. Bailey, Kt, OBE, JP
October 1962–	Brigadier H. A. T. Jarrett-Kerr, OBE

Portrait of lieut- General Sir Giffard Le Q Martel KCB KBE DSO MC

Some of General Martel's Successors at Christchurch

Brig H. H. Bateman, DSO, MC; Brig S. G. Galpin; Col G. H. Hunt, MC; Brig G. R. McMeekan, CB, DSO, OBE; Brig L. R. E. Fayle, CBE, DSO, OBE; Sir Donald C. Bailey, Kt, OBE, JP; Brig H. A. T. Jarrett-Kerr, OBE.

Some Of General Martel's Successors at Chistchurch

2nd lieut G Hutchinson, late johore Volunteer Engineers

The Johore Volunteer Engineers

The Royal Engineers Historical Society is glad to publish, as its first paper, this story of the Johore Volunteer Engineers.

Acknowledgments are due to Colonel H. C. T. Faithfull's article on the Johore Volunteers published in the December 1935 "Journal", and to Captain T. M. Winsley's "History of the Singapore Volunteer Corps". The major part of the story, however, is based on a manuscript written by G. Hutchinson, Esq, a former officer of the Johore Volunteer Engineers, passed to the Institution by Major-General J. F. D. Steedman, CMG, CBE, MC. Thanks are also due to Brigadier Sir Mark Henniker, Bt, CBE, DSO, MC, for his contribution on the post-war situation in Malaya.

The Society hopes that this story will serve as a small tribute to those gallant officers and men of the Johore Volunteer Engineers who took part in the defence of Malaya and Singapore in 1942, suffered so cruelly for four long years as prisoners of war in Japanese hands and endured the hardships and dangers during the post-war Terrorist activities in Malaya, and as a belated homage to those who died as prisoners or were murdered by the terrorists.

THE British connexions with Malaya originated in the trading ventures of the eighteenth and nineteenth centuries. They became firmly established when Sir Stamford Raffles, an officer of the Honorable East India Company, recognizing the great possibilities of a base and trading unit offered by the island of Singapore, made a preliminary agreement with the Sultan of Johore in 1819 for the founding of a British settlement there. Five years later, the island was by agreement and financial settlement ceded to the Company under the Anglo-Dutch Treaty of London. This treaty settled outstanding issues between the Dutch and British East India Companies and recorded, amongst other things, the Dutch acceptance of British rights in Singapore.

Between 1824 and 1914 British rule and protection was gradually extended until it covered all the states of the Malay Peninsula.

Johore secured its treaty of protection in 1855, and in 1914 under a new treaty a British Adviser was appointed.

At that time the whole peninsula was divided into three political groups:—

The Crown Colony of the Straits Settlements comprising the island of Singapore, the island of Penang with Province Wellesley and the Dindings, and the Settlement of Malacca.

The Federated Malay States Perak, Selangor, Negri-Sembilan and Pahang.

The Unfederated Malaya States Johore, Kedah, Perlis, Kelantan and Trengganu.

Sovereignty in the Unfederated States remained with the rulers and the formal role of the British officials was to guide and advise the rulers in the government of their States, although the problems presented by a rapidly developing country ultimately resulted in the assumption by the British officials of the whole burden of administration.

This system of political groupings and British control continued up to the outbreak of the Second World War and formed the background to the gradual development of the Volunteer movement in Malaya. With British control originating in the island of Singapore it was natural that the original Volunteers to be formed were The First Singapore Volunteer Rifle Corps first exraised in 1854. From then onwards the Volunteer movement grew and extended throughout the Peninsula marching in step with the growth of British control.

The Sultans of Protected Territories, both Federated and Unfederated, recognized the advantage of having adequate efficient Volunteer Forces, particularly as a safeguard against internal civil disturbances which occurred in the States from time to time. The First World War 1914–18 accelerated the expansion of the Volunteer organization. Up to 1914 only three Volunteer Corps existed in Malaya namely The Singapore Volunteer Corps, the Penang Volunteers and the Malay States Volunteer Rifles. By 1918 the following additional forces had been raised: The Malacca Volunteer Rifles, The Province Wellesley Volunteer Rifles, The Malayan Volunteer Infantry, The Johore Volunteer Rifles, The Labuan Volunteer Defence Detachment and The Kelantan Volunteer Rifles.

The Johore Volunteer Rifles were formed in October 1914 and the Johore (European) Volunteer Enactment was assented to by His Highness the Sultan on 18 August 1915 to provide for the organization and maintenance of the force. Under this Enactment the Governor of the Straits Settlements had power to accept the services of any European resident in the State, to commission officers, with the concurrence of His Highness the Sultan, and to call out the Corps with the concurrence of the General Adviser in case of an emergency in the State of Johore.

The training of these newly-formed units in the States was difficult because the Volunteers were scattered over wide areas in their respective territories. Johore, for example, extended over approximately 7,500 square miles, with large areas of the interior covered with jungle. Nevertheless, the Johore Volunteer Rifles had received sufficient training during the last quarter of 1914 to enable the Sultan to send a force of 200 men, under the command of Captains Cullimore and Adul Joffor, to Singapore on 14 February 1915 for garrison duties to replace the 5th Light Infantry Indian Regiment which had been placed under orders to proceed to Hong Kong. The Indian Regiment, however, mutinied and the Johore Volunteers played a small but effective part in helping to crush the mutineers, the last of whom surrendered on 23 February 1915. This incident, and the possibility of a reoccurrence, was the reason why Singapore and Malayan Peninsula Volunteer units were retained for garrison duties throughout the First World War.

During 1922–6 the Johore Volunteer Rifles (European British) were *attached* to the Fifth Singapore Volunteer Corps of the Straits Settlements Volunteer Force, which comprised the Singapore Volunteer Corps, the Malacca Volunteer Rifles and the Penang and Province Wellesley Volunteer Corps.

Early in 1927 a proposal was made to change the Johore Volunteer Rifles into an engineer unit on the grounds that, as the unit was scattered over a number of small centres throughout the State, it would be more practical to train the small groups of volunteers as Sappers rather than as Infantry. The Advisory Committee unanimously agreed, and as from 1 January 1928 the unit became the Johore Volunteer Engineers for a trial period of four years, and this was eventually ratified in the Johore Government Gazette No 220 of 1932.

The cap badge of the new unit was the same as the previous one except that the word "Engineers" was substituted for "Rifles", but new collar badges and buttons were introduced.

The Johore Volunteer Engineers were organized as a Field Company. The Officer Commanding, his Second-in-Command and the junior officers were all volunteers, and the OC was assisted in his duties by a Regular RE Adjutant and a Regular RE CSM Instructor. Captains H. C. T. Faithfull, H. E. Pike and P. L. Wilkinson, all regular RE officers who subsequently had distinguished careers, were in turn appointed adjutant; and Captain M. R. (Hindenburg) Caldwell, as the Brigade Major Federated Malay States Volunteer Force from 1931 to 1934, was closely concerned with the training of the unit. Brigadier M. R. Caldwell, CBE, was killed on active service at Bari, Italy in 1944 when Chief Engineer V Corps.

The official duties allocated to the JVE covered the safeguarding, in collaboration with the Police, of European women and children in the event of internal unrest, and the performance of certain tasks connected with local defence in the event of invasion.

The OC was responsible to the GOC Malaya for the training and discipline of the unit, and the Adjutant, in his capacity as Head of a Government Department, was responsible to the Government of Johore for the financial administration of the unit and, with the CSMI, he carried out the instruction of unit personnel.

The Sultan of Johore, then His Highness Sir Ibrahim, GCMG, KBE, who celebrated the fortieth anniversary of his accession to the throne on 17 September 1935, was a keen soldier and Honorary Colonel of the JVE.

The Government of Johore provided the total cost of upkeep of the JVE (including the pay of the Adjutant and CSMI) but all military control was vested in the GOC Malaya.

Only men of pure European descent were enrolled in the unit. Most members were British subjects, but there were a few aliens including Danes, Frenchmen, Germans, Italians and Norwegians. Membership was of two categories "Colour Service" and "Auxiliary Service". Colour Service men were expected to attend a fixed minimum number of hours of instruction each training season, fire their musketry course, and pass an examination in fieldworks before being classified as "efficient". Auxiliary Service members did practically no training except to fire the annual musketry course, they were largely men of over forty years of age and those younger men who lived too far away from a drill centre to enable them to attend the normal training periods. By 1935 the number of Colour Service men in the State was about 120 and the number of drill centres ten.

The annual training programme was drawn up by the OC and approved by the HQ Local Forces, that branch of the GOC Malaya's staff which dealt with all the Volunteer Forces in Malaya. Men classified as "efficient" at the end of the training season had the privilege of treatment in Government hospitals for themselves and their families during the ensuing year at rates applicable to Government officers.

The number of Volunteers who attended any one drill centre varied from four to twenty-five. A minimum of three drill parades a month were held at each place during every month of the training season which ran from 1 February to 31 October. Either the Adjutant or the CSMI was present at the majority of the parades and each travelled over a thousand miles and was away from HQ seven or eight nights every month.

Training was confined almost entirely to weapon training and fieldworks. The JVE had the use of three ranges located at Johore Bahru, Muar and Segamat, and the standard of shooting was high. JVE teams did consistently well in competitions open to the Regular Garrison of Singapore. Fieldworks training was difficult because only a few men could be got together at any one training period, and this rarely lasted more than one and a half hours since the parades were held in the evenings, in the spare time of the Volunteers, and darkness fell at 6.30 pm throughout the year. The transport of fieldwork stores to and from the parades was not easy. The JVE had one small lorry to convey stores to and from the main store at HQ in Johore Bahru and the three smaller store sheds located elsewhere within the State territory.

Two training camps a year were held and each lasted for seven days. One was held in Malacca for the benefit of the Volunteers in North Johore, and one on the island of Singapore, at Changi, for the South Johore men.

Unit personnel changed over fairly frequently because most of the Volunteers were rubber planters and, as such, were subject to being moved by their companies to estates located outside of the State of Johore. About a quarter of the Volunteers were Government servants and these men also had changes of employment within the Government departments of the Malayan States. This particularly affected the training of efficient officers and NCOs.

Volunteers were keen and it was rare that any officer or man was asked to resign, or as a last resort, be dismissed by HE the Governor who was empowered to do so without giving any reason for his action.

In 1938 the total strength of the JVE, including auxiliaries, rose to 234. Camps were held at Changi on the island of Singapore and at Malacca, about three miles north of the town at Tanjong Kling. The camp programmes included engineering tasks, gas drill, wiring drill, revolver tests, and lectures. The percentage of efficiency was then almost 100 per cent.

All Volunteers for the JVE enrolled with the rank of Sapper, irrespective of previous military or engineering experience. None were tradesmen in the actual sense of the word, but many were qualified civil and mining engineers and essentially practical men as a result of their varied experience as planters.

In 1939 the Officer Commanding was Major C. H. F. Pierrepont who in civil life was the Manager of the Sedenak Rubber Estate.

The unit consisted of four sections:—

No 1 whose HQ was at Johore Bahru, with sub-sections at Koto Tinggi and Sedenak.

No 2 had its HQ at Segamat in North West Johore, near the borders of Pahang and Negri-Sembilan.

No 3 was located at Kluang in Central Johore.

No 4 at Muar in North West Johore near the Malacca area.

Each was approximately fifty men strong and No 1 Section included ten Danes, all of whom were employed as planters on the Mount Austin Estate.

In September 1939, just after the outbreak of war, some of the more elderly planter Volunteers were appointed as "keymen" in various Districts with special duties; whilst some of the Government servants were exempted further military service.

Conscription followed later and included all suitable non-enemy Europeans who were known to be pro-British. The working strength of the unit was also increased with an influx of Chinese who were employed as cooks, batmen and labourers, and Malays who were used exclusively as MT drivers.

The unit was provided with requisitioned transport vehicles consisting of two lorries per section (one for tools and the other for tents and camp equipment), a number of fifteen-seater buses for troop carrying, and one car per officer.

Towards the end of 1939 the unit was sent for two months training to the Johore Military Forces Camp at Kota Tinggi, some 25 miles north-east of Johore Bahru. Training covered PT, drill, weapon training, the construction of machine-gun posts, the wiring of obstacles, demolitions, and the construction of timber bridges. Later No 2 Section built and wired a number of defensive posts for the main concrete bridge over the Tebrau river north of Johore Bahru, and along the route of the Jamaluang Road. On completion of the two months training the unit reverted to its normal programme of weekly parades, although the duration of these was lengthened.

Early in 1941 the parades were supplemented by a week-end exercise with other units to test the defences in the Jemaluang-Kluang area. A day exercise was also held at Tebrau in conjunction with the Singapore Volunteer Armoured Car Section. Later in the year the unit was again embodied for a second two months' training period. The HQ was at Kota Tinggi, but engineer training was done at Jemaluang, where Nos 1 and 2 Sections erected some heavy timber bridges on the approaches to artillery positions, provided water points, constructed a number of semi-permanent jungle tracks, and built a PW cage. Nos 3 and 4 Sections constructed jungle tracks, water points and a PW cage near Johore Bahru, and MG emplacements along the Kota Tinggi–Mersin Road.

After the arrival of the Australian Imperial Force the 2/12th Field Company, Royal Australian Royal Engineers were stationed at Tebrau and instructed the JVE in the use of box girder and pontoon bridges. The Australian Sappers of 2/12th from New South Wales, and later, the 2/10th from Victoria, became firm friends of the unit and did much to help them.

Many of the Volunteers were able to snatch a short leave during the summer of 1941 before mobilization in early December. Some were actually on leave when it occurred and hurried back from places as far apart as India and Australia in order to report at Johore Bahru. A change of unit command followed and Major J. Crosse became Officer Commanding in replacement of Major C. H. F. Pierrepont. The unit at this time also lost a number of the original Sapper Volunteers who were commissioned to officer a unit of the Mysore State Infantry then stationed at Kluang. The strength of the JVE was also seriously reduced when it provided Malay-speaking European Volunteers to serve as interpreters with Australian units.

Two days after mobilization the depleted Sections were allocated their various defence tasks and moved out to live on the sites. No 1 Section took over the maintenance and operation of the improvized Tonkang-type pontoon bridge which had been prepared by Madras Sappers and Miners at Kota Tinggi a few months previously to serve as an emergency crossing in the event of the main Kota Tinggi bridge being destroyed by enemy bombing. The working party consisted of twenty-five men. No 3 Section was split into two working groups. The first manned a defensive post and operated the floodgates of an artificial dam near Mawai, some twelve miles from Kota Tinggi in the Mersing road area. The second group manned the boom defences which had been constructed across the Sedeli river, 12 miles downstream from Mawai. Nos 2 and 4 Sections built a large PW cage.

Early in January 1942 the JVE Headquarters was accommodated in the bungalows of the REM (Kota Tinggi) Estate.

The unit was again asked to provide more men for police duties, guides for other units and transfer to the RAF. Volunteers from the Government Survey Department were all commissioned and posted away to help form a special survey unit.

On 10 January the JVE with the exception of No 1 Section under 2nd Lieutenant J. Hutchinson, moved to Kluang. At that time the Australians left the Kota Tinggi area and No 1 Section came under the command of III Corps, Indian Army. Shortly afterwards detachments of No 3 Section served at Mawai and Ula Sedeli.

During the night of 14/15 January there was an abnormal fall of rain. The local rivers flooded, the artificial dam at Mawai burst, and next morning the area around, and the Mersing road, was under 3 ft of water. The boom defences on the Sedeli river were also seriously damaged and local camp sites had disappeared. The pontoon bridge was not, however, seriously affected. Working parties suffered no loss of life and were eventually rescued from various isolated above-water positions. The floods took three days to recede and during this time there was no visible change in the tide at Kota Tinggi although normally it had a 12-ft rise and fall.

The Japanese bombed the area soon afterwards and the Johore Military Force was withdrawn. On 29 January No 1 Section received orders to cross the Johore Causeway into the island of Singapore, except for a demolition party which remained to demolish the pontoon bridge and the motor ferry across the Kota Tinggi river. Orders for demolition were received at 8 pm and each "blow" was successful.

No 1 Section made its way to the Tengah airfield on the island of Singapore and eventually joined the remainder of the JVE at a rubber estate adjacent to Bulim village between the Tengah and Jurong roads. A few of the JVE were then given permission to visit the Singapore Docks to ascertain if their families, whom they had not seen since Christmas Day, 1941, had been able to get away from the island. Several of the JVE were actually fortunate enough to witness their families embark and leave. Greatly relieved they then returned to the camp at Bulim.

During the fortnight before Singapore fell the unit was mainly employed on the erection of dannert wire obstacles. No 1 Section wired the 218th AIF front and No 2 Section the area where the road from Alma Keng joins the coast, a total of 3 miles of wire. Improvements were also made to the defences of Tengah airfield. Some men from an Indian Labour Battalion were attached to the unit for these tasks and, in spite of their youth, worked well. The wiring party was often held up by lack of wire which could never be supplied quickly enough from base store depots.

On 10 February the JVE complete with all equipment, tools and transport, were camped off the Bukit Timah Road. Later they withdrew under orders to Reformatory Road and then into the Tanglin Club area. The unit was then attached to the Singapore Volunteer Brigade and helped form a continuous line of defence along the Scott Road—Tanglin Hill area. On 14 February the line was bombed and several members of the unit were killed and wounded.

Singapore surrendered at 4 pm on 15 February 1942 and the surviving members of the unit, frustrated and angry because they had been denied the chance of fighting it out, became prisoners of war in Japanese hands.

The Johore Volunteer Engineers as Prisoners of War

This record has been compiled from information made available by 2nd Lieutenant J. Hutchinson, JVE who commanded No 1 Section from the time of Mobilization in December 1941 until the fall of Singapore on 15 February 1942, and then, like all the surviving members of his Section, spent almost four years as a prisoner of war.

The captivity of the JVE falls into two distinct periods. Firstly their incarceration in the Changi PW Camp during the months of February to October 1942, and secondly, the subsequent years spent in Siam until their eventual release in August 1945.

The hardships suffered by British and Commonwealth prisoners in Japanese hands have already been the subject of many books of personal experiences and official publications, and it is doubtful if the full story of their fortitude and courage in the face of their arrogant and brutal captors will ever be known. This record, however, whilst acknowledging with respect the sterling qualities shown by the prisoners, confines its detail to prisoner locations, the work they were compelled to do, and only touches on the adversities they had to endure. As the detail given is based on the personal experiences and knowledge of just one member of the JVE it is possible that there may be many omissions. These are regretted.

Changi Prisoner of War Camp (February to October 1942)

When Singapore fell the JVE comprised nine British officers (including the Adjutant and the two Medical Officers), 114 British and European other ranks, and thirty-six local Malay and Chinese personnel. All became prisoners of war with the exception of the local native contingent who went to ground.

The first reaction of the OC, Major J. Crosse, MC*, was to get the nine Danes of No 1 Section out of uniform and into the partial security of the Danish Embassy to avoid the possibility of them being shot by the Japanese as aliens in the pay of the British forces. One of the Danes, Captain Laub, was later killed in Siam whilst helping British Intelligence. Two others, Sappers Hjerrild and Hausen were killed when serving with Force 136 in

Malaya. The rest were sent back to their estates by the Japanese and survived the war.

The other immediate problem was to obtain water. This was eventually overcome by draining off the water from the cylinders of the hot water systems in the private, unoccupied houses within the Tanglin area.

To avoid the chance of liquor falling into the hands of the Japanese troops with the possibility of subsequent drunken killing of Europeans, two parties of the JVE destroyed the large spirit stocks of the well-known Coconut Grove Restaurant and the Tanglin Club. It was estimated that the stock was valued at $10,000.

Orders were received on 18 February for the unit to march to Changi where the cantonments of Kitchener, Roberts and Selerang Barracks had been turned into a British Forces PW Camp area. Before moving the unit removed the bolts of their rifles and disposed of them, and then destroyed their Lewis guns. On arrival the JVE officers and men were all housed in half the ground floor of "B" barrack block in the overcrowded Kitchener Barracks. Members of the unit had their personal kit, a three days' supply of rations and, as a Volunteer unit, no regimental or other funds which could be used for the purchase of additional food from the local Malays and Chinese.

The area water supply system was out of action and supplies were obtained by collecting rainwater. The Swimming Pagar was used for ablutions, sanitary arrangements were improvized, and no cooking facilities existed owing to lack of power and fuel.

Within a few days the JVE were living on the meagre Japanese ration of ½ lb of rice and a few small vegetables per day.

Life improved as the camp became more organized. The JVE food was pooled, strictly rationed, and issued by an officer and the senior regular Warrant Officer Instructor. During the first few weeks the prisoners were not detailed for working parties by the Japanese and to keep up morale they played organized games, arranged concert parties and ran a study centre. The latter, known as "Changi University", was staffed by members of the SSVF several of whom were previously professors and lecturers in the Raffles University of Singapore. The staff, mostly middle-aged, bearded men, known affectionately as "The Apostles", lectured on arts, architecture, engineering, law, mathematics, science and theology.

Major Crawford the SMO of the JVE remained with the unit at Kitchener Barracks, but Captain R. Hall, the other Volunteer medical officer went to Roberts Barracks to work in the PW hospital.

Later the Japanese demanded the provision of working parties for a variety of tasks. One group of the JVE went to the Mata Ekan beach to disarm British anti-tank mines. This lasted several days, fortunately without casualty among the Volunteers who had no experience of this kind of work. Parties also spent some time in Singapore town repairing buildings destined for military use by the Japanese. The amount of work done was never large, just enough to get by without too much trouble from the Jap guards and supervisors. Twenty of the JVE were members of a large party sent to the Caldecott Estate for road making, the Japanese having decided to develop the Estate into a rest camp and shrine for their own troops. The party was under the control of a Brigadier Williams who succeeded in getting improved rations and laid on several other amenities including a shop where small purchases of food and tobacco could be made.

For refusing to sign promises not to try and escape all the PW at Changi were sent to Selarang Barracks on the outskirts of the Changi area. This barracks, designed in peace-time to accommodate a British Battalion, now housed some 20,000 officers and men. The JVE shared the top floor barrack rooms of one block with some men of the Manchester Regiment; there was just enough room for the occupants to lie down shoulder to shoulder. The overcrowding, lack of sanitation and poor feeding brought the inevitable scourge of diarrhoea, diphtheria and skin trouble, and the health of the men deteriorated rapidly, with the result that some, including the JVE, were returned to Changi, but not to those barrack sites which overlooked the Straits.

During the latter part of their imprisonment in Changi parties of JVE men were sent daily to Bukit Timah to work in the big granite quarries, a foretaste of their later slavery in Siam.

One highlight of their last days in Changi was the arrival of a bulk supply of Red Cross food, which when pooled and rationed out at intervals did much to eke out the meagre Japanese rations. The JVE subsequently received only one issue of Red Cross parcels, in 1944, and the supply scale was one parcel per eleven PW.

Siam: October 1942–August 1945

Towards the end of October parties of approximately 600 prisoners were sent by train to unknown destinations up-country. Rumour was rife and there was optimistic talk of "proper camps with electric light and running water". Twenty-five men of the JVE under 2nd Lieutenant Hutchinson joined the fourth party which comprised a number of Gunners and other Sappers to form "W" Battalion. At the last moment this was changed and the JVE joined "J" Battalion, an almost all-Volunteer unit under the command of Lieut-Colonel James of the FMSVF. There were about 250 officer Volunteers and about eighteen regular officers, mostly RASC. The other ranks comprised forty RASC, thirty Military Police and twenty-nine others from miscellaneous Regular units, the balance were all Volunteers.

A party of forty JVE subsequently left Singapore under Major Crosse about a month later. This party joined the Battalion which eventually was located at Chunkai.

Each man of "J" Battalion was issued with his share of what was left of the Red Cross food, a Red Cross hat (South African brown felt hats) and a pair of boots. At dawn on 28 October "J" Battalion embussed, the men being allowed to take a kit bag and valise apiece. The first stop was at Changi prison where the officers and men were paid by the Japanese for the work they had been compelled to do. The system of payment for officers was on a monthly basis. Lieut-Colonels received \$250 and this was decreased on a sliding scale according to rank, a 2nd Lieutenant receiving \$80. A deduction was then made of \$70 to cover rent, lighting, soap and other items! Any "unissued pay" was banked by the Japanese on behalf of the prisoners! Other ranks were paid at a daily working rate, 10 cents for privates, 30 cents for sergeants and 40 cents for warrant officers.

On arrival at Singapore railway station the Battalion was divided into groups of thirty, officers and men separately, and each group allocated a covered railway goods wagon with sliding doors. The train left Singapore at 6 pm on the 28th and travelled via Kuala Lumpur and Ipoh to reach Ban

Pong at 5.30 pm, 31 October. After a short stay in the local transit camp the Battalion moved 30 miles by lorries to Kanburie Camp which was located on a small airfield. The next day they marched 15 miles to Lajo Camp, a considerable achievement after months of captivity on a starvation diet.

Next day, less one hundred of their number who were unable to continue, the forced march was resumed to Tarsoa with a day's halt *en route*. All the JVE arrived having covered 50 miles in three days carrying their personal belongings. The strain of the march was the beginning of the end for many of the Battalion who subsequently died during the next year whilst working on the infamous Siam military railway.

The journey was then continued by barge upstream of Tarsoa, past Kanu where "W" Battalion was located, and on to Kinsayok. Here "J" Battalion occupied a partially built camp.

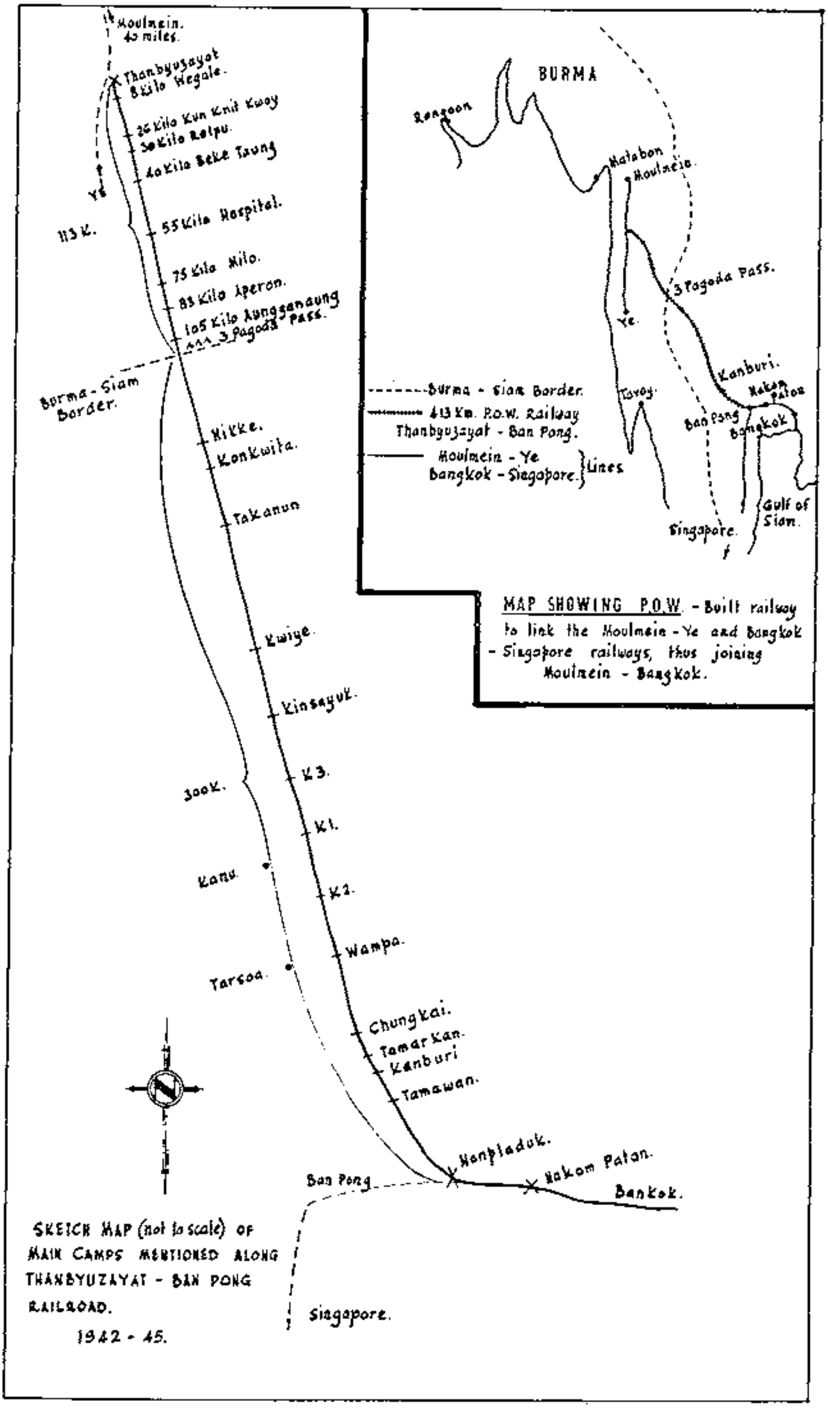
2nd Lieutenant Hutchinson's party then found that two other parties of the JVE were in the camp vicinity. A group of ten including J. M. Herries were members of a PW Company employed on anti-malarial duties and the siting of camps. Another group of eight with Lieutenant F. A. F. Johnstone were with "A" Battalion.

At the beginning of their stay men worked on the camp site completing attap huts and digging latrines etc. The food was terrible. Rice at dawn, and rice and yam water at mid-day and 6 pm. Occasionally yams were issued. The days were hot and the nights cold. Soon afterwards A. M. Noble and "Tebrau" MacDonald of the JVE became very ill and were sent back to the PW hospital at Tarsoa.

"J" Battalion moved to Kanu on 20 December, 1942, to join "W" and "E" Battalions. The camp was incomplete and huts had to be erected. When finished the camp held 1,500; Lieut-Colonel Mackie Moore was the Senior British Officer until he was sent to the base hospital and his duties taken over by Lieut-Colonel James, who in turn was relieved by Lieut-Colonel Warren of the Royal Marines. Work varied from cutting the railway trace to doing camp chores. The men who worked were paid, usually retrospectively, and everyone gave 10 per cent of their pay to the messing fund. Unfortunately owing to the pay scales junior ranks were unable to further supplement their rations by local purchase. This camp was later fenced around its perimeter with bamboo spikes and the Battalion was for the first time caged in.

Early in January 1943 work was commenced on the building of a new camp K1 at the top of the escarpment above Kanu and the cutting of a new section of the railway trace. The huts were made from bamboo and the men suffered badly from the cuts and wounds they received when getting through the razor sharp base thorns to cut down the fully grown trees with the useless and inadequate tools supplied by the Japanese. The wounds invariably turned septic and then graduated into a jungle sore or ulcer which often spread from knee to ankle and exposed the whole of the shin bone. When the camp was part finished the prisoners moved in and many lived in tents, nineteen in each 15 × 15 ft tent, eight aside inside and three under the flaps. Half the camp soon became a hospital due to the effects of dysentery, filth and mud. Many officers and about 400 men were moved to Camp 2, among them "Bunny" Bragg of the JVE.

Work on the railroad then began in earnest with a completion date set for July 1943. Men from the three Camps K1, K2, and K3, formed tree-cutting parties along the railway trace, the timber being used for bridge building.


Moulmein. 40 miles.
Thanbyuzayat
8 Kilo Wegale.
26 Kilo Kun Knit Kway
30 Kilo Retpu.
40 Kilo Beke Taung
Ye
113 K.
55 Kilo Hospital.
75 Kilo Milo.
83 Kilo Aperon.
105 Kilo Aungganaung
3 Pagoda Pass.
Burma - Siam Border.
Nikke.
Konkwita.
Takanun
Kwiye.
Kinsayuk.
K3.
300 K.
K1.
Kanu.
K2.
Wampo.
Tarsoa.
Chungkai.
Tamar Kan.
Kanburi
Tamawan.
Nonpladuk.
Nakom Paton.
Ban Pong
Bankok.
Singapore.
SKETCH MAP (not to scale) OF MAIN CAMPS MENTIONED ALONG THANBYUZAYAT - BAN PONG RAILROAD.
1942 - 45.
BURMA
Rangoon
Matabon
Moulmein.
3 Pagoda Pass.
Ye.
Kanburi.
Tavoy.
Nakom Paton
Ban Pong
Bangkok
Gulf of Siam.
Singapore.
Burma - Siam Border.
413 Km. P.O.W. Railway Thanbyuzayat - Ban Pong.
Moulmein - Ye
Bangkok - Singapore. Lines
MAP SHOWING P.O.W. - Built railway to link the Moulmein - Ye and Bangkok - Singapore railways, thus joining Moulmein - Bangkok.

The trees were of teak, as hard as iron and about the size of a fully grown beech. The railway trace at "Hell Fire Corner", about four miles upstream, passed through a rock face sloping one in one, a ravine, a large bend and then on through isolated pinnacles of rock standing out from the main cliff face. The rock was blasted out and men worked in pairs to prepare the holes, one using the sledge hammer, the other holding and turning the drills which varied in length up to five feet long. After blasting the rocks were removed by hand, the number of hands depending on the size of the rocks. Earth moving by pick and shovel followed and this was a welcome relief from drilling. Food ran short as supplies were either pilfered *en route* or failed to get through owing to the condition of the earth road that was often a huge sea of mud. Working hours were from dawn to dark with a short tea break at 11 am and a 2-hr break at 1 pm. Clothes became scarce and most of the soldiers were practically naked.

About 1,000 officers and men of Camp K1 were soon reduced to hospital cases by diphtheria and dysentery, the remainder, including the JVE, were then moved on foot to Camp K3 and into tents. Living conditions were at their lowest due to the appalling conditions that prevailed. Cholera struck the camp in June and by the end of the month the working party had been reduced from 1,000 to 200 men. By mid-July only 100 of the original party remained. In the period between April 1943 and July 1943 the three Kanu camps, which at first mustered 2,000 PW, lost 1,000 men, 200 died in the camp and another 400 after evacuation down river.

By the end of July the railway track around "Hell Fire Corner" was completed and Camps K1, K2, and K3 were shut down. A temporary transit camp by the river was occupied by 800 very sick men who fended for themselves and buried the cholera victims as they died. Rations surprisingly improved, meat was supplied and the camp and the surrounding area denuded of timber in order to cook it.

At the end of August the men moved down river by barge to Tarsoa near Wampo and the worst medical cases taken into the PW hospital. The camp had been rebuilt during the time the men of the Kanu camps had pushed the railway through and it was comparatively well laid out and clean. The occupants settled into a routine life for the next fifteen months. There were two huts for the officers, all the remainder were occupied by other ranks, with a couple of officers and WOs in each hut to maintain discipline. The daily tasks were done in and around the immediate vicinity of the camp, and consisted of felling timber for railway fuel, loading and unloading lorries, road repairs, and the provision of guards for the hospital.

In April 1944 several of the JVE who were very ill moved to Tamawan Camp. This was a huge place and held Nos 1, 2, and 3 Working Groups. Apart from the usual camp chores the fit men were employed in a large ammunition dump and an adjacent oil-storage depot. Compared with the other camps it was a rest centre, although the Japanese still demanded a full day's work from each prrisoner.

In January 1945 batches of officers and men moved to Kamburie and very soon it held about 3,000 officers and fifty other ranks. Here they rebuilt the old camp huts, constructed new living huts and a huge new kitchen and canteen.

By June 1945, after the Japanese surrender, the remaining JVE were moved to Bangkok and then by air to Rangoon and freedom.

Roll of Honour
World War II 1939–1945
Died in Action or as PW

Regimental No	*Rank*	*Name*
152	Captain	E. C. Crosse, MC
	Captain	G. Laub
350	WO2	E. A. J. Brooks
525	Sergeant	R. Meldrum
487	L/Sergeant	F. W. Saunders
763	Corporal	A. B. Agnew
716	L/Corporal	A. B. Pargiter
924	L/Corporal	S. W. Sidford
938	L/Corporal	I. McArthur
966	Sapper	K. J. Anderson
1282	Sapper	R. V. Brant
977	Sapper	F. R. Calthorpe
	Sapper	F. M. Cameron
1261	Sapper	D. T. P. Crawford de Witt
1275	Sapper	M. E. Earle
6	Sapper	M. E. Edmett
1277	Sapper	E. W. Ellaby
401	Sapper	J. L. Gray
1239	Sapper	D. Gronow-Davies
	Sapper	C. D. Haggit
	Sapper	A. O. Hansen
992	Sapper	S. A. Hjerrild
1228	Sapper	A. F. Johnson
951	Sapper	R. F. Kent
967	Sapper	G. W. Lawrie
1219	Sapper	W. J. McGubbins
886	Sapper	J. L. McKendrick
1274	Sapper	J. D. Morey-Taylor
845	Sapper	A. M. Noble
983	Sapper	G. Robertson
956	Sapper	N. H. Sands
920	Sapper	G. D. Templer
843	Sapper	C. H. Wooding

The Fight Against Post-war Communism in Malaya

The story of the men of the JVE does not finish with the end of World War II although the unit ceased to exist. Many of them returned to Malaya to take up employment in Government service and the rubber planting and mining industries. It was then their unfortunate lot to find themselves involved in the struggle against the Communist terrorism which developed in the Federation of Malay States during the post-war years.

Organized Communism in Malaya began with the formation of the Malayan Communist Party in 1928. Its activities were at first confined to the island of Singapore but by 1939 its tentacles had spread into the Malayan Peninsula.

Six months after the conquest of Malaya by the Japanese the top men of the Party in Singapore were arrested and executed, and by March 1943 Communist activities on the island had ceased entirely. On the mainland the Japanese successfully ambushed a meeting of Party leaders at Kuala Lumpur in September 1942, and it took some time for the Party to reorganize itself in the Western States and Settlements of the Peninsula.

Communist guerrillas then reformed in the jungle, organized themselves into groups, and gradually developed themselves into independent State "regiments" of the new Malayan People's Anti-Japanese Army.

The guerrillas attacked small Japanese units and isolated police stations and reports of their successes reached the headquarters of the Allied South-East Asia Command. In 1943 Force 136, a guerrilla organization, was formed by SEAC to fight behind Japanese lines in South-east Asia, and members of this force were sent by Lord Mountbatten, the Supreme Commander SEAC, to contact the Communist leaders in Malaya and agree a system of mutual aid with the object of stepping-up anti-Japanese activities until such time as a full scale invasion of Malaya could be mounted.

An agreement was made and the Allies "dropped" supplies of weapons, explosives and other supplies to the Chinese Communists and sent British Liaison teams to train their guerillas. Three of the Danes who had previously been members of No 1 Section of the JVE joined Force 136 and helped the Communists, unfortunately these brave men were captured by the Japanese and executed.

When the Japanese surrendered in 1945 there was an inevitable pause before any British Military Government could establish itself over the length and breadth of Malaya. It consequently turned out that in some areas of Malaya it was Force 136 and the Malayan Peoples Anti-Japanese Army (MPAJA) who disarmed the Japanese and established control in their place. This control was exercised in some out-of-the-way parts of Malaya for as long as three weeks.

On assuming control again after the Japanese surrender, the British did their level best to co-operate with the MPAJA who had endured such hardships in the common cause against Japan. But it was not easy; for the MPAJA was at heart a Communist organization and had for its political goal the establishment of Communism in Malaya. This the British could not concede. First it was necessary to call upon the MPAJA to hand in their arms. This order was obediently carried out by the MPAJA as far as the arms dropped to them by the Allies were concerned. There were, however, vast stocks of other (un-counted) arms in circulation—Japanese, British (from the 1942 surrender) and American—and these were retained concealed in the jungle.

By gradual degrees the British and the MPAJA came to be more and more in opposition to one another. The former had democratic methods as its aim; the latter Communism. The leaders of the MPAJA drifted back into the jungle reforming such of their adherents as they could as the Malayan Peoples Liberation Army (MPLA). It was a deceptive name for most of the force was Chinese (not Malay) and there was no intention of liberating anybody; but it sounded good to the uninitiated.

By 1947 the Government in Malaya and the Communists were at loggerheads completely. The Communists decided to achieve their ends by force. They had the arms mentioned above and they had some 5,000 men in the jungle, which is a perfect terrain from which to operate a guerilla war. Had they acted skilfully they could hardly have failed to reduce orderly government to a standstill and replace it by their own. There were very few troops in Malaya in 1947, the Police were not armed, and the planters as a whole carried no weapons.

Though it was serious enough as it was, the Communists plans went off at half-cock. There were murders of European planters and administrators, there were train derailments, the burning of property and the terrorization of the people generally throughout 1947 and into 1948. In that year the Government declared a State of Emergency and British, Gurkha and Malay reinforcements were hurried to the worst areas to combat the threat. Gradually, by political, administrative and military measures the Communist menace was first controlled and then subdued.

By 1950 the Emergency was ended, but it had been a hard struggle and many will say that the brunt of it fell on the European planters and tin-miners, living with their families in lonely bungalows on the fringes of the jungle. They lived in a state of semi-siege, with wire and searchlights around their homes: they went about their business in armoured cars or with escorts of Special Constables (largely trained by themselves); and they somehow contrived to maintain production and husband their estates. It was a fine achievement; but many lost their lives, including the following nine ex-members of the JVE whom we all salute:—

Ex-Sapper E. Alcock	Ex-Sapper S. Harper Ball
Ex-Sapper I. Corley	Ex-Sapper R. D. Harrison
Ex-Sapper G. A. A. Denne	Ex-Sapper R. L. Inder
Ex-Sapper L. Edmonds	Ex-Sapper A. Nicholson

Ex-Sapper J. B. Stoker

After the war a North Wing was built on to the main structure of Singapore Cathedral to provide accommodation for the various committees engaged on administrative work. Around the outside of this wing were mounted the regimental badges, in colour, of all the units that served in Malaya during 1941–2. The SSVF badge was placed over the west door of the wing; and the FMSVF badge, surrounded by the badges of other independent units like the JVE, was mounted over the east door. The *Rhino of Johore* will, therefore, be proudly displayed as long as Singapore Cathedral stands, and serve as a tribute to the gallant services of the Johore Volunteer Engineers during the Second World War.

Railway Safety—Past, Present and Future

This paper by Brigadier C. A. Langley, CB, CBE, MC will be presented for discussion at a Joint Meeting of the Institution of Royal Engineers and the Institute of Transport to be held in the Lecture Theatre of the Royal United Service Institution, Whitehall, London, SW1, on Monday, 27 January 1964.

The meeting will be open to all members of both Institutions, and will begin at 6 p.m. Teas will be available from 5.15 p.m.

* * * * *

Opening Remarks

For the past century or more railways have provided vital arteries for trade and travel and, during this period, they have done more to foster and stimulate national economy than any other form of transport.

Railways have also played a notable rôle in war, and the Corps of Royal Engineers has been closely associated with their construction, operation and safety for the last 124 years. It is, therefore, appropriate that railways should form the subject for discussion at this Joint Meeting of the Institute of Transport and the Institution of Royal Engineers.

I have chosen for my subject the all-embracing one of "Railway Safety, Past, Present and Future". I hope to show briefly how the principles of railway safety have been formulated, improved and extended from experience gained during the nineteenth and twentieth centuries. I shall refer to railway safety legislation and to the work of the Inspecting Officers. I shall touch on the part played by railways in war and finally I shall speculate for a few minutes on the future so as to arouse, I hope, some interesting, though maybe controversial, discussion.

This paper is based on my experience as an Inspecting Officer of Railways, though I have delved into the past for historical background. The views expressed in this paper are entirely my own.

When the first railways were built in the early part of the last century their activities were controlled only by the clauses in their own private Acts. Throughout the nineteenth century the policy of *laissez faire* was applied to the control of railways as well as to other rising industries. Private enterprise was given a very free hand, subject only to the minimum of statutory control, often only enforced when the pressure of public opinion caused governments to take action.

With such a new form of transport, conditions of travel were rather primitive, and accidents were by no means infrequent. In fact, tragedy marred the celebrations attending the opening of the Liverpool and Manchester Railway on 15 September 1830, when that famous statesman, William Huskisson, was killed by the locomotive "Rocket". It is of melancholy interest to record that the Armed Services were indirectly associated with this accident because Mr. Huskisson, with others, had alighted from his carriage and was talking to His Grace the Duke of Wellington when the locomotive was seen returning from watering on the adjoining line. The Duke called out to the unfortunate gentleman to get into his carriage, but he was run down before he could do so.

The Railway Inspectorate

Despite its tragic opening the Liverpool and Manchester Railway was an immediate success and soon railways began to spread throughout the country. The railway Directors were, not unnaturally, anxious to open their lines as soon as possible, and some did so before they were fully completed and before embankments and other works were properly consolidated. The resulting accidents from these and other causes led to agitation in Parliament, and in 1840 the first Regulation of Railways Act was passed. This Act required the Railway Companies to report to the Board of Trade all accidents involving personal injury and to give one month's notice of the opening of any new line. It also authorized the President of the Board of Trade to appoint Inspecting Officers, and this led to the first association of the Royal Engineers with the railways. Lieut-Colonel Sir Frederick Smith was the first Inspecting Officer, and was given the title Inspector General of Railways. Since then all Inspecting Officers have been drawn from the Corps in unbroken succession down to the present day. Their names are given in the accompanying table.

Inspecting Officers of Railways

*Lieut-Colonel (later General) Sir J. M. Frederick Smith	1840–1
Lieut-Colonel R. Thomson	1840
Captain S. C. Melhuish	1840
*Major General (later General) Sir Charles Pasley	1842–6
Captain J. Coddington	1844–7
Captain (later Field Marshal) Sir J. Lintorn A. Simmonds	1847–54
**Lieut-Colonel (later General) George Wynne	1847–58
Captain (later Lieut-General Sir Robert) R. M. Laffan	1847–52
Captain (later Sir Douglas) Galton	1847–60
**Captain Sir Henry Tyler	1853–77
**Colonel W. Yolland	1855–84
Captain G. Ross	1858–61
**Colonel F. H. Rich	1861–91
**Major-General C. S. Hutchinson	1867–95
**Colonel Sir Francis Marindin	1877–99
**Lieut-Colonel Sir H. Arthur Yorke	1891–1913
Lieut-Colonel G. W. Addison	1894–9
**Lieut-Colonel P. G. Von Donop	1899–1916
**Colonel Sir John Pringle	1900–29
Lieut-Colonel E. Druitt	1900–18
Lieut-Colonel E. Hall	1919–27
**Lieut-Colonel Sir Alan H. L. Mount	1919–49
Colonel A. H. C. Trench	1927–49
Lieut-Colonel E. P. Anderson	1929–34
Lieut-Colonel E. Woodhouse	1930–49
**Lieut-Colonel G. R. S. Wilson	1935–58
**Brigadier C. A. Langley	1946–63
**Colonel D. McMullen	1948–
Colonel R. J. Walker	1949–52
Colonel W. P. Reed	1953–
Colonel J. R. H. Robertson	1959–
Lieut-Colonel I. K. A. McNaughton	1963–

*Inspector General of Railways. **Chief Inspecting Officer of Railways.

Some notable Inspecting Officers. Sir Frederick Smith after two years' service at the Board of Trade, was appointed to succeed Sir Charles Pasley as Director of the Royal Engineers Establishment, now the Royal School of Military Engineering, Chatham. Sir Charles, who had been Director since the Establishment was founded in 1812, applied for Sir Frederick's job and got it. He was, from all accounts, a somewhat stormy petrel and did not take kindly to the ways of the Civil Service. He did, however, establish exceptionally good relations with the Railway Officers, lunching and dining with Saunders and Brunel of the Great Western, Joseph Locke of the London and South Western, as well as with many other notable Railway Pioneers. He preserved, however, his strict impartiality and set the tradition of co-operation rather than coercion that has lasted to the present day.

In those days the Inspecting Officers were usually serving Sappers, like Sir Frederick, who spent a few years with the Board of Trade and then returned to active Army life; for example, Captain Laffan became CRE at Aldershot and gave his name to Laffan's Plain to which all good Sappers march so vocally on festive occasions. He later became a Lieut-General and Governor and Commander in Chief, Bermuda.

Captain Simmonds, who ended his military career as a Field Marshal, spent a long leave in Eastern Europe in 1853, and when war broke out between Russia and Turkey he immediately offered his services to the Turkish Army. His continued absence from his official railway duties eventually led to his recall by the Board of Trade, but Simmonds promptly resigned his appointment and continued in command of his Turkish Cavalry Force. He did not, however, give up his interest in railways and in 1874 he was a member of the Royal Commission on Railway Accidents.

Captain Sir Henry Tyler, who served in the Railway Inspectorate for twenty-four years, is one of its most noted members. He made it his practice to walk the whole length of every line he inspected, often to the discomfiture of the Railway Officers who accompanied him. He published the first Annual Report in 1871 and led a campaign to induce recalcitrant railway managers and engineers to modernize their ideas on railway safety and accept interlocking of points and signals and the Absolute Block system of operation. His paper "Simplicity as the essential element of safety and efficiency in the work of railways" which was read to the Society of Arts in May 1874 reviewed the whole field of railway safety and criticized many eminent railwaymen who had condemned the Board of Trade on the general theme that they trusted to new-fangled mechanical devices rather than to the integrity of the men. I have little doubt that Captain Tyler's reports and his criticism of unsafe railway working, coupled with the complaints from the public of the unpunctuality and general inefficiency that prevailed on some railway systems, led to the appointment of the Royal Commission of 1874.

Captain Tyler also spent long leaves in foreign countries, and in 1868–9 he constructed the first railway in Greece, and hired six brigands to police the line. He demonstrated most effectively the healthy active life that is led by Inspecting Officers, for when he retired in 1877 he promptly became Chairman of the Westinghouse Brake Company. Later he was made Chairman of the Peruvian Corporation, and President of the Grand Trunk Railway of Canada. He kept up his railway interests until his death at the age of 81.

Major-General Hutchinson was the officer who inspected the Tay Bridge some eighteen months before it collapsed on the night of 28 December 1879. This disaster, occurring so quickly after the bridge was opened for traffic, created great public concern, and General Hutchinson was subjected to considerable criticism, but he was entirely exonerated by the President of the Board of Trade, and later he was appointed to inspect the Forth Bridge once a quarter during the six years of its construction.

Sir John Pringle was Chairman of the Railway Electrification Committee set up in 1927 to review the types of electrification that might be permitted on British railways. He was also Chairman of the Committee to consider the extension of the Automatic Train Control system that had been developed by the Great Western Railway. The Committee recommended the extension of ATC, now known as the Automatic Warning System (AWS) as well as the provision of more powerful signal lights and further controls to prevent Signalmen's errors.

Sir Alan Mount was also a strong advocate of AWS, and shortly before he retired he received from the Railway Executive their assurance that this safeguard would be extended generally to the main lines of British Railways. He was Chairman of the Pacific Locomotive Committee appointed in 1938 by the Governor General of India to consider the design and operation of a series of new locomotives which had developed unusual riding qualities and had caused a number of serious derailments. His Committee of international civil and mechanical engineers made sweeping recommendations that were generally adopted by the Indian Government.

Lieut-Colonel Wilson, who held the inquiry into the triple collision at Harrow, died tragically in 1958 whilst still investigating the Lewisham disaster. There is little doubt that the strain and distress occasioned by this last investigation contributed to his untimely death. Some years before, he created great interest with his Canton Lecture to the Royal Society of Arts on "Safety on the Railways" which he gave in 1954, just eighty years after Captain Tyler had addressed the same Society.

These were some of the RE officers who moulded and upheld the traditions of the Railway Inspectorate, which throughout its existence has used its influence to promote railway safety in all its aspects with the minimum of statutory power and authority.

Railway Safety Legislation

The principles of British safety legislation place on the managements the responsibility for the safe construction, operation and maintenance of their railways, allow them the maximum freedom to develop projects on their own initiative, and restrict Governmental control to the minimum.

Early Acts. The Regulation of Railways Act 1840 was the first step taken by the Government to safeguard passengers. It was followed two years later by another Act which gave the Board of Trade power to postpone the opening of a line should its condition be unsatisfactory.

Neither of these Acts gave the Board authority to order inquiries into accidents, though these were held from the earliest days.

Curiously enough, no control was exercised over the design and construction of locomotives and rolling stock, though as a result of criticism by the Inspecting Officers and others about the poor and dangerous condition of travel for third-class passengers, a clause was inserted in the 1844 Act whereby each railway was obliged to run one train per day at a cost of not more than 1d per mile for third-class passengers, with carriages properly protected from the weather, and designed to the satisfaction of the Inspecting Officers acting on behalf of the Board of Trade. These trains became known as "Parliamentary trains", and although the Act has long since been repealed the name lingers on in some railway circles.

1871 Act. Several Select Committees and Royal Commissions considered problems of railway safety from time to time, but little was done. In 1868 the provision of an efficient means of communication between passengers and train crew was made compulsory, but the most important legislative step was the Act of 1871 whereby the functions of the Board of Trade were enlarged, the powers of the Inspecting Officers were defined, and the reporting of accidents was made more precise. The same Act legalized for the first time the holding of official accident inquiries and authorized the setting up of more formal courts in special cases, but it did not give the Board of Trade power to enforce any of their recommendations.

Royal Commission of 1874. By this time the railway system as we know it today was nearly complete and the railways had obtained a virtual monopoly for travel, having practically eliminated all competition from stage coaches and canals. This led to slackness in operation in those areas where a railway company reigned supreme, and to intense and sometimes dangerous competition on those routes, such as the ones to Scotland, where companies operated in deadly rivalry. Complaints were frequent both in and out of Parliament, and eventually the Royal Commission of 1874 was appointed to inquire into the causes of railway accidents. It submitted a massive report in which it recommended that the powers of the Board of Trade should be vastly increased and that the principles of safe railway operation should be enforced by law. Although no legislative action was taken for fifteen years this report had its effect, and gradually all the important railways began to adopt the safeguards that were so strongly pressed by Captain Tyler and his successors.

1889 Act. Some railways still continued to work their lines on out-moded and unsafe principles, and in 1889 another Act was passed as a direct result of the Armagh disaster on 12 June, when a heavily laden excursion train of fifteen vehicles, fitted throughout with the non-automatic brake, failed to reach the top of a severe gradient. The train was divided to enable it to proceed in two parts, but the rear ten vehicles were inadequately secured and ran back 1½ miles towards Armagh. The runaway vehicles crashed at high speed into a slowly moving passenger train which had left Armagh 20 minutes after the excursion, in accordance with the time-interval system.

The new Act at last gave the Board of Trade power to order the adoption of the Absolute Block system on passenger lines, the equipping of passenger trains with continuous automatic brakes, and the interlocking of points and signals. Thus these three safeguards were at last established on a statutory basis as fundamental principles of railway working in Great Britain.

Safety of Employees. Towards the end of the last century the safety of railway employees began to attract attention in Parliament. In 1893 the Board of Trade was given powers to inquire into complaints about excessive hours of work by railwaymen, and this did much to improve working conditions and reduce casualties from fatigue.

In 1900 the Railway Employment (Prevention of Accidents) Act gave the Board of Trade power to make rules to reduce or remove the dangers and risks incidental to railway service. It also authorized the appointment of Assistant Inspecting Officers, now known as Railway Employment Inspectors, to hold inquiries into accidents to railway employees.

Recent Legislation. In 1919, the Ministry of Transport was formed and took over the duties of the Railway Department from the Board of Trade. Jurisdiction over the Irish railways ceased in 1921. The Road and Rail Traffic Act of 1933 brought railway legislation up to date and in particular amplified the provisions regarding the types of work which required the Minister's approval before they were brought into use.

Approval of the design and construction of locomotives and rolling stock was still excluded, but an exception had been made when Tube railways were first introduced. A clause in each Act, authorizing their construction, instructed the managements to submit to the Board of Trade drawings of rolling stock for their approval. The prime object was to ensure that adequate precautions were taken against the risk of fire and electric shock. These Acts are still in force today.

Finally, the Act of 1947 nationalized the British Railways and placed them under the control of the British Transport Commission. The duties and responsibilities of the Railway Inspectorate were in no way altered. In fact, the co-operation between Inspecting Officers and Railway Officers has become closer and more cordial, to the mutual benefit of both.

Railway Safety in the Nineteenth Century

When railways were first opened for public service in 1830 speeds were low and trains ran on sight. During the opening ceremonies of the Liverpool and Manchester Railway, to which I have already referred, eight trains took part, running in procession on two parallel lines, and during the confusion following Mr Huskisson's accident the Duke of Wellington's car was hauled for part of the way by a chain attached to a train on the adjoining line. Eventually the engine of the Duke's train that had been used to convey Mr Huskisson to hospital returned with George Stephenson in charge, having travelled at speeds up to 34 mph towards the approaching convoy.

Signalling. With the rapid extension of railways, confusion arose at junctions, and accidents were so numerous that some form of signalling became imperative. The first types were boards and lamps fixed on revolving poles. They were turned to face the oncoming traffic when the line was blocked, and turned at right angles when it was clear. Even to this day the expressions "The board is on" or "The board is off" are sometimes used by the older drivers.

Various types and shapes of board and signal were developed according to the fancy of the individual designers, but gradually the semaphore signals, as we know them today, were evolved. With the increase in speed, longer distances were needed for stopping, and Distant signals were introduced. The early Stop signals were worked by handles on their posts and the distant signals by wires from levers on the ground. Similarly, the points were worked by hand levers alongside them.

By degrees as stations and junctions grew more complicated, points and signals increased in number, and sometimes points were worked by one man and signals by another. Mistakes, misunderstandings and accidents resulted, and led to the concentration of signal and point levers in signal cabins. Mistakes could still be made by a signalman pulling a wrong lever, and hence interlocking was suggested by Colonel Yolland following a collision at Bricklayers' Arms Junction in December 1855. The first patents were taken out by Mr Saxby, the well-known signalling contractor, and further interlocking improvements were gradually introduced.

Interlocking Rules. In the early sixties the first elementary interlocking rules were included in the Board of Trade Requirements, and these still hold good today. They were that the levers "should be so arranged that the signalman shall be unable to lower a signal for the approach of a train until he has set the points in the proper position for it to pass; that it shall not be possible for him to exhibit at the same moment any two signals that can lead to a collision between two trains; and that, after having lowered the signals to allow a train to pass he (the signalman) shall not be able to move any points in the wrong direction so as to cause a collision between any two trains".

These were not statutory requirements and although enlightened railway managements adopted these safeguards, others refused to do so on the ground that new-fangled mechanical devices made things more difficult and that they preferred to trust to well-trained pointsmen using simple equipment. Captain Tyler attacked these heresies in his outspoken paper presented to the Society of Arts in May 1874, and gradually, as a result of lessons painfully learned from accidents, even the conservative managements came into line and interlocking of points and signals had become the practice on most railways by the time it was made a statutory obligation in 1889.

Double Line Working. The technique of controlling the movements of trains between stations was also developed to ensure safety and increased efficiency of operation. The early railways were nearly all double lines, and with the increase in speed and density of traffic, steps had to be taken to space trains at safe distances. The time-interval system was at first adopted and it worked satisfactorily so long as the trains kept to time and did not break down, but unpunctuality was a constant source of dissatisfaction and danger. Captain Melhuish on an inspection in October 1840 found that this was due to some extent to the clocks in different towns varying by 10 to 15 minutes, and his suggestion was adopted that London time should be universal on the railways; this became known as "Railway time".

Absolute Block Working. The electric telegraph was first used on railways to give advice of train movement, and from it the block, or space interval, system of working was developed.

The block instruments enabled a singnalman to authorize the passage of a train through a section only when he was satisfied that the previous train had passed through completely, thus ensuring a clear space between every train. The block instruments had either two or three indications to show the signalman the condition of the line both in rear and in advance of his box, namely, "Line blocked" when there was no train in section and none had been accepted, "Line clear" when the train was accepted by the signalman in advance, and "Train on line" when the train was in, or entering, the section.

Bell codes were introduced to indicate the type of train and the message that was being transmitted, and handles on the instruments enabled the appropriate signalman to turn to the required position both the instrument in his box and the corresponding instrument in the box at the other end of the section. This system was much safer than the time-interval or permissive block systems, but it relied on the signalman at the box in advance never restoring his instrument to "Line clear" until the train that he had accepted had passed out of the section complete with tail lamp.

Lock and Block System. Despite these safeguards a number of accidents occurred as a result of signalmen's forgetfulness or failure to carry out the Block Regulations. In order to prevent irregular block working the "Lock and Block" system was devised, whereby signals were interlocked with the block instruments, and these in turn were controlled by devices operated by the train. With this system the Signalman cannot give "Train out of Section" until the train has actually arrived and operated a treadle, and he cannot lower his Starting signal until the Signalman in advance has accepted it. In order to allow for shunting and other movements a cancelling key has to be provided. Unfortunately, the irregular use of this key has led occasionally to accidents.

Single line working. On single lines the first safety move was to introduce the train staff which alone was the authority for the train to proceed into a section between two boxes. This was satisfactory so long as working was balanced, but should two trains be following each other, delays occurred whilst the staff was retrieved from the box to which the first train had taken it. The Staff and Ticket system was, therefore, evolved to enable trains to follow each other through the section, provided the drivers were first shown the staff which was carried by the last train.

This system still caused delay which was eventually reduced by the invention of the tablet or token instrument. One of these instruments was installed in the box at each end of the section, and interlocked electrically so that only one tablet could be taken out at a time; this had to be returned either to its own instrument or to the one at the other end of the section before another tablet could be released. This system, which is now standard in this country, enables trains to pass freely and safely between two stations, but ensures that only one can be in the section at a time.

Locomotives and Rolling Stock. The first locomotives were small and light, and boiler pressures were low, but with the rapid expansion of the railways the size and power of the locomotives were increased and boiler explosions, which nowadays are almost unknown, were all too frequent, bringing death and destruction in their wake. The early types of safety valve could be tampered with easily and after an explosion of a goods engine boiler in 1849 the Inspecting Officer found that the safety valve was set at 150 lb. per sq. in, instead of the working pressure of 70 lb. Those early years brought reports of similar casualties, but by 1870 the numbers began to fall, largely as a result of more careful inspection and testing, but also by the substitution of steel for wrought iron.

Braking system. More important still was the provision of adequate and effective brakes. The first trains were equipped only with hand brakes on the guard's van, and the engine was often reversed in order to stop it. But, as speeds increased, brakes were fitted to the engines and more braked vehicles were included in trains.

The next development was the introduction of the vacuum brake. This was applied throughout the train, but at first it was not automatic, that is to say the brakes were only applied by the creation of a vacuum in the train pipe, and thence in the brake cylinders on the vehicles. Thus, should the train pipe be fractured or pulled apart by a break-away the brakes immediately ceased to function.

The next stage was to develop the automatic continuous brake which reversed the operation, so that the brakes were held off by the creation of a vacuum in the train pipe, and thus were applied instantly should the train become divided. Attention was focussed on this important subject by the brake trials at Newark in 1875, but little was done.

Clearly better brakes were needed and, in 1877, the Board of Trade circulated their views to the railway companies recommending the adoption of the automatic continuous brake on passenger trains, but it was not until after the Armagh disaster that this was made compulsory. By this time, the more efficient Westinghouse compressed air brake had been introduced from the United States of America. It was adopted by some companies, but as the majority still adhered to the vacuum system this was finally adopted as standard when the railways were amalgamated in 1922.

Track and Structures. When railways were first opened, the condition of the formation sometimes was unsatisfactory and on a number of occasions the opening dates were postponed. With the increase in speed more attention had to be paid to maintenance and gradually the old wrought iron rails were replaced by steel. Contrary to the practice in Europe and America, where the flat-bottomed rail on hard-wood sleepers was favoured, the bull-headed rail resting in cast iron chairs fixed to soft-wood sleepers became the standard for British Railways. Lengths were gradually increased, first to 30 ft then to 45 ft and finally, at the end of the century, 60 ft rails were beginning to be used to give even smoother running. Similarly, weights were increased until 95 lb per yd was adopted as standard for main lines.

Tay Bridge disaster. The failure of structures has caused some bad accidents, of which by far the most serious was the collapse of the Tay Bridge as a train was passing over it on the night of 28 December 1879. A strong gale was blowing across the bridge and the ill-fated train had reached the centre when the middle 1,000 yd section toppled over and the girders, piers and train fell into the river below.

One of the few formal Courts of Inquiry was held to investigate the disaster, and its finding was that the bridge was badly designed, badly constructed and badly maintained. The chief fault lay in the slender cast iron piers that had flaws in some of the members, and were incapable of withstanding the heavy stresses produced by the high wind pressures on the girders that they were supporting. As a result, the Board of Trade, in the next issue of their Requirements for new works, made special reference to wind pressure and prohibited the use of cast iron columns in high bridges. A few years later cast iron was not allowed to be used except in arch rib girders where the material was in compression.

Work of the Pioneers. Considering the uncharted fields that they were exploring, the engineering pioneers made few mistakes. Tunnels, bridges and viaducts built well over one hundred years ago are still standing as monuments to those men, and are carrying traffic of a density, weight and speed undreamed of by their creators. Amongst such masterpieces of engineering are the Britannia Tubular Bridge over the Menai Straits, built by Stephenson and opened in 1850, the Royal Albert Bridge over the River Tamar at Saltash, built by Brunel and opened in 1859 shortly after his death, and the comparative newcomer, the Forth Bridge opened in 1890.

Summary. The nineteenth century was an era of railway adventure, of invention and rapid development of new engineering techniques, of fierce rivalry, of amalgamations and of monopolies. It was under such conditions that the requirements for railway safety were defined, tested and adopted, at first half-heartedly, but at last universally. The period of seventy years from the opening of the first public railway in 1830 to the end of the century saw the creation, and eventually the wholesale adoption of the three great safeguards for railway working, viz. the Absolute Block System of operation, the interlocking of points and signals, and the equipping of passenger trains with continuous automatic brakes. At the end of the century, railway managers had become largely safety conscious, thanks in no small measure to the powers of persuasion, both in private and in public, exercised by the Inspecting Officers.

Railway Safety in the Twentieth Century

The twentieth century has seen the consolidation, the further amalgamation and finally the nationalization of the British Railways. There has been growing competition from road transport, which began in the previous century with the rapid expansion of urban tramways and horse omnibuses and has now assumed such proportions that the railways are being streamlined to fit the pattern of the modern transport age. Through two world wars the railways were stretched to their utmost capacity to provide vital arteries of travel to sustain the mighty industrial and military effort of this country.

Engineering techniques—mechanical, electrical and electronic—have progressed at an ever accelerating rate, and many have been applied to railway engineering and safety.

Passenger rolling stock has increased in weight to provide the comfort and even luxury now considered essential for long-distance travel, and large and heavy freight vehicles have been designed to cope with the industrial loads. Steam locomotives have grown in size and weight, but now they are being replaced by lighter and more efficient diesel and electric locomotives. These developments have produced their safety problems and I shall endeavour to show how they have been met.

Signalling and Block Working. Safety requirements have been concentrated primarily on giving additional aids and safeguards to those two classes of railwayman—the signalman and the driver—on whose skill and devotion to duty the safety and efficiency of train operation ultimately rests. Signalling technique, which is now firmly based on the principle that failures must be on the side of safety, has made substantial and striking advances. Of these, the track circuit has probably been of the greatest value, and it is the basis of modern signalling.

The Track Circuit. A track circuit is the passage through the rails of electric current that closes a relay. The underlying principle is that positive action, such as clearing a signal, working points, giving "Line Clear" for a train, can only be taken when the relay is closed. Should the circuit be broken by track occupation or by a fault, the relay is opened and the associated circuit is either locked so that points, signals, etc. cannot be operated, or else cautionary action is taken, such as returning a signal to Danger or turning a block instrument to "Train on line".

Signalmen's mistakes. In semaphore signalled territories, with train movements controlled by block instruments, the mistakes to which signalmen are sometimes prone arise from forgetfulness, misunderstandings, and even mental aberration from which most of us suffer from time to time. Examples are, the clearing the the Starting signal for a train before receiving acceptance from the box in advance; overlooking a train stopped at a Home signal or sent forward to the Starting signal to await acceptance; the irregular clearance of the Block under the impression or even conviction that the train has passed when in fact it has not yet arrived; failing to return signals to Danger behind a train; returning signals to Danger before a train has passed them and then setting up a conflicting route under or directly in front of a train.

Signalling Controls. The controls that prevent these mistakes are set out in the 1925 Requirements of the Ministry of Transport. They include:—

(*a*) The release of the Starting signal, for one operation only, by acceptance from the box in advance;

(*b*) The prevention of such acceptance unless the Distant signal at that box is at Caution and or the Home signal at Danger;

(*c*) The interlocking of successive Stop signals so that none can be cleared unless the next ahead is at Danger;

(*d*) The placing and maintaining of the "Train on line" indication on the Block instrument so long as the Home berth track circuit is occupied;

(*e*) The prevention of acceptance of a train unless the previous train has passed through the section and has occupied and cleared the track circuit at the forward end.

This last control was introduced after a serious collission at Welwyn Garden City in 1935 and is known as the Welwyn control.

Colour Light Signals. Progress in electric lighting has led to the introduction of multi-aspect colour lights in place of semaphores; and long lengths of continuously track-circuited lines have enabled the space-interval between trains to be maintained by signals controlled automatically by the occupation and subsequent clearance of track circuits. Under this system the signalman controls the signals within his immediate vicinity, but others between his box and the next which nowadays may be up to 50 miles away are worked automatically.

In contrast to semaphore practice, automatic colour lights are normally Clear until a train passes them when they immediately turn to danger and do not clear again until a sufficiently long space interval has been provided.

Modern Signalling Installations. When first introduced, electrically controlled signalling was worked by miniature levers with mechanical locking. In modern installations, switches associated with route relay interlocking have taken the place of levers and they are mounted on illuminated panels, showing the lay-out of the lines controlled from the box. By this means, the signalman can set up a route through a complicated junction by turning a single switch, and, provided the line is clear and no conflicting route has been set up, all the points in the route will be set and locked correctly and the appropriate signals will clear. The setting up of a route is shown on the panel by a row of white lights and its occupation by red lights. The entrance-exit system with two push buttons, is used in the latest installations, and there are other variations.

In addition to controlling the signals in the immediate neighbourhood, a signalman can now control movements at stations and junctions many miles from his box by means of high-frequency impulses sent to an all-relay panel at the outlying station. These impulses can be sent through ordinary telephone cables because the integrity of the working is maintained by the panel locking. There are many variations of the same principle.

Briefly, modern signalling practice is to concentrate the control of large areas in one box and so arrange the electrical interlocking and controls that it is virtually impossible for a signalman to make a dangerous mistake. With these schemes, large numbers of old boxes can be abolished, resulting in a substantial saving in signalmen, more efficient train operation, and safer working.

The responsibility for safety and efficiency has to a considerable extent been transferred to the signal engineer, whose staff of technicians maintain these large and intricate installations at such a high state of efficiency that failures are very rare. With the concentration of so much work in a single box, serious dislocation of traffic may arise from a power failure and consequently supplies are invariably duplicated. Even so, a fault can occasionally occur and have serious repercussions, as happened at Waterloo on Friday, 9 August 1963 during the evening peak, when a small fire cut off all power supply and put out of action for twelve hours practically all the signals at this, the busiest terminal in London, if not in the world.

Single-line Working. On most single lines, token working with semaphore signals is still in use, but on some of them direction lever working with continuous track-circuiting has been introduced. With this system, the Starting signal cannot be cleared until the line is proved clear by the track circuits and the signalman at the far end has operated his release lever.

Aids for Drivers. Until the early years of the century, little was done to aid the driver in his responsible task. While locomotives grew larger, with bigger boilers to obstruct the driver's view, semaphore signalling grew more complicated, with formidable arrays of signals at large junctions and terminals. The driver, therefore, had to (and still has to) acquire an intimate knowledge of the road before taking charge of a train over it. In addition to knowing the gradients, curvature, and speed restrictions, he has to learn the position and significance of every running signal and know exactly where to look for it.

Well-sited colour-lights with their penetrative power, particularly in fog, and direction indicators in place of innumerable junction signals, have done much to simplify the driver's task, but his greatest aid to safety has been the introduction of the Automatic Warning System.

Automatic Warning System. The first time this was applied to main line operation was in 1906 by the Great Western Railway, who introduced a system known as Automatic Train Control (ATC). A steel ramp, connected electrically to the signal, was placed in the 4-ft way on the approach to a Distant signal, and a spring-loaded receiver was mounted on the locomotive. When the signal was at Caution, the ramp was "dead" and when it was Clear the ramp was "alive". On passing over the "dead" ramp the receiver on the locomotive was lifted, a siren was sounded and, unless acknowledged by the driver's pressing a cancelling key, the brakes were applied. If the ramp was "alive" the current that passed through the receiver stopped the siren but sounded a bell during the period of contact. This system was gradually extended to cover the whole of the Great Western Railway and it was so effective that Inspecting Officers constantly recommended its universal adoption.

An inductive system, known as the Hudd, was used on the London Tilbury & Southend Line from 1938, but it was not until the railways were nationalized that the Railway Executive announced their intention to extend this safeguard to all main lines. It was decided, however, to design an improved inductive system incorporating the best features of the two others. Development was slow, and it was not until 1952, when the Harrow Disaster emphasised so drastically the need for such a safeguard, that real progress was made. Eventually, in 1956, the system, now known as the Automatic Warning System, was finally approved.

Instead of a ramp, two magnets are placed in the track at each location, one is permanently magnetized but the other is an electro-magnet, energized only when the signal is Clear. A receiver that responds to the induced currents from the magnets is mounted on the locomotive. On approaching a signal at Caution, a siren is sounded in the locomotive cab and the brakes are applied unless the cancelling key is operated. This cancellation also causes a disc in the cab to turn to black and yellow, thus reminding the driver that he has acknowledged the Caution signal. Should the signal be Clear, a bell rings for one to two seconds and the disc is turned to black.

This and the Western Region system are now in use on over 2,500 route miles and have proved invaluable aids to drivers, particularly in fog. During the twelve years 1946–57, 55 per cent of all passenger fatalities in train accidents were caused by collisions arising from drivers passing signals at Danger, and nearly all might have been prevented by AWS.

Public Road Level Crossings. In many countries level crossings are a serious hazard both to road and rail users, but in Great Britain the safety record has been exceptionally good, thanks to the precautions that have been adopted since their inception.

The early laws of the last century laid down that at public crossings, gates had to be provided, to close alternately across road and rail. Normally they were kept closed against the road, and when open they had to fence the railway completely. Later this rule was relaxed at crossings carrying heavy road traffic to enable gates to be kept open for the road. On Light Railways, public crossings without gates have been permitted where road traffic is light, but severe speed restrictions have been imposed on the trains.

In recent years road traffic has expanded rapidly, while the cost of manning crossings has risen sharply. The law has, therefore, been amended to allow the introduction of lifting barriers in place of gates. The object is to ease the position both for the railway and for the road user. There are two main types:—

(*a*) the full barrier, either in one or two sections, protecting the complete width of the road and worked directly or remotely from a signal box or gatehouse;

(*b*) the automatically-operated half barrier covering only half the width of the road on each side of the crossing.

Directly worked barriers are installed at heavily worked crossings where delays occur in the operation of the gates. At most of these barriers, light signals are also provided to help the gateman to control the road traffic.

The remotely-worked barriers are only used where road traffic is comparatively light and not more than two railway lines have to be crossed. They are usually open to the road, and the protective devices include gongs that sound before and during the lowering of barriers.

The automatically-operated half barrier is the latest and most sophisticated type of crossing protection. In this case, the barriers are normally open to the road, and on the approach of a train they are lowered automatically by the operation of a track circuit or treadle. Each barrier fences only half the road so as to allow space for a vehicle to escape, should it be caught on the railway as the barriers are lowered. Gongs sound and lights flash both before and during the lowering of the barrier, but the time between the first warning and the arrival of the train has been cut to the minimum—15 seconds only in the case of the fastest train. This has been done deliberately so that motorists held up at the crossing will not be tempted to "jump the lights".

Locomotives and Rolling stock. One of the difficult problems facing the mechanical engineer has been the design of springs and bearings suitable for modern high-speed traction of heavy loads. In some cases, comfort was sacrificed for safety, but the latest bogies give excellent, smooth and safe support to passenger coaches, and the modern diesel and electric locomotives give much smoother running than their steam counterparts. Trouble has been experienced with the fast running of some types of freight vehicle and speed restrictions have been imposed, but the latest stock is satisfactory.

Much thought has been given to the design of coaches and couplings to withstand the shocks and stresses of high-speed movement. All-welded coaches, with Buckeye couplings and Pullman-type corridor connexions, have provided strength to the coaches and rigidity to the connections without affecting the flexibility needed on a railway track. These features have undoubtedly reduced damage and casualties in a number of high-speed derailments and collisions by holding the coaches in line and reducing overriding.

Fire Hazards. A hazard for passengers at the beginning of the century was from gas-lit coaches, and the casualties in a number of accidents were seriously increased by the spread of fire. Of these by far the worst was at Quintinshill in May 1915 when a troop train ran at high speed into a stationary passenger train, and the wreckage was hit by a fast express travelling in the opposite direction. The troop train comprised old gas-lit wooden coaches, most of which were shattered, the gas caught alight and soon the wreckage was a blazing inferno. The train was carrying men of the Royal Scots to Liverpool to embark for Gallipoli. The exact casualties were never ascertained as the Regimental rolls were destroyed in the fire, but it was estimated that 227 persons lost their lives. This was by far the worst disaster on British Railways, but it received little publicity because the authorities did not wish to create alarm and despondency in wartime. I understand that the efficiency of the War Office was such that casualties and equipment were made good in record time and the Regiment was able to sail with the convoy.

Fire Precautions. Electric lighting has now entirely replaced gas in coaches, but in recent years a series of fires in modern passenger stock caused much concern, and as a result drastic steps were taken to modify design and decor so as to eliminate as far as practicable further chances of serious fires. Alterations have been made to prevent the accumulation of inflammable rubbish in inaccessible places, and cleaning arrangements have been simplified. Inflammable material has been reduced to a minimum, and furnishings and paint have been made more fireproof. Additional centre doors have also been provided in vestibule stock to enable passengers to alight more quickly should the need ever arise.

Track and Structures. Up to the nationalization of the railways in 1947 bull-headed track remained the standard. Since then flat-bottomed rails have been introduced on main lines to cope with the additional stresses produced by high speed diesel and electric traction, and each year long lengths of all-welded track with rails on concrete sleepers have been laid in the main lines.

Long Welded Rails. This track has the advantage of providing smoother running and more economical maintenance, but special care has to be taken to prevent buckling. The answer lies in the rigidity of the rails, the strength of the fastenings, the stability of the sleepers, and the strength of the ballast to resist side thrust. The old theory that a rail must be allowed to expand and contract freely has been reversed, and with welded track the fastenings are designed to prevent rail movement except in the last hundred or so feet at each end, which are allowed to "breathe".

The expansion in the rails is restricted in hot weather, and consequently stresses build up as the temperature rises. The rail becomes, in fact, a strut supported every two or three feet by the sleepers, and buckling is prevented by the frictional resistance between the sleeper and the ballast surrounding it. This track gives excellent riding, and little trouble has been experienced provided the rails are de-stressed at times of mean temperature, should they have been laid originally at too low a temperature.

Bridges. Bridge engineering technique has also advanced during the century. All-welded steel work and, more recently, pre-stressed concrete are being used in railway bridges. With the former type, brittle fracture caused trouble in some places, though not in this country, and nowadays notch ductile steel is specified for thick welded tension plates.

Electrification. The electrification of railways in Great Britain has had a somewhat varied career. The low voltage (660 volts) DC third-rail system was adopted for the Metropolitan and District lines (later changed to fourth rail), and this system found favour on the Mersey Railway, on the Liverpool–Southport line, and on Tyneside. It was also adopted by the London & South Western Railway, and later by the Southern Railway.

On the other hand, the high voltage (6,600 volts) single-phase AC overhead system was used for the first electrification of the London–Brighton and South Coast suburban lines, though later it was converted to the third-rail system to come into line with the rest of the Southern Railway. The Midland Railway introduced the same high voltage system on the Lancaster–Morecambe–Heysham line, and in 1953 this became the first testing ground for the new high voltage AC single-phase system at industrial frequency, which became standard in 1956.

The overhead system at medium voltage (1,500 volts) DC was chosen for the Manchester–Altrincham line, and later it was adopted for the Manchester–Sheffield main line electrification and for the suburban electrification from Liverpool Street.

These variations in systems led to doubts about the inter-running of stock, should electrification be widely extended, and in 1927 the Pringle Committee was set up and recommended standardization on the low voltage conductor rail and the medium voltage overhead DC systems. These recommendations were given statutory force by the 1932 Electrification Order.

The High Voltage AC System. In 1951 the British Transport Commission accepted the 1,500 volts DC system as standard for all lines except those in the Southern Region and London Transport, though they did not rule out the possibility of using 3,000 volts DC or high-voltage AC on secondary lines. As a result, however, of the successful development of the high-voltage single phase system at industrial frequency, the Commission decided to change their plans and adopted this system for future electrifications except on those lines already equipped with the conductor rail system. As was to be expected there were some initial difficulties, but all of them have been resolved, and from experience so gained efficient and trouble-free equipment has been evolved.

Safety Precautions on Electrified Lines. Additional safeguards have been introduced to protect staff and public from electric traction. Special care is given to the insulation of cables and equipment carrying lethal current especially in vehicles where the vibration and shock effects from the movement of steel on steel produce their own problems. On the track the conductor rail can produce fatal shocks if touched. Hence in all urban areas and in other places where children are liable to stray on to the line special unclimbable fencing is provided alongside the railway. All level crossings are "gapped", protective boards are fitted on either side of the conductor rails at places where staff cross the line regularly, and permanent way men and others working on the line are provided with insulated mats, tools and even clothing depending on the type of work they are undertaking.

The introduction of the high voltage AC overhead system produced a different hazard which at first was serious. Some railway staff, enginemen in particular, failed to realize the danger from the overhead lines and several fatalities arose from men climbing on to locomotives or vehicles and inadvertently touching the contact wire. An intensive campaign was organized, including demonstrations, special instructions and the placing of warning flashes on all engines and vehicles likely to run on overhead electrified lines. The results were striking, for despite the increase in electrified mileage, casualties were reduced by two-thirds in three years.

Underground Railways. On the Underground Railways, which have contributed so much to the carriage of urban passengers, the additional hazards from fire, electric shock, overcrowding, and the difficulty in carrying out rescue operations, have led to extra safeguards being taken to reduce risks to a minimum. Stock has been made as near fireproof as possible and insulation against electric shock is of a very high standard. Two-aspect colour light signalling with train stops and continuously track circuited lines virtually eliminate the risk of collision during normal working, and the signal circuits are meticulously maintained to reduce their chance of failure.

A clearly defined code of procedure is laid down for dealing with emergencies and for allowing the train service to proceed in safety in the event of failures of any kind. Telephones are installed to enable drivers to speak to their guards and, in emergency, to the Traffic Controllers, and traction current can be switched off immediately by the train crew. Passenger car doors are locked before a train starts to prevent passengers from falling out or being caught in a closing door and carried into a tunnel.

The standard of safety on the London tubes is exceptionally high and it is satisfactory to record that accidents have been very few indeed.

Safety of the Staff. In the early days of the railways little attention was paid to the welfare and safety of the staff. Hours of work were long and conditions were often dangerous. In particular, goods guards and shunters suffered heavy casualties in coupling and uncoupling vehicles in yards and sidings. Many platelayers, whose work is of necessity hazardous, were killed on the permanent way. The annual fatality rate at the end of the century was:—

Goods guards	3 per 1,000 employees
Shunters	5 per 1,000 employees
Platelayers	2 per 1,000 employees

These rates were much too high, and a campaign was launched to reduce them. In 1902 the Board of Trade Prevention of Accident Rules were promulgated. They were designed to reduce the dangers inherent with shunting and working on the track. The placing of labels on both sides of a wagon was made compulsory; the movement of wagons by means of a pole, known as "propping", and "tow-roping" of vehicles were generally prohibited. Point rodding and signal wires had to be covered to save men from falling over them, and the ground levers placed so that men working them would be clear of the line; adequate lighting had to be provided in stations and sidings where shunting took place at night. Finally the companies were required to appoint look-out men to give warning to men working on or near the railway for the purposes of relaying or repairing the permanent way in all cases where danger was likely to arise.

The great progress made towards reducing casualties to the railway staff is well illustrated by the 1961 fatality rates for the three classes I have quoted. They were:—

Guards	0.4 per 1,000 employees
Shunters	0.5 per 1,000 employees
Platelayers	1.0 per 1,000 employees

The present situation is not, however, viewed with any complacency, and the measures taken to avoid accidents are to be intensified with the object of reducing still further the casualty rate to all classes of railway employee.

Summary. This century has seen the growth of passenger and freight traffic up to peaks of 2,000 million passengers and over 300 million tons of freight carried annually during the prosperous years between the wars, but with the increase in road competition numbers have fallen to 1,500 million passengers and 240 million tons of freight in 1962.

During this period much progress has been made in the provision of safeguards of all types and high standards of safety have been achieved. During the five-year period 1956–61 which included the Lewisham disaster, where eighty-nine were killed, only one passenger lost his life in a train accident for every 60 millions carried. Not even this good record is acceptable. Too many accidents still occur from human failures of one type or another. The distractions of this age undoubtedly play their part, and with the increase in the speed of modern traction, more automatic safeguards will be needed to maintain progress.

Railways in War

This paper would not be complete without a reference to the part played by railways in war. Almost since their inception, railways have been used for the carriage of military men and material. In India, the lines to the west of the Indus were built primarily for strategic purposes to enable the troops to maintain order amongst the tribes of the West and North-West frontier. Many Sappers have learned the art of railway construction and operation in the service of the Indian railways.

Early Campaigns. In 1897, Lord Kitchener conceived the bold project of constructing a railway across the Nubian Desert for 230 miles from Wadi Halfa to Abu-Hammen and thence to Atbara to sustain his forces for the re-conquest of the Sudan.

During the South African War the railway was by far the most important transport agency and it kept going despite assaults by the enemy and interference by some of its military users. The Boers made raids on the lines and caused destruction and delay with contact and observation mines under the track. On our own side, senior officers sometimes used armoured trains for inspection purposes and took them out in the face of trains from the opposite direction, much to the alarm of the staff and to the detriment of safe traffic working. One garrison commander refused to allow a locomotive to take coal at a station because he had used the coal stack to form part of his defences!

The World Wars. In both World Wars the railways played a major role. In the 1914–18 War the troops on the Western Front were maintained almost entirely by rail, and the Palestine Railway was built to support Lord Allenby's advance from the Suez Canal. In the 1939–46 War all forms of transport—rail, road, air, sea and river—were brought into service, and each in its own particular sphere made vast contributions to meet the huge transportation load. The Western Desert Railway was extended to Tobruk; the Palestine Railway was joined to the Syrian Railway.

In Burma all forms of transport were pressed into service. Railway locomotives were carried complete on tank transporters from India to the Chindwin, floated down river for 200 miles, put ashore on a sandbank and sent straight into action on the railway. Others went by road to the Irrawadi and some were flown in by air. Even jeeps were fitted with railway wheels and used to haul trucks of supplies to the fighting troops.

In Europe, railways were used for the concentration of the BEF and later, despite the severe bombing damage, they helped to support the advance across France into Germany and the bridges built over the Seine and the Rhine were some of the finest engineering feats of the war. In this campaign, however, roads undoubtedly made the greater transport contribution.

At home, railways provided the vital movement arteries, but time does not permit a description of this work; though I believe it would be of interest to refer to the arrangements made in connection with the Dunkirk evacuation, known as "Operation Dynamo".

Operation Dynamo. A few days before the operation began a meeting was held between the Movement and Transportation Officers of the War Office and the Railway Operators. No one knew how many troops would get away, but the plan was designed to cope with the maximum and to be flexible. Bombing was expected at the ports and on the lines leading from them, and it was thought that London would suffer too. Dover, Folkestone and Ramsgate were the three reception ports, with Dover taking the major share, and Dover Castle was the control centre for the whole operation. The returning troops were to be dispersed amongst the military centres throughout the country on the basis of doubling-up on the existing barrack accommodation; no attempt was made to sort out units. The railway plan was simple. One meeting with the Railway Officers sufficed to settle it, and a second to confirm the details.

The trains were of standard size to carry 500 men and two trains were always ready at each port. As soon as they were loaded they were dispatched to a regulating station at Redhill where Army Movement and Quartering Officers planned their onward movement with the Railway Staff. A Railway Construction Group, RE was based at Ashford and made fully mobile to deal with any emergency. Fleets of buses were held in readiness at the ports to take the troops from their disembarkation points to outlying entraining stations should bombing cut the railway exits.

The railway effort was an epic of emergency train operation. Train sets were furnished by each company and marshalled at centres on the routes to the Kent Coast. Normal services were drastically cut or suspended during the operation, and altogether 620 trains carried 320,000 troops from the ports to their destinations throughout the country without a single casualty. This was achieved because the principles of safe railway operation were maintained though unorthodox methods were used.

Safety Principles. It is seldom, however, that British Railway operating methods can be used on a military railway. The military railwayman must plan his work to suit the conditions that he finds in the theatre of operations, which, in the future, may be in support of one of the Afro-Asian countries. He can adopt simplified methods providing always he does not abandon the fundamental principles of safety.

For example, the telephone and ticket system can be used for single and double line working in place of tablet or block working. Under this system the signalman exchanges messages on the telephone and then issues a ticket authority to the driver. This method of working is quite safe provided a clear code of messages is laid down and a high standard of discipline is maintained. The timetable and train order system, as practised on many railways, is also satisfactory, and pilot working can be introduced when communications have broken down. Station limit boards and simplified signals can be adapted should the existing signalling system have been destroyed. Standards of track maintenance can be reduced, provided speeds are restricted, but there is a limit beyond which the engineer must not go, as was exemplified by the serious derailments and delays that occurred on some of the new lines built during the Somme Battle in the First World War.

Let it be remembered always that once the railwayman, whether civil or military, foresakes his safety principles and allows others to force his hand, delays, derailments or even disasters will ensue as has been demonstrated so many times both in peace and war.

Railway Safety in the Future

It is with some trepidation that I turn to the speculative side of this paper. What of the future? Who can tell what is in store for us? An atomic war may blot us out, or leave us devastated to start life afresh with the standards of the Ancient Briton. On the other hand, we may see flights to the Stratosphere become a commonplace, and our children or grandchildren soaring to the Moon.

To come back to earth, however, let us consider what progress can be made in railway safety. To do so we must endeavour to forecast the future shape and scope of the railways.

The Future British Railways System. The report on the reshaping of British Railways presented in 1963 envisaged the remodelling of the railway system to a size and pattern best suited to modern conditions and prospects. The plan is that redundant lines and stations will be closed and traffic in general will be concentrated on a number of high-speed routes. Liner trains, carrying freight containers, and other specialized freight trains will run at the speed of passenger trains. The slow stopping passenger train will no longer obstruct the main lines, and slow freight trains will as far as possible be confined to independent routes.

Under such a policy much simplification of signalling should be possible. The closure of intermediate stations and sidings and the elimination of the stopping passenger and "pick-up" goods trains should result in the removal of large numbers of points and crossings and signals, and the control of signalling from a few widely spaced boxes. These will be at main stations and junctions, and the intermediate signals between them will be worked automatically by track circuit occupation, or other means, to maintain an adequate space-interval between trains. AWS will, I believe, be extended to cover all such main routes and we shall see trains running at high average speeds with a maximum of about 100 mph or possibly more.

All this is an extension of existing signalling safeguards but with the segregation of traffic the prospects of more sophisticated forms of operation and control are promising.

Radar. Suggestions have often been made that radar should be introduced on railways to enable a driver to get warning of obstructions ahead. People sometimes forget that railways run on restricted tracks, around sharp curves, under bridges and through tunnels, with trains passing constantly on adjoining lines. Under these conditions, normal radar is quite incapable of distinguishing structures and moving loads that can be passed with safety from the rare obstructions that might cause danger. Recently, however, experiments have been made with radar, guided by wires or cables fixed in relation to each track, so that obstructions on an individual line, such as a train ahead, or a car on a level-crossing, can be positively identified. There are many technical difficulties still to be overcome, but should this equipment be proved safe, reliable and reasonably cheap it may well be associated with the automatic operation of trains.

Radio. Radio should also play a bigger part in the future. In some countries radio communication has been established with moving trains, but in Great Britain its use has been confined principally to marshalling yards where radio links have been established between the controller and the shunting engine driver. The chief objection to radio links with moving trains has been the difficulty of directing messages to one particular receiver which can be identified without fail, and of ensuring that messages to and from that receiver will not be overheard by any other. This problem has now been virtually overcome by a selective calling system whereby each locomotive receiving set has a selector that responds only to its particular code, and the central controller has the equivalent to a telephone dial which enables him to call up one particular locomotive without alerting the others.

In a system that I inspected recently, ninety-nine separate codes could be used, but I understand that with the latest equipment almost an infinite number are available. A selective radio of this type could, I believe, be used with advantage as a link between driver and guard of a long freight train, and possibly between controller and driver to give him working instructions and to exchange information in the event of an emergency. There are, however, many difficulties still to be overcome before reliable communication can be established between controllers and drivers. Deep cuttings and tunnels present problems, and an intensive network of transmitter/receiver stations will be needed.

Should developments prove successful in establishing the selectiveness and integrity of this equipment, it might be used in the future to control all movement of trains on freight lines and lead to the removal of signals and the withdrawal of signalmen. The drivers would then work directly under the controller, who would know the position of every train on the line and give the requisite orders for their movement. A high standard of discipline in the giving and receiving of messages will be required, and it might be advisable to combine this system with guided radar.

The use of radio to give a direct link between the drivers of trains on passenger lines and signalmen and controllers might also be of value especially in emergency, but I would not contemplate the control of passenger trains by this medium until its integrity and reliability reaches the safety standards of conventional signalling, and problems of fading and of interference from outside sources have been solved. A radio telephone link between passengers and the GPO telephone system may also be practicable, but costs may be too high to make it attractive.

The Channel Tunnel. The recent report of the Anglo-French team of Government Officials holds out a promise that a Channel Tunnel may at last become a reality. The operation of trains through such a long tunnel will present a number of safety problems. Electric overhead traction will undoubtedly be used, maybe with automatic train operation or else with speed control and train stopping equipment. Whatever system is adopted the chances of a collision must be eliminated as far as is humanly possible. A fire is probably the greatest hazard, because motorists may be allowed to remain in their cars whilst being conveyed in railway vans through the tunnel. Their cars may not be in first class condition, and the casual and thoughtless driver may be tempted to light a stove for a meal, or be careless with cigarettes. Road accident records suggest that this risk is slight, but it cannot be ignored. The car trains will have to be designed so that sections can, if necessary, be isolated rapidly, and they will have to carry adequate fire fighting equipment and staff. Special ventilation will be needed to disperse fumes quickly should a fire ever occur. I have little doubt, however, that by the use of modern equipment and techniques, the safety arrangements in a Channel Tunnel will be such that the chance of a serious fire or accident will be neglibible.

Transport of the Future. The problem of keeping existing traffic moving will, I am sure, be a major factor in the future development of any new railway, or private way, such as the Mono-Rail, Hover-Car, Leva-Pad or Linear Motor. Hence it seems likely that a completely new formation will be needed for any novel form of traction. Furthermore, the curvature both horizontal and vertical and the many bottlenecks on existing British lines precludes the possibility of introducing super high speed trains running at 200 to 300 mph. Whether such a railway would ever be economically practicable or desirable will depend to a great degree on the future development of road and air transport. Progress has been so fast in recent years that it is difficult to forecast future trends. Would it not be desirable, therefore, to set up a national body to cast horoscopes of the future and endeavour to plan a co-ordinated transport system best suited for the needs of our densely populated country?

CONCLUSION

I hope that in this paper I have shown how railwaymen of past and present generations have placed safety to the forefront, how they have brought to their profession the technical developments of their time and have set a tradition of safe and efficient service to the community. Railwaymen of the next generation will, I am sure, uphold and expand these traditions in the running of future forms of transport, however sophisticated they may become in shape, style and performance.

Correspondence

The Editor,
RE Journal.

From Mr Pitt H. Jones, ACGI, MICE,
The War Office,
St Christopher House, Southwark Street,
London SE1.

29 September 1963.

Dear Sir,

THE DEVELOPMENT OF ENGINEER EQUIPMENT FOR THE ARMY

Colonel Lawrie must be congratulated on his clear description of the War Office Development/Procurement System, which he outlined in your September issue. It is only when such a system is fully set out that it is possible to start to criticise it constructively.

Let us consider what the system is trying to achieve—it is to provide the troops with up-to-date equipments. Any equipment which has taken over-long to develop may have become out-of-date before development is completed, moreover the development cost is likely to be high as a result. Perhaps it might be fruitful to consider the designer himself who is obviously the most important part of the system. If he could work in vacuo, completely divorced from all previous projects and could concentrate solely on the work in hand, undoubtedly design time could be very substantially reduced and by much more than the sum total of the interruptions he now endures. Each time he has to break the train of his thoughts he loses ground. Moreover, when he is forced to amend one of his own previous designs he is apt to think of new improvements and devote more attention than is justified to the making of an essential modification. One way to alter this would be to wrench his design and calculations from him as soon as the prototype is completed. These would be handed over to an independent post-design specialist team, who would handle all modifications and amendments thereafter. The team would preferably be situated within the R & D Establishment.

Considering now the spares situation, which Colonel Lawrie emphasises in his paper, I am quite sure that in this field, perhaps more than in any other, could improvements be made.

Obviously, with specially developed equipments it is essential to order all such spares as special extrusions, special forgings or rollings, or special materials at the same time as the contract is placed for the equipment, otherwise if obtained later, as is only too often the case, they may be extremely costly and take an inordinate time to obtain. The solution here is that scaling must be phased in to enable this type of spare to be bought at the right time, and since at this stage the main equipment is not catalogued, does it really matter that the spares are not catalogued either? It would seem better to get the spares when they were available and to devise machinery for attaching the right label to each part later when the cataloguing is done. ESE have done this sometimes and it would seem to be the best solution for this type of equipment.

Turning now to proprietary items, obviously spares scaling cannot start until a contract has been let and the contractor is known, thus it may often take up to five years for the scaled and catalogued spares to become physically available. To enable items to be maintained during this period, spares are issued in the form of an MSP (Makers Spares Pack), but since most proprietary equipments are Ordnance Stores and Ordnance Depots have no machinery for reconciling these spares with future catalogue numbers, they are never brought on charge and may be lost, damaged or divorced from the equipments before very long. The above provisos may also apply wholly or partly to modified proprietary items. Eventually, after up to five years, the system becomes fully working and the Ordnance Stores hold all the spares, but by this time some equipments may well have become out-of-date, either simply by commercial evolution or because entirely new methods have been introduced, or they have been ruined because they have been used without proper maintenance through lack of spares.

The NATO Cataloguing System may well ensure that no one article is ever kept in two different bins under different catalogue numbers. (Perhaps this was more important under last war conditions of enormous stores holdings than in the present and future), but the expenditure of effort and cost of cataloguing, the waste of spares issued under the MSP System, the disruption of morale because of the lack of a proper spares backing to new equipment, are a high price to pay for this.

For obvious reasons, we now aim at procuring as much equipment as possible in the standard unmodified commercial form, and these items frequently have a world-wide spares backing which it would be possible to make use of by using running contracts or local purchase powers, and ordering from makers' catalogues. By this means we could reduce spares holdings to the minimum emergency requirements and these too could be procured the same way after experience of using the equipment had dictated the proper spares to procure.

Of course, with equipments which have a life expectancy of fifteen or more years my argument against cataloguing carries less weight, but here, and wherever scaled spares are planned, the existing commercial system could well be used to fill the gap between the issue of the equipment and the eventual supply of scaled spares.

Yours faithfully,

PITT H. JONES.

From Brigadier R. M. N. Patrick, RAOC,
The War Office,
First Avenue House,
High Holborn, London, WC1.
5 November 1963.

The Editor,
RE Journal.

Dear Sir,

I would like to take Mr Pitt H. Jones up on the remarks in the latter part of his letter, which give a somewhat distorted picture of Ordnance methods in dealing with spares.

I do not know on what instances his statements are based (I understand from the Directory that he deals mainly with RE Structures, which include few if any items of Ordnance supply) or how recently they occurred. He may not be aware however that a proper "drill" was instituted in 1961 by the setting up (largely as a result of Ordnance initiative) of the Initial Spares Requirement Planning Committees which have been meeting at intervals ever since. I do not know of any recent case where "equipments . . . have been ruined because they have been used without proper maintenance through lack of spares", but if Mr Jones will quote chapter and verse I shall certainly investigate.

May I briefly correct some erroneous impressions given by his letter:—

(*a*) Specially developed equipments—we *do* have machinery to order spares before cataloguing, and this has become more the rule than the exception since 1961.

(*b*) It is not true to say that "it may often take up to five years for the scaled and catalogued spares to become physically available". There were, it is agreed, a few slow cases before 1961—the longest we record is three years. The present system is not only quicker, but its flexibility enables the gap to be bridged where necessary by the use of maker's packs.

(*c*) It is also untrue to say that maker's pack spares are "never brought on charge and may be lost etc". Each pack held by Ordnance is given a special part number under which it is vouchered and brought on charge. I cannot of course say what happens in units.

(*d*) Running contract and local purchase are in fact used wherever necessary and applicable.

I am not sure whether Mr Jones appreciates, as Colonel Lawrie has in his admirable article, that the maker's pack is at best a stop-gap, albeit a useful one. The real aim is to ensure, in the time bracket available, the best possible cataloguing, scaling, and screening, so that the Army gets the deployment of spares it needs and the taxpayers money is not wasted on unnecessary items or quantities. So far from the last war inventory having decreased, Mr Jones must be aware that with the complexity of new equipment, particularly in the electronics field, it is increasing monthly; with the commonality existing it is more than ever necessary in ordering spares to use the methodical processes of the computer age rather than the hit-or-miss methods of the maker's pack, useful though these may be as palliatives in specific cases.

Yours faithfully,

R. M. N. PATRICK.

The Editor,
RE Journal.

Colonel W. G. A. Lawrie, MA, AMICE.
HQ, ESE (UK),
King's Buildings,
Dean Stanley Street, SW1
14 October 1963..

Sir,

Mr Pitt Jones has hit the nail on the head when he suggests that improvements might be made in the field of spares provision. The aim is to ensure that every item of equipment has maximum usage throughout its working life by providing an adequate backing of spares at minimum cost.

In the case of standard commercial equipments it would obviously be ideal if we were able to cut out our own spares holdings and rely on buying what was required on an *ad hoc* basis from local agents. There are, however, two reasons why this is not possible:—

(*a*) We must cater for limited war operations and peacetime projects in areas where there are no local agents, eg, Christmas Island.

(*b*) We have found in the past that civilian manufacturers are apt to change the design of their machines and the catalogue number of their spare parts with bewildering frequency. Civilian users find it economical to scrap a machine after a year or two and buy a new model. We cannot do that. Our plant often spends a considerable part of its life in War Reserve depots and is still serviceable ten years after its introduction, provided that spares are available.

It follows that there must be a military organization for scaling, provisioning, holding and issuing spares. By setting up the RE Repair and Maintenance Team at MEXE and by holding regular meetings of all interested persons we hope to have ensured that the necessary steps are taken at the earliest possible moment.

In the case of service-developed equipments, I am sure that we could achieve economy by making a ten year buy of special parts and components concurrently with the main production run. The difficulty here is to persuade the Treasury to part with more funds initially against a promise of long-term savings. Another problem which has to be considered is the increased storage space and handling commitments involved in increasing our holdings.

As regards NATO cataloguing, we would be prepared to do without it, but we are bound by an international agreement to catalogue all new service equipments to the NATO system. This does take time. The UK has 800 men working on this. The Americans have many thousands, plus electronic computers.

These comments may be sufficient to indicate the complexity of the problem. There is no obvious solution, but the importance of finding improvements to the present system is so pressing that it would be well worth while instituting a fully documented and costed work study. This is what we hope to do.

Yours faithfully,

(Signed) W. G. A. LAWRIE.

The Editor,
RE Journal.

Major T. W. Stanier,
The Poplars,
Horsmonden,
near Tonbridge, Kent.
21 October 1963.

Dear Sir,

The article by Colonel W. G. A. Lawrie in the September issue of the *Journal* on "The Development of Engineer Equipment for the Army" is extremely interesting, and covers this important matter in almost frightening detail. Following experience during the War as OC of a Mechanical Equipment Company in the Middle East and later as DADWS Plant in Cairo, I saw a good deal of the spares problems involved with construction equipment. I am now with the Marshall/Fowler organization, which has supplied large numbers of Class II crawler tractors to the Army as well as manufacturing the "Gainbsorough" medium wheeled tractor, and have thus also seen the problem from the manufacturer's point of view. Consequently I am encouraged to take advantage of Colonel Lawrie's invitation at the end of his article to make suggestions that might improve the system and reduce the appalling time lag in making plant available to the Army, with an adequate backing of spares.

In venturing to comment, I should make it clear that I am thinking primarily of construction plant normally available for commercial use. Specialized items of RE equipment, developed solely for military purposes, doubtless require the full treatment, and perhaps the eight-year time lag is inevitable. I have always understood, however, that it is an accepted principle for the Army to use commercial plant wherever practicable, thus facilitating rapid expansion in time of war. This applies particularly to construction equipment, which is a normal tool of civil engineering.

Turning to the spares problem, the crux of the matter is pinpointed by Colonel Lawrie in his last paragraph on page 281, in which he points out that there is only one cataloguing authority for the whole Army, and that the whole process of scaling and cataloguing spares may take as long as two years.

In my own experience we have supplied Class II crawler tractors to the Army, which are prefectly standard equipment (with very minor modifications for military purposes) and which have gone into service with units long before the official Army spares book was available, with the result that there was no procedure for the ordering of spares by units. I should make it clear that my own Company was quite prepared to supply the normal commercil spares book with each tractor, but was instructed not to do so. I should also make it clear that there was no delay on our part in supplying the necessary information on spares to enable cataloguing and scaling to proceed. It is simply the bottleneck, to which Colonel Lawrie refers, that is the cause of the trouble.

It seems to me that a completely new approach is necessary if we are to overcome this Gilbertian situation in which spares are readily available from the manufacturer, but cannot be channelled satisfactorily to the operating unit in Malaya, Germany or elsewhere, owing to the rigidity of the present system. No one disputes the necessity for eventually supplying Ordnance, REME and RE depots and sub-depots with packs of fast-moving spares, but what seems to be entirely lacking in the Army system is some provision for obtaining an individual spare urgently. I am aware that local purchase from manufacturer's agents can be authorized in emergency by Command Secretaries, but doubt whether this is known to the average Sapper Subaltern. In any case, if he is doing his job, he wants to keep his plant in operating condition, irrespective of whether there is an immediate emergency or not.

We in industry have much the same problem in our export markets. We try to persuade our overseas distributors to stock spares on a sensible scaling, but if they are looking after the customers in their territory properly, they frequently have to cable for an urgently required part to be sent out by air to keep plant in operation, for, however carefully the scaling is done, there are always unexpected items required. In other words, getting the vital part to the right place at the right time, is the distributor's responsibility.

Surely it should be possible, with all the communications and transport available to the Army, for the same principle to be applied particularly when it is remembered that *most Army plant is very lightly used indeed.* In peacetime a large proportion of Army construction equipment is used solely for occasional training or is standing in depots, and it is very seldom that the actual operating hours recorded are appreciable. In wartime also, plant may be used intensely for short periods, but seldom accumulates sufficient operating hours to involve serious wear and tear in the commercial sense. Consequently, both in peace and war, genuine wear and tear is rarely experienced, and the part required is usually some item that has broken, either through an accident, misuse or enemy action, and which is very probably not included in the normal spares scaling.

It is suggested, therefore, that, for this type of plant, it is equally if not more important to make provision for the rapid supply of the individual spare from the factory to the plant in the field, than it is to fill the pipeline with a vast quantity of spares in depots, most of which will never be used.

It is suggested also that, if once the system were modified to facilitate the rapid supply of spares when required, very considerable economies would result, simply because the quantity of spares held in Army depots could be substantially reduced. At present, the scaling, if it is done conscientiously, is really a form of insurance, and must include every conceivable item that could possibly be required. If the principle of rapid supply were once accepted, it would only be necessary to hold in depots packs of fast moving parts, and the resultant all-round economies would be considerable.

In this mechanical age, we are in danger of being strangled by our own detail and paper work, and it seems to me that the Sappers would benefit greatly if they decided to back up their plant by intelligent spares supply, rather than by vast stock holdings and "insurance" spares, most of which become redundant. Furthermore, plant acquired by the Army could then be issued to units and put into effective service much more rapidly, because it would no longer be necessary to accept the two-year time lag at present involved in spares scaling, acquisition and distribution to depots.

It may not be appreciated also that the existing time-wasting procedures tend to result in the Army always having plant that is out-of-date by the time it is put into service. If the spares bottleneck could be by-passed in the way I suggest, the Army would be much better able to keep in step with commercial practice and development, to the great advantage of all concerned.

Yours faithfully,

(Signed) T. W. Stanier.

Brigadier Sir Mark Henniker, Bart,
CBE, DSO, MC.
Pistyll, Began Road,
St Mellons, Cardiff.

The Editor,
RE Journal.

26 October 1963.

Dear Sir,

Colonel Lawrie's paper in your September number on the Development of Engineer Equipment for the Army is a formidable work, and must have entailed much toil in collecting the facts. But he tells us it takes eight years for a new equipment to get launched; and looking at the maze of channels through which it must go one cannot wonder that progress is slow.

The process seems to have two defects. First, too many people have a finger in the pie, with the result that the product tends towards the ideal at the expense of the good. Consider the two vehicles, the Champ and the Land Rover. The former incorporates every embellishment that anyone could think of (including the ability to travel at 40 mph backwards); but in practice it is little better (if at all) than the Land Rover.

Secondly—and this springs from the same causes—consultation is a most time-consuming process. It is not that those consulted are slow or indolent; but where busy men are concerned their convenience must be studied in fixing meetings, and there is inevitable delay in getting a number of them together properly briefed for the occasion. Then there is the actual bureaucratic delay while typing is done and while documents are in the post. Thus, weeks become months, and months years. At the end of it all, come success or failure, there is no single individual who can be held accountable for a notable achievement or an engineering monstrosity.

Naturally, an outsider cannot hope to make procedural suggestions; but it does seem to the outsider that swifter and surer progress would be made if each project were linked with some recognisable individual who could be praised or blamed according to the result.

Yours sincerely,

M. C. A. HENNIKER.

The Editor,
RE Journal.

12 July 1963.

Dear Sir,

GRANTS CROSSING OF THE RIVER JAMES

I have just finished reading your interesting article in the June 1963 issue of *The Royal Engineers Journal* on "Grant's Crossing of the River James." It brought back memories of my Civil War studies.

More to the point, and somewhat supporting the comment on the progress of wet bridging techniques, when I joined my first Regiment in 1936 as a green lieutenant, our bridging equipment was still that you described, developed during the Civil War—the same pontons, on the same wagons—I might almost say drawn by the same mules! The same balk and chess to be lashed to the gunwhales, the problems of caulking.

One of the more ridiculous periods was when we became partly motorized a year later, with trucks replacing the mules, including the job of towing these wagons with their loads. Speed increased slightly, but the chief result was an accelerated loss of wagon wheels. I was delighted to see these replaced by aluminium bridging the following year.

Sincerely,

T. J. HAYES.
Brigadier General, USA.

The Editor,
RE Journal.

Brigadier H. de L. Panet, CBE.
161 Wilton Road,
Salisbury, Wilts.
14 August 1963.

Dear Sir,

"HISTORICAL OCCASIONS"

Referring to your notice in the August *Supplement* about the McLeod of McLeod, did you know the bomb badge of Bomb Disposal forms part of an armorial achievement matriculated in the Lyon court?

J. H. Macpherson of Dunmore who was, until invalided out, a Captain in Bomb Disposal RE (AER) matriculated arms in Scotland as the head of a cadet branch of the Clan Macpherson, and to mark his service in Bomb Disposal was awarded the crest of the traditional wildcat of the Macphersons with the augmentation of the Bomb Disposal badge, technically "a cat-a-mountain sejant grasping in its dexter paw outstretched horizontally an aerial bomb vanes upward or banded of two barrulettes azure".

Is there any other instance of such a distinctive Corps activity being included in a personal achievement of arms?

Yours faithfully,
H. de L. PANET.

Editor's note

The notice referred to in the August 1963 *Supplement* reported on this year's annual camp of 101 (London) Corps Engineer Regiment (TA) in Scotland and the exchange of telegrams between the Regiment and Dame Flora McLeod of McLeod.

The Regiment was founded in 1860 by Lieut-Colonel the McLeod of McLeod.

There are other previous examples of Corps motifs (if not actual Corps activities) being included in a personal achievement of arms. Notable examples are:—

General Sir William Green (1725–1811) who, when Chief Enginer in Gibraltar, raised the first Company of Soldier Artificers in 1772 and who from 1787 to 1802 was the Chief Engineer of Great Britain. Three traditional engineer "castles", representing the Corps "fortifications" activities, were incorporated into his coat of arms on his return to England in 1783 after the Great Siege of Gibraltar when a baronetcy was conferred upon him.

Lieut-General Sir Harry Jones (1791–1866) who, as a Subaltern, fought in the Peninsular War being severely wounded and taken prisoner during the assault on San Sebastian in July 1813, and in the Crimean War when he commanded the British forces sent to the Baltic and later took over from General (later Field Marshal) Sir John Burgoyne as the Senior Engineer Officer in the Crimea.

During his military career he saw the conversion of the Corps of Royal Military Artificers into the Corps of Royal Sappers and Miners in 1812 towards the end of the Peninsular War, and the absorption of the corps of Royal Sappers and Miners into the Corps of Royal Engineers in 1856 after the Crimean War. His coat of arms has incorporated into it the engineer castle, and the supporters consist of a Private of the Royal Military Artificers in his blue coat and white breeches and a Sapper of the Royal Engineers in his scarlet jacket.

Field-Marshal Lord Napier of Magdala (1810–90) who started his military career in the Bengal Engineers of the Honorable East India Company's Army. He served with distinction during the Indian Mutiny 1857–9. After the Mutiny the government of India was transferred from the East India Company to the Crown and British officers and other ranks in the Company's service to the Queen's Army. In 1862 the officers of the East India Company's Madras, Bengal and Bombay Engineers were absorbed into the Corps of Royal Engineers. To commemorate that union the supporters of Napier's coat of arms consisted of a Sapper of the Royal Engineers and a Sepoy of the Bengal Engineers.

Napier later commanded a Division in the China War and in 1866 he became Commander-in-Chief of the Bombay Army. He was Commander-in-Chief in the Abyssinian Campaign of 1867–8 being the first Sapper officer to command a British Army in the field. He was made Commander-in-Chief in India in 1870 and Governor of Gibraltar in 1876. In 1883 he was made a Field Marshal and appointed Constable of the Tower of London.

The Editor
RE Journal. 2 August 1963.

Dear Sir,

JOURNAL ARTICLES

I have recently been reading copies of two American military journals and have been impressed by the quality and content of some of their articles. They pay particular attention to developments in other Armies and their articles are fully illustrated with diagrams and photographs, eg, "Armor" has had a detailed article on the new Swedish Tank S with its novel suspension and gun controls, while the *Military Engineer* has had excellent articles on the German M2 Bridge, the American Mobile Assault Bridge, Dracones in Greece, our own Uniflote equipment and the new American Universal Engineer tractor. These types of article are all well worth reading and provide what is often the only source of information for many officers on current developments.

Cannot the *RE Journal* contain some articles of this type, perhaps from official sources rather than from individual officers? I feel that the *Journal* pays too much attention to the past and insufficient to the future. Almost the only forward-looking articles in the past year have been those dealing with ground effect machines and we have had nothing on mine clearance, minelaying, earth moving equipment or aids to river crossing, particularly exits for amphibious or schnorkel fitted vehicles. As a Corps we can only progress if we have a plentiful supply of new ideas and there is a requirement to stimulate such ideas. What better medium is there than through the pages of the *RE Journal*?

Yours faithfully,
G. L. C. Cooper,
Major RE.

Note by Author

Major Cooper has been asked to submit for publication in the *RE Journal* an article dealing with the special equipment of the Squadron he commands.

The Editor,
RE Journal.

Colonel W. G. A. Lawrie,
HQ, Engineer Stores Establishment (UK)
Kings Buildings,
Dean Stanley Street,
London, SW1.
9 October 1963.

Sir,

EFFECTS OF SCOUR IN RIVERS

You published an article by me in the *RE Journal* for September 1952 entitled "The effects of Scour on military bridge design" in which I evolved a formula* which might be useful to an engineer officer faced with constructing an L of C bridge in an undeveloped country where hydrological data was not available. In support of my suggestion I quoted data from several Indian rivers.

Since this article gave rise to a number of letters from officers who were interested in the subject, it may be worth mentioning that the Hydraulic Research Station at Wallingford have recently been studying a proposed crossing of the River Kaduna in Nigeria and have compared the results obtained from my formula with river observations and model studies which they have carried out.

The figure which they have sent me are as follows:—

Observed scour depth in 1962 flood of 200,000 cusecs(the highest observed in fifteen years)	= 38.8 ft
Estimated value of scour depth for a flood of 350,000 cusecs based on Lacey/Blench equations (occurring perhaps once in 500 years)	= 51 ft
Observed value of scour depth for a flood of 350,000 cusecs (on hydraulic model in the Meander area at Wallingford)	= 47.3 ft
Calculated maximum scour depth from my formula (taking the average meander length obtained from aerial survey as 8,745 ft)	= 42.5 ft

It would thus appear that the formula would have given a very reasonable scour figure for a structure which was not designed for a particularly long life, eg, for an operational military bridge.

It would be interesting to know if any other data has come to light which support the formula, particularly in the case of rather smaller rivers.

Yours faithfully,

W. G. A. LAWRIE.

* The formula is:—

Maximum depth of scour $= \frac{M^{\frac{1}{2}}}{10}$ where M is the average breadth of a meander loop.

Memoirs

MAJOR-GENERAL SIR MILLIS JEFFERIS, KBE, MC

MAJOR-GENERAL SIR MILLIS JEFFERIS, who ranked among those outstanding men of rare inventive genius whom the Corps throughout its long history from time to time produces, died on 5 September last in his sixty-fifth year.

Millis Rowland Jefferis was born on 9 January 1899, the son of Rowland John Jefferis, of Porthgwarra, Cornwall and, like so many Cornishmen, he had an inborn love of the sea. He was educated at Tonbridge School and the Shop, being commissioned into the Corps on 6 June 1918.

After completing a short JO Course at Chatham he was posted in October 1919 to Germany as a Troop Officer in the 1st Field Squadron RE, with which unit he was to serve again sixteen years later. His stay with the 1st Field Squadron was not a long one, and in July 1920 he was posted to India where he joined No 3 Troop of the 2nd QVO Madras Sappers and Miners at Sialkot. Then followed a period in Works Services at Kohat and Khaisen during which time he saw active service in the Waziristan Campaign in which he was employed on operational road building and awarded the Military Cross.

In 1923 he came home for Supplementary Courses at the School of Military Engineering and at Cambridge University, after which he returned to India where he was to spend a further seven years. His appointments included special duty at Kabul for the Political Department of the Government of India and various Works appointments in which he saw further active service on the North West Frontier and where he was able to exercise his genius in bridge design. He also served as a Company Officer with the Royal Bombay Sappers and Miners at both Wana and Kirkee.

In October 1936 he joined the 23rd Field Company, RE at Aldersot and in the following January he took over command of the 1st Field Squadron, RE. When the Squadron was encamped for manoeuvres on Windmill Hill the idea of building a yacht germinated. She was eventually built in six months in a disused carpenters' workshop at Gibraltar Barracks, Aldershot

Major-General Sir Millis Jefferis KBE MC

by a syndicate composed of Millis Jefferis, one of his subalterns, a Royal Signals Officer and a friend in business in London. The story goes that *Prelude*, as the 5-ton Bermuda sloop was called, was an unusual boat in many ways; her starboard deck was half an inch wider than her port deck, a rusty spanner became lost in her bilges and one of her ribs was sawn through by mistake. She proved, however, to be a most successful yacht, winning the RAOC 1938 Points Cup and gaining points for the REYC. Her safe trip by road from Aldershot to Chichester and her successful launching were not without incident but, due to excellent Squadron planning, the moments of real anxiety were few.

In March 1939 Millis Jefferis was chosen for work on the staff and he was selected for special duty with the Expeditionary Force sent to Norway in 1940. After that ill-fated expedition he was employed, until November 1945, in the Ministry of Supply on the secret production of a wide range of anti-tank and other weapons. His outstanding ability was soon recognized by the Prime Minister, Mr Winston Churchill, and in 1945 he was created KBE for his original work in connexion with the development of special weapons. Mr Churchill, in his book: *Their Finest Hour*, described Millis Jefferis as that "brilliant officer whose ingenious, inventive mind proved fruitful during the whole war".

From being DMD at the Ministry of Supply, Jefferis was once more to return to India where he had previously served so long, becoming a Chief Engineer and eventually, after partition, Engineer-in-Chief Pakistan from 1947 to 1950.

His last appointment was Chief Superintendent of the Military Engineering Experimental Establishment, Christchurch, a post he held from April 1950 until his retirement in July 1953. He was ADC to the late King George VI in 1951 and ADC to our present Queen from 1952 until his retirement.

In 1925 he married Ruth Carolyne, daughter of G. E. Wakefield, CIE. They had three sons, one of whom is a Major in the Corps.

His funeral took place at Porchester crematorium on 9 September 1963. Among those present were:—

Lady Jefferis (widow), Major D. M. Jefferis, RE, and Mrs Jefferis (son and daughter-in-law), Mr J. Jefferis and Mr J. A. Jefferis (sons), Mr M. Jefferis and Captain J. Jefferis RN (retd) (brothers), Colonel and Mrs A. Wakefield (brother-in-law and sister-in-law), Mrs J. Wakefield (sister-in-law) and other members of the family.

Major-General T. H. F. Foulkes, representing the Engineer-in-Chief, The War Office, Sir Peter and Lady Garran, Lady (Hugh) Allen, Lieut-Colonel B. A. Clark representing the Military Engineering Experimental Establishment, Brigadier and Mrs J. Gavin, Mr and Mrs Michael Huxley, Mr Michael Trubshaw, Wing Commander T. Murray.

A friend paid the following tribute:—

The *Times* of 7 September gave an excellent, factual account of Sir Millis Jefferis' brilliant and nationally-useful life. He himself with his endearing modesty would ask for no more, but in his life and character lay aspects which those who knew him will not forget.

I first knew him well when he was on the North West Frontier of the then India. He was one of those fabulous characters who knew the language and the tribesmen intimately and was loved and greatly respected by them. They saw in him some of their own tougher and better characteristics.

His exploits as First Whip of the famous Peshawar Vale Hunt were quite exceptional. The artist "Snaffles" has caught him in action several times in his book *Sketch Book in the "Shiny"*. As a horseman, though not of copybook pattern, he was extremely effective and without doubt the boldest of the bold. This quality was completely absorbed by his mounts and the pair would often be seen attempting, though perhaps not always clearing, obstacles that others had not started to contemplate. This would not be as bravado, but because his duties required him to be up with the hounds. Later, with the Poona and Kirkee Hounds, he would often be seen arriving at the Meet in his none too large car with his wife, son and the latter's pony.

His very full war-time activities have been described in the obituary of 7 September, but it is not generally known that during the Norwegian campaign he was sent direct from England to behind the enemy lines to lay his recently invented protracted delay action explosive charges, which went off at varying periods of up to two years. This must have been most worrying and confusing to the Germans, and must have put great heart into the Norwegian Resistance. He returned only just in time to be re-embarked with only three survivors from his party of fifty Sappers. For this he was awarded a high Norwegian award for valour.

Though always in the greatest of heart, Millis was probably at his happiest at sea. In characteristic fashion his yacht *Prelude*, a beautiful and well-known ocean-racer, was built by himself and friends at Aldershot, transported by road to Chichester harbour, and suitably launched on a successful career. His skill and knowledge of the sea caused amazement even among the Cornish fishermen of his birth place Porthgwarra.

There were few war-winning inventions in which he did not have any hand and many of them were his own brain-children. It is probable that his personal experiments with submarine escape apparatus, and his saving of a colleague in a deep diving tank led to his protracted lung trouble, from which he suffered progressively more intensely, and which he faced with the utmost bravery and cheerfulness. In spite of all this, he refused a five figure monetary award for his inventions.

He was in a senior position and he thought this was the correct example to others in the scramble for monetary awards.

He was the first Engineer-in-Chief of Pakistan where he was a well-loved figure, and where he started many of the projects which have come later to fruition.

Although he was a brilliant mathematician, and an exceptionally active man, he was extremely well-read and wrote excellent prose and some very good poetry. Socially he was a tonic of great cheer. He was the cleverest, bravest and kindest man I have ever known, though the first two qualities were much hidden by his great modesty. I am sure that all who knew him will agree with me.

J.M.L.G. writes:—

Millis Jefferis had more drive and resource than anyone I have ever known. Difficulties existed only to be surmounted; and whether we were trying out a new idea for a bridge, or a new camouflet equipment, or building *Prelude*, or sailing her short-handed round the Fastnet Race, there was no setback that a little thought and determination could not overcome.

In bridging, Millis was a great believer in the continuous beam or limited articulation principle for floating bridges, and many different designs were tried out across the Basingstoke Canal in the middle 1930s. I remember one of these, a sort of early treadway bridge, subsiding gently into 5 ft of water complete with one of our squadron vehicles, to the huge delight of all the sceptics; but I have photos too of some of the successful ones—very similar in design to our present-day equipment bridges. His other great interest then was in rapid road-cratering devices, and when we were not building bridges my troop was often to be seen hammering pipes into the ground. Under Millis it all seemed very worthwhile, and we all joined in and captured something of his enthusiasm.

Later in the War, with the proper resources at his command, he was to produce the Piat gun and a host of other war-winning weapons and devices. At this time he threw himself heart and soul into anything he was engaged in, and it was not unusual for him to get up in the middle of the night and go back to the office to work out some idea he had had, or to spend twenty-four hours at desk and drawing board without a break and hardly a meal.

But most of my memories of Millis are sailing ones. He was a natural sailor, instinctively doing the right thing and using his great strength to the best advantage. He was always happy at sea and no one could wish for a better companion. He was reliable and tough, kind and generous, with an impish sense of humour and a stimulating, piercing brain.

It is cruel that one who was so strong and tough should develop bronchial trouble that more and more curtailed his sailing and gradually reduced him to an invalid. He never complained or lost his good humour, and he remained to the end the same kind, keen, tolerant, optimistic man who never thought badly of anyone. No one who knew him will ever forget him.

BRIGADIER (GROUP CAPTAIN) P. W. L. BROKE-SMITH, CIE, DSO, OBE

Philip William Lilian Broke-Smith was born on 27 August 1882, the son of Surgeon Major-General P. Broke-Smith. He was educated at Cheltenham and the Royal Military Academy, Woolwich, and commissioned into the Corps of Royal Engineers on 18 August 1900.

Although he served with distinction in the First World War and in India thereafter, his name will best be remembered in connexion with his pioneer work in early military flying, the development of which from 1878 to 1912 was the responsibility of the Corps of Royal Engineers.

After completing his Young Officer training Broke-Smith was posted to the 5 Balloon Section RE at Aldershot which he subsequently commanded. He qualified as a balloon pilot and navigator, and during the winter of 1903–1904 he conducted ballooning trials at Gibraltar. Shortly afterwards he was engaged in work connected with man-lifting kites, for use when the wind was too strong for the safe employment of captive balloons for observation purposes. He attained a record height of 3,340 ft in a kite.

He was later sent to India where he commanded an Experimental Balloon Section of the Bengal Sappers and Miners, which laid the foundation for military flying in India. On returning home in 1910 he assumed command of 2 Balloon Company RE at Farnborough (now the Royal Aircraft Establishment) where he was engaged in pioneer work on military airships.

With the advent of the aeroplane he helped to develop the first prototype military flying machines becoming a pilot and navigator in that type of heavier-than-air aircraft. He was also involved in the development of aircraft wireless which achieved a ground to air operational range of 30 miles, the development of aircraft compasses, air speed and height recording instruments and other navigational aids, gyroscopic stability control, air photography and bomb sights. On 1 April 1911 he became Assistant Adjutant and Instructor of the Air Battalion RE consisting of a headquarters and two companies, one for airships, balloons and kites and the other for aeroplanes. The aim of the unit was to train officers and men in the handling of all types of aircraft and to provide a small nucleus of expert airmen from which air units could be raised in war. In August 1911 it was decided that, as aviation had emerged from the experimental stage, military aeronautics should no longer be included among the tasks of the Corps of Royal Engineers and on 13 May 1912 the Royal Flying Corps, containing a Naval and a Military Wing, was formed from the Air Battalion RE absorbing most of its personnel. From that beginning have sprung the Fleet Air Arm and Royal Air Force of today. After its formation Broke-Smith was seconded for a while to the Royal Flying Corps as an instructor at the Central Flying School, Upavon.

Brigadier (Group Captain) PWL Broke-Smith, CIE DSO OBE

During his early flying days Broke-Smith became a balloon pilot in 1902, obtaining the Royal Aero Club's Aeronauts' Certificate No 17, a man-lifting kite pilot in 1904 and an airship pilot in 1910, Royal Aero Club Certificate No 2, and an aeroplane pilot in 1912, Royal Aero Club Certificate No 204. In helping to establish what is today the Royal Aircraft Establishment, Farnborough he worked on the development of the Cody Kite which could be flown from an anchored steel cable or, on suitable ground, towed behind a horse-drawn vehicle moving against the wind at a walk or trot. During the 1905 manoeuvres this latter method was successfully adopted. He was also closely connected with the development of *Nulli Secundus* I and II, the first two British airships built following the success of the German Zeppelin.

During the First World War he served as a Deputy Assistant Director of Aviation in Mesopotamia. For his war services he was awarded the DSO. He returned to India in 1918 to become ACRE Peshawar and after being specially employed in 1919 he was appointed AD Works of the North West Frontier Force with which force he took part in the Mohmand and Afghan Wars and was awarded the OBE. The final appointment of his overseas tour was that of Assistant Director General of Military Works.

He returned in 1924 for a short spell to the United Kingdom to become successively ACRE London District and SORE to the Chief Engineer Eastern Command and to attend the Senior Officers School at Sheerness.

He went back to India in 1926 where he held CRE appointments in the Presidency District, Fort William, Calcutta and in Baluchistan. In 1931 he became Deputy Engineer-in-Chief India and the following year he became Chief Engineer Eastern Command at Naini Tal. He retired on 23 December 1936 and was awarded the CIE.

On the outbreak of the Second World War Brigadier Broke-Smith was re-employed in the Ministry of Supply as Director Passive Air Defence with the rank of Group Captain, RAF. He wrote a series of articles, published in the *Royal Engineers Journal*, on the history of early British Military Aeronautics. He was a Member of the Institute of Civil Defence.

Last summer, during one of the functions connected with the Jubilee of the Royal Air Force, he took over control in the air of one of the latest types of supersonic aircraft, a remarkable feat for a man 80 years old, and a far cry from his early days of balloons, kites, airships and open-cockpit flying machines.

In 1908 he married Dorothy Margaret, daughter of Vice-Admiral G. O. Twiss of Lindfield, Sussex. They had one son and two daughters. His widow and children survive him, and to them the deepest sympathy in their loss is extended.

He died peacefully on 10 November 1963 in his eighty-second year.

Book Reviews

STREET WITHOUT JOY

By Bernard B. Fall *with a Foreword by* Marshall Andrews

(Published by Pall Mall Press. Price 35*s*.)

The main north-south artery along the coast of Viet Nam is properly called Road 1, but during the fighting in Indo China part of it was known by the French forces as *la rue sans joie*; and hence the title of this book *Street without Joy*, with its sub-title of *Insurgency in Indo China*, 1946–1963. The third Revised Edition is that under review.

The troubles in Indo China sprang from the same sources as those in Malaya. The country was occupied by a colonial power (France) until 1940, it was occupied by the Japanese during World War II with local communist elements acting against them as a resistance movement. Then, with the return of French forces after 1945, there was a built-in communist opposition dedicated to independence from France as a first objective with the evolution of a communist Chinese satellite as a second. The principle difference between the two theatres is that Indo China adjoins China itself—which Malaya does not—and thus permitted free access for Chinese arms in so far as communications allow. In this respect Indo China resembled Korea; but whereas in Korea the terrain was mainly open, in Indo China it was mainly jungle and swamp. Secondly, the French forces available were insufficient for the job. Behind the Russian front in World War II, we are told, the Germans required a Corps to eliminate a Russian guerilla force of 3,000; and in Malaya 250,000 regular troops (Author's figure) took twelve years to defeat a maximum of 8,000 communist guerillas. The Author says that in Indo China no operation could succeed without a numerical advantage of 15 or 20 to 1, which the French could seldom raise locally and never over-all. So the communists were bound to succeed in the end according to the theory.

The reader who served in Malaya will recognize many similarities. Eager commanders planned major operations to "sweep" or "bottle-up" or otherwise "eliminate" a known guerilla formation in a certain place; but when the troops were deployed the opposition either slipped through the net or reverted to peaceful cultivators tilling the paddi fields with no arms in sight. The French continually sought—as did the British at one time in Malaya—a set piece battle, where their equipment and training would bring them a real advantage. The guerillas, on the other hand, usually tried to avoid it unless the scale were tipped the other way by error—as at Dien Bien Phu.

The scale of the communist opposition in Indo China is illustrated by their ability to deploy artillery, flak and mortars which the opposition never could in Malaya. Not only were "soft" convoys ambushed in Indo China, but their escorts were anihilated too. Secondly, it seems from this book, that the French relied mainly on armed force and paid little heed to the political battle "for the hearts and minds" of the people.

Reading this book, your reviewer feels that the French took on a proposition that was militarily hopeless from the beginning. Whether there was a political hope of success is another question; but this book sheds no light on that. Certainly there was no lack of courage and sacrifice on the part of the French. We are told that the French Union lost 95,000 men, including four generals and 1,300 subalterns. The communist losses are not given, but the presumption is that they were fewer. The communist leadership was excellent and the rank and file hard and well trained.

What may come as a surprise to British readers is the extent of American participation. At Dien Bien Phu American air-crews were flying at least one quarter of the aircraft used for re-supply; and after 1954 there was even greater American involvement both in the air, and on the ground, as well as politically.

Many people think that anti-guerilla warfare should be widely studied today; and this book throws an interesting light on how this type of warfare should and should not be waged. It is well written, authentic and very easily read. Your reviewer cannot agree with all the conclusions, and (as stated above) there is a considerable gap that might be filled by an appraisal of the political steps, if any, that were taken to combat communist political influence in the area.

A word about the author: Dr Fall is a Frenchman by birth, who served in the Resistance as a youth. He made two visits to Indo China as well as having access to innumerable written sources in Paris and elsewhere. He includes some convincing eye witness stories. He writes in English (with a trace of Gallic idiom) from Alexandria, Virginia. Who Marshall Andrews is your reviewer is too ignorant to know, but he writes from Virginia and spells his name with two "l"s so one need not presume that he is a Marshal of France. An excellent book to get from the library, but rather expensive to buy. M.C.A.H.

VACUUM TECHNIQUES IN METALLURGY

By J. A. Belk, BSc, PhD, AIM

(Published by Pergamon Press Ltd, Headington Hill Hall, Oxford. Price 25*s* net.)

Vacuum has rapidly become an essential constituent of a variety of metallurgical processes and the author, a Senior Lecturer of the Department of Metallurgy in the College of Advanced Technology, Birmingham, has succeeded in presenting the essential aspects of this large subject in a manner which is suitable for students and qualified engineers alike.

In a short historical introduction he reviews the more important discoveries made in this particular field of science since the experiments of St Claire Deville and Troost in the mid-nineteenth century proved that hydrogen could be diffused through heated plates of iron and platinum, and Lake introduced the first vacuum induction melting furnace in 1890.

The associated theoretical background of thermo-dynamics and kinectics are clearly and concisely explained in just twenty-five pages, and the rest of the book is devoted to descriptions of vacuum equipment and the modern processes for degassing, induction melting, arc melting, electron beam melting and zone melting, solid state and special applications. The theory and application of each subject is presented in a manner which can be readily understood by anyone with a fair background knowledge of metallurgy and general engineering experience.

The diagrams, sketches and photographs of equipment and circuits are first-class, and a number of excellent graphs and comparative tables are included. This is the type of technical book which could be of great service to military engineers of general experience, and others, who are at times expected to take over and operate specialist plant at short notice, to such persons, and to students of near degree standard, this book is highly recommended. F.T.S.

SPARK ATLAS OF STEELS

By Gerhart Tschorn

(Translated from the German by Herbert Liebscher)

Published by Pergamon Press Ltd., Headington Hill Hall, Oxford. Price £5 5*s*

Engineers have been using the "spark-test" method to identify metals for the past 160 years; and the possibility of distinguishing between different steels by their spark pictures, which are formed by the shower of sparks thrown from the wheel when a sample is passed against a high-speed grinding wheel, was discussed in detail by Professor Bermann as early as in 1909. His recommendation that spark pictures be sub-divided into carrier-lines, spark-stream and spark-bursts has been retained to this day.

All engineers realize that the spark-test method is only a makeshift for the exact analysis which can be obtained from laboratories equipped with modern testing equipment. They also realize that such specialized equipment is not available in the field, where a quick, reasonably accurate and simple form of identification is often required.

This book, therefore, makes available to the practical engineer all the present known information on spark-testing, which can be easily understood and quickly applied to the identification problems of factories, storage depots and works sites.

The book outlines the theory of spark-testing and contains 108 spark-pictures in colour, and black and white, to cover the following steels: plain carbon, carbon constructional and carbon tool, and in addition, steel alloys containing proportions of silicon, manganese, chromium, vanadium, titanium, molybdenum, nickel, tungsten and cobalt. Other pictures of hot-die and high-speed steels, grey cast-iron, chill castings, pig-iron, ferro-alloys and other metals are also included.

Each spark-picture carries the designation of the material tested, its composition, similar foreign standards, and an explanation of the picture.

A supplement at the end of the book includes a number of tables giving details of the composition of various test samples; comparisons of British and American Standards; Japanese Industrial Standards; comparisons of steel grades, identification numbers, material numbers and sheet numbers according to TGL, SES and DIN; and the composition of German, Swedish, Soviet and Czechoslovakian structural carbon and alloy steels.

Lists of references and additional reading are also given.

Until the present system of marking industrial steels for identification purposes, by painting on the approved standardized colours, is altered to something which is more durable and capable of standing up to the wear and tear which all steels are subjected to in large army and civilian storage depots and workshops, the spark-test method of identification will always be in demand.

Military engineers whose activities are world-wide, under a considerable variety of site conditions, will find this book with its tables of steels and metals produced by foreign countries extremely useful.

The book is excellently printed and well-bound, my only criticism is that the spark-pictures could, with advantage, show the approved standard identification colours used by industry, so that when samples and stocks were identified they could be so marked for reference.

F.T.S.

THE USE OF RADIOACTIVE ISOTOPES FOR CHECKING PRODUCTION PROCESSES

By B. I. Verkhovskii

Translated from the Russian by H. S. H. Massey

(Published by Pergamon Press, Ltd, Headington Hill Hall, Oxford. Price 21*s* net)

The claim that "the first atomic power station in the world was created by the efforts of Soviet scientists and engineers", tends to put a reader on his guard, particularly when similar claims are made by ourselves and the USA. Perhaps the main objection to the book is that it was published in Russian in 1959, and many advances can be made in a period of four or five years. Consequently, a book of this type can be seriously out of date, particularly when quoting instrumentation and performance figures.

The first two chapters deal with elementary nuclear physics and with ionization chambers, geiger counters and scintillation counters, the subject matter being dealt with in a clear and simple manner. The third and final chapter gives the physics and the corresponding application, and covers such subjects as thickness measurement, flaw detection, density measurement, measurement of humidity, determination of chemical composition, measurement of levels, measurement of plating thickness, measurement of gas pressure, determination of gas composition, measurement of gas velocity, removal of static electricity and automatic fire alarm system.

Some of these applications are described using alpha, beta, gamma or neutron radiation where possible, and each description includes considerable detail on types of isotope, limitations of the method, equipment and basic layout employed. This I think is most commendable.

Although science is said to be an International subject, having read this book I had a feeling of being brainwashed, particularly when faced with the "Directives of the Twentieth Session of the Communist Party of the Soviet Union on the sixth Five-Year Plan for the Development of the National Economy of the USSR".

However, despite this, I feel that this is a well written book for the engineer where knowledge of nuclear physics is negligible, and for those who are interested in isotope applications and measuring techniques I would strongly recommend it, even if only to become aware of what can be done. D.R.T.

POWER HYDRAULICS

By A. B. Goodwin, BSc (Eng), AMIMechE

(Published by Cleaver-Hume Press Ltd, 10–15 Saint Martins Street, WC2. Price 42*s*)

The author, a Senior Lecturer in Mechanical Engineering, Leicester College of Technology, recognizing that some of the leading colleges are now providing separate courses of instruction on the application of fluid mechanics to oil hydraulic machinery and transmission systems, has produced a text book which covers the syllabus of the Higher National Certificate and Diploma examinations in this subject.

The book will also be of considerable use to designers and practical engineers in their efforts to keep abreast with the rapid development and application of power hydraulics to modern control systems.

The contents cover: Units, Definitions and Dimensions; Properties of Fluids; Mechanics of Fluids; Fluid Friction in Pipes; Introduction to Circuits and Components; Hydraulic Pumps and Motors; Valves; Pump and Motor Units; Valve Theory; Detailed Circuits; Power Transmission in Pipes; Effects of Fluid Compressibility, Surge Pressures and Hydraulic Lock. In addition there is a section containing a fair number of calculation exercises, with answers, and an Appendix which is an extract from a paper entitled "Development in High Performance Servo-mechanisms at the RAE Farnborough".

The chapters dealing with the Introduction to Circuits and Components, Hydraulic Pumps, Motors and Valves are largely descriptive; whilst the principles of the remaining subjects in other chapters are explained mathematically. Students who already hold the Ordinary National Certificate and have a reasonable knowledge of mathematics should not find the latter chapters difficult to follow.

The book contains a large number of diagrams and graphs in support of the text and the standard of these and the printing is first class. F.T.S.

LINEAR CONTROL SYSTEMS

By Edwin C. Barbe

Assistant Professor of Electrical Engineering, West Virginia University

(Published by the International Textbook Company, Scranton, Pennsylvania)

All electro-mechanical systems using various devices to obtain a response, or output, from an input of any form contain a number of inherent factors such as mass, friction, compressibility and/or electrical characteristics. These factors prevent the desired response being obtained unless some form of compensator is included in the system to offset them. Such corrective action is achieved by means of feedback and the systems are then called feedback or closed-loop systems. Responses need not necessarily be of the same form as the input. The power elements used to obtain responses can, for example, vary from amplifiers, electric motors, or hydraulic and pneumatic motors or actuators, and the input, whether voltage, current, or other form of signal, can be made to produce shaft velocity, positional change or pressure variations etc.

This book has been written with the express purpose of helping students understand and use the basic principles and concepts underlying feed-back control systems.

Chapters 1–6 deal with the theories and techniques of the subject matter. Chapter 7 bridges the mathematical and theoretical data of the early chapters and their application to feed-back systems by describing the functions of devices and networks commonly used in system applications. Chapters 8–14 cover the basic operation of feed-back systems and the means by which such operation is achieved.

There are three appendices and these cover: The Theory of the AC Motor as a Demodulator, Diagrams of Magnitude and Phase Plots, and Laplace Transform Pairs.

The subject matter is mostly presented in mathematical form and is therefore only suitable for graduate students, or those in possession of the Higher National Certificate or Diploma for Electrical or Mechanical Engineering.

Engineers concerned with the design of linear control systems will find this book excellent for reference purposes. The standard of printing and production is first class. F.T.S.

INTRODUCTION TO AUTOMATIC CONTROLS

By Howard L. Harrison and John G. Bollinger

(Associate and Assistant Professors The University of Wisconsin)

(Published by International Textbook Company, Scranton, Pennsylvania, USA. Price 10 dollars)

This book has not been written to introduce new theories and applications of automatic control. Its purpose is to present basic control theory in a manner which will facilitate the teaching and understanding of senior students in electrical and mechanical engineering. It is not suitable for beginners because the theory and application of controls is explained mathematically and students require a knowledge of elementary calculus and some understanding of differential equations in order to cope with the text.

The chapters cover the following subjects: Orientation to Automatic Controls, Differential Equations for Physical Systems, Solving Differential Equations, Applying the Analog Computer, System Response, Laplace Transformation, Block Diagrams and Transfer Functions, Control Actions and System Types, Frequency Response, System Analysis using Polar Plots (Nyquist Diagrams), System Analysis using Logarithmic Plots (Bode Diagrams and Nichols Charts), System Analysis using Root-Locus Plots, System Compensation and Control System Non-linearities.

There are six appendices A–F which deal specifically with: Digital Computing for Control System Analysis, Solution of Equations, Routh's Criterion, Transfer-Function Simulation on the Analog Computor, Tables and a Decibel Conversion Table.

The book is excellently produced and contains a large number of diagrams and graphs. It is recommended for reference purposes in the technical libraries of universities and colleges of technology. F.T.S.

A COURSE OF MATHEMATICAL ANALYSIS

Part II

By Professor A. F. Bermant

Translated from the Russian by D. E. Brown, MA.

English Translation Edited by I. N. Sneddon, Simson Professor of Mathematics, The University of Glasgow.

(Published by Pergamon Press Ltd. Headington Hill Hall, Oxford. Price 60*s.*)

Professor Bermant's treatise is being published in two parts. Part I, Volume I, covers the theory of functions of one variable, but the English translation has yet to be produced. This volume, Part II, is devoted to the theory of functions of several variables, ordinary differential equations, and the elements of the theory of Fourier series. The book contains a large number of worked examples, but no problems for solution by the student. English translation of a companion book of problems prepared by Dr G. N. Berman will be published shortly.

Part II is, in fact, Volume 30 of the International Series of Monographs on Pure and Applied Mathematics published by Pergamon Press, and the chapter subjects are: Functions of several variables; Differential calculus; Applications of the differential calculus; Multiple integrals and Iterated equations; and Trigonometric Series (Fourier).

Students desirous of digesting its contents will no doubt find this well bound and excellently printed book a good 60*s.* worth. F.T.S.

APPLIED THERMODYNAMICS

By A. E. J. Hayes, MA, AMICE,

Lecturer at the Oxford College of Technology)

(Published by Pergamon Press, Headington Hill Hall, Oxford. Price 21*s.*)

This is Volume I of the Mechanical Engineering Division of The Commonwealth and International Library of Science, Technology, Engineering and Liberal Studies published by Pergamon Press.

The aim of the Library is to provide readers with a series of low-priced, high-quality, soft-covered text books and monographs, and the books issued will cover the needs of instructors and pupils in all types of schools and educational establishments (including industry) from elementary to the most advanced levels.

The text of this book, which covers the syllabi of the HNC and HND in Mechanical Engineering and the examinations of the Professional Institutions, contains many worked examples which have been taken from relevant examination papers. At the end of each chapter further examples of questions set in recent examinations are given.

Chapter I is an introduction to fluids and processes, and subsequent chapters deal with: thermodynamic processes, entropy, use of charts, thermodynamic cycles, ideal cycles using gases, power cycles using vapours, gas turbine cycles, refrigeration and heat pump cycles, flow in nozzles, combustion, turbines, compressors, mixtures of fluids, and reciprocating internal combustion engines.

This text book is an excellent introduction to applied thermodynamics. The descriptive matter is presented in a simple, precise style which is easy to understand, and the examples are worked out in detail. It is strongly recommended to Clerks of Works (Mechanical) and junior officers of the Corps, who would find this book of considerable value in their studies of mechanical engineering. F.T.S.

CONCISE VECTOR ANALYSIS

By C. J. Eliezer, MA, PhD (Cantab) DSc (London)
(Professor of Mathematics in the University of Malaya)
Published by Pergamon Press, Headington Hill Hall, Oxford. Price 15*s*.)

This book is Volume 8 of the Mathematics Division of The Commonwealth and International Library of Science, Technology, Engineering and Liberal Studies and, when compared with the Library's other recent edition: "Applied Thermodynamics", illustrates the wide range of studies published by the Library.

"Applied Thermodynamics" catered for students up to HNC level, "Concise Vector Analysis" meets the needs of advanced university students of mathematics and engineering.

The subject matter covers vector algebra, vector calculus and standard applications, each chapter being devoted to illustrative examples.

A large number of other examples, taken from the examination papers recently set by the Universities of Cambridge, Ceylon, London and Oxford are given at each chapter end, without answers, which is, perhaps, unfortunate for the average student.

F.T.S.

Technical Notes

CIVIL ENGINEERING

Notes from *Civil Engineering and Public Works Review*, July 1963

Stress Changes in the Beams of a Filler-joist Bridge Deck. When a bridge, carrying the Great North Road over the railway at Biggleswade, was rebuilt in 1952 the opportunity was taken to fit six vibrating wire strain gauges to the road bearers of the central span of 26 ft. The bridge consisted of RSJs embedded in a concrete slab. The bridge deck was designed so that the RSJs carried all the load. The dead loads produced a stress of about 2½ tons/sq in, and temperature changes stress variations of about 1⅓ ton/sq in, while an axle load of 47 tons produced a stress of 1 ton/sq in. These results indicate that the composite action of the structure reduces the steel stresses considerably, and the method of design needs revision.

The Verrazand-Narrows Bridge. The Verrazano-Narrows Bridge is the world's largest suspension bridge, and when finished it will connect Staten Island to New York. The centre span will be 4,360 ft. This article describes the erection of the towers and the cable-spinning. It is interesting to compare the design of this bridge and the building techniques with those of the Forth Bridge.

Two aspects of design of water courses and earth. The author gives a simple way of designing erosion resistant earth channels with the necessary theory clearly explained. He also gives a method of designing the confluence and diffluence of water courses. This article with two previous articles by the author gives practical methods for designing earth channels, which is normally a very complex problem.

Direct Moment Distribution for Rigid Frameworks. In the July and August issues the second and third articles show the application to structures with sideway. This method is undoubtedly simpler and quicker than normal moment distribution, but it requires a deeper understanding of moment distribution theory and experience in using it in analysis. It is a method for the specialist designer of rigid frameworks.

Notes from *Civil Engineering and Public Works Review*, August 1963

THE NEW FORTH ROAD BRIDGE. Progress is described in a short article. The main cables and suspenders are complete, and the deck is more than half complete. The method of constructing the deck is explained, together with the final compressing of the main cables.

FLOUR SILOS OF REINFORCED PLASTIC. Two 32-ton flour silos have been built at Gosport. They are 45 ft high and 10 ft diameter with a double plastic shell wall. Between the shells there is a rigid plastic foam for insulation. The material is self-coloured and non-corroding, so there is reduced maintenance, and they are light with no joints or internal obstructions.

DEPRECIATION COEFFICIENTS IN PIPELINES. The author has investigated the deterioration and consequent increase in roughness of the interior surface of pipes. From his and other researchers' results he has produced curves by which the designer can estimate the Manning "n" for the pipe during its estimated economic life.

MOTORWAYS. The South Lancashire section of the M6 and the Medway Motorway were opened in July and are described in detail. The M6 is a three-lane motorway, and it is built through an area where mining subsidences are to be expected, and the special precautions to prevent damage include concrete rafts over shallow workings and jacking arrangements at the bridges. This section includes the Thelwall Viaduct and Bridge over the Mersey and the Manchester Ship Canal. Besides the Medway bridge other points of interest in the Medway Motorway are the Mount Lane and Stockbury viaducts, and the twelve miles of concrete surface at the eastern end.

FLEXURAL STRAIN DISTRIBUTION IN COMPOSITE AND PRESTRESSED CONCRETE BEAMS. An article in July is concluded in the August issue. It is common practice to use precast prestressed sections as shuttering for slabs as well as for beams in beam and slab construction. Under CP 114 and CP 115 linear strain distribution is assumed from top to bottom of the whole composite construction. This article describes tests carried out on a number of composite prestressed concrete beams, where it was found that the strain distribution was non-linear. However, the authors do not deduce a new design method from their experimental results.

R.D.P.B.

Notes from *Civil Engineering and Public Works Review*, September 1963

STRUCTURAL ASPECTS OF STONEWARE PIPELINES. The loads and resultant stresses in stoneware pipes are discussed. Loading is due not only to gravitational forces from the fill above the pipes, but also to soil movements, thermal and moisture changes, road traffic, and growing roots. The crushing strength of pipes can be found by test, but various allowances must be made before deciding on suitable working stresses. Different types of flexible joints are described, and their uses discussed. This article is to be continued.

OPTICAL CONTROL METHODS APPLIED TO PRESTRESSING. Large diameter prestressing strands have a non-linear stress-strain relationship and the loads cannot easily be determined. Two forms of gauge called the Load Cell and the Stress-meter have been developed; these are based on photo-electric principles and the measurement of fringe patterns. Although simple and relatively robust, these gauges are likely to be used mainly on experimental work and for measuring relaxation and creep effects.

THE ASBASTOS-CEMENT PIPE. This article describes briefly the development and manufacture of this form of pipe; the two main types are pipes for pressure work and those for low pressure drainage and sewerage. The advantages of asbestos-cement pipes are their light weight, freedom from corrosion and tuberculation, and their hydraulic flow characteristics which remain constant for life.

THE FFESTINIOG PUMP STORAGE SCHEME. This is a comprehensive description of the civil engineering works involved in the scheme. A short introduction explains the advantages of pumped storage. Details are given of the upper and lower reservoirs with their respective dams, the pressure shafts and penstocks, and the power station. Interesting features on which the author lays particular stress are the pressure grouting and concrete work.

APPLICATIONS OF DIMENSIONAL ANALYSIS METHODS TO CIVIL ENGINEERING PROBLEMS. This lengthy title heads the first part of an article explaining the relationships between experimental observations on models and the stresses and performance of structures for which the models were used in analysis. Examples are given to illustrate the mathematical theorems involved, followed by descriptions of the practical application to structural analysis problems.

THE FIXBY TREATMENT WORKS. This is a completely new works for treatment of water from the Pennines for the Wakefield and District Water Board. The plant is designed to combine sedimentation and rapid gravity filtration with enough flexibility to meet seasonal variations in the raw water. The process is described briefly, as are the arrangements for reducing the manual handling of chemicals. The majority of the work is in concrete.

THE DEFLECTION OF FLAT PLATE STRUCTURES. Cases have occurred of cracking of masonry walls supported on flat concrete plates, even where the designed deflections were not exceeded. Recent experiments have been made on both short-term and long-term deformations. Initial deflections can be computed with fair reliability, if allowance is made for reduction in stiffness once concrete has cracked. Recommendations are given for suitable span/deflection and span/depth ratios to prevent rupture of brick partitions.

RECENT WORK AT THE BUILDING RESEARCH STATION. This is a summary of recent studies, and includes notes on aerated concrete, lightweight aggregate concrete, effects of fire on prestressed concrete, and composite steel/concrete construction. Other subjects are drainage, soil mechanics and building construction, the latter with particular reference to mechanical handling.

J.C.P.

ENGINEERING JOURNAL OF CANADA

Notes from *The Engineering Journal of Canada*, June 1963

THE NPD FUELLING MACHINES: This is a detailed description of the design, development, and testing of remote-controlled fuelling machines for the charging, replacement, and withdrawal of fuel bundles used in the pressurized heavy water NPD reactor. The reader cannot but be impressed by the critical problems involved, and by the success so far achieved in their solution.

PROBABILITY CHARTS FOR PREDICTING ICE THICKNESS: In regions subjected to heavy ice cover, records and estimates of ice thickness are important not only for the determination of bearing capacity but also in relation to pressure against dams, the design of water intakes, and the prediction of run-off. This paper describes the use of probability charts based on statistical analysis.

SOME PERTINENT QUESTIONS REGARDING ENGINEERING EDUCATION: Modern requirements in engineering education have been widely discussed. This is an incisive plea for greater interest by professional engineers and for their participation in the deliberations of the educators.

HYDROLOGIC SIMULATION OF A RIVER BASIN: A brief review of the development of hydrological analysis points the necessity for laborious and repetitive computations. Simulation of conditions by computer programme is described. The speed and accuracy of forecasting flood conditions by this method have been proved in practice.

THE CANADIAN TOPSIDE SOUNDER SATELLITE: *The Engineering Journal* for January 1962 contained an interesting paper on the design and instrumentation of this satellite (see *RE Journal*, June 1962). The present paper summarizes design features and the evaluation of frequencies and power needs, and reports on the very satisfactory performance of the various systems during five months in orbit. A further paper in the issue for August 1963 describes the tests carried out prior to launch in September 1962.

Notes from *The Engineering Journal of Canada*, July 1963

PONTS EN BÉTON PRÉCONTRAINT: The author of this paper, written in French, points out that the first prestressed concrete structure in Canada, a baseball stadium, was completed only in 1953, yet over thirty prestressed bridges have been built in the Province of Quebec since 1958. Of these several are briefly described in three groups—simple, cantilever, and continuous beam bridges. The advantages of prefabrication are pointed out, but unimaginative standardization is deplored. A bridge should be a work of art as well as being functional. The two aspects should never be divorced.

THE ANALYSIS OF STRUCTURES BY AID OF MODELS: The study and testing of models are now commonplace in structural design. The examples quoted clearly indicate the scope and value of such investigations.

THE DANGER OF SPECIALIZATION: The author deprecates the "empirical" approach to engineering, and advocates a four-year university training in fundamental sciences, leaving it to industry to provide specialized professional training.

UNDER A BUSHEL: Here, in the simplest of language, is the ABC of man-management. It is well worth reading.

Notes from *The Engineering Journal of Canada*, August 1963

THE ENVIRONMENT OF SPACE: Space conditions and the need for extreme reliability in space vehicles are briefly discussed, and the methods of space simulation and equipment testing, prior to the launching of the Topside sounder satellite, are described. The success of these techniques has been triumphantly proved.

TORONTO SUBWAY TUNNEL SHIELDS: The tunnel-driving shields used in the construction of a recently completed subway in Toronto are believed to be the first self-contained equipment built for work of this size, the only external service brought in being electric power cables. The internal diameter of the running tunnels is 16 ft, that of the station tunnels 24 ft. There are many interesting features in this description of the design and operation of the equipment.

PRECAST AND PRESTRESSED WATER TANKS: This short and most interesting paper outlines a method of constructing prestressed circular water tanks without the use of special winding machines or complicated jacking systems. All the components except the foundation are precast. The exterior of the tank walls is battered at a slope not exceeding 12/1 and, after the wall panels have been erected, circumferential prestress is induced by winding wire round the outside either by hand or from a truck-mounted reel and then forcing it downwards, much as metal hoops are used on a wooden barrel. The wires are then protected by gunite.

No information is given about calculating the predetermined pattern for winding on, nor the predetermined final positions of wire rings. Vertical prestress is not mentioned, but is presumably taken care of when the precast components are fabricated. The author states that tanks of from 300,000-gallon to "several" million gallon capacity can be built in this way. The example given is a roofed tank of 138 ft diameter, with a wall height of 19.7 ft: capacity 2.2 million gallons.

A most interesting method which might be invaluable for military purposes, but more design data is needed. R.P.A.D.L.

THE MILITARY ENGINEER

March–April 1963

Operation Chlorine by Colonel Warren S. Everett, Corpos of Engineers, US Army. This is a very clearly written well illustrated account of what the author describes as one of the most exciting operations ever conducted by the Corps of Engineers on the Mississippi River. The operation was the removal of four large steel tanks containing 1,100 tons of liquid chlorine from a chemical barge which foundered in the river. The chlorine presented a lethal threat to 80,000 people living within a thirty-miles radius of the place where the barge went down. Very interesting details are given of the methods used in locating the wreck, which was largely covered by silt, the technical problems of the operation itself and their solution, and of the precautions taken by the civil authorities to minimize the ill effects of an escape of gas.

Typhoon Karen on Guam by Read Admiral Norman J. Drustrup, US Navy Civil Engineer Corps. This contains a brief account of the typhoon itself and an analysis of the damage caused to various types of building. The best typhoon resisting buildings were those constructed of reinforced concrete with rigid framing and shear-resistant walls. There is summary of the various lessons learnt which will guide the reconstruction of the damaged installations.

Maps for Lunar Exploration by Major William B. Taylor, United States Army (Retd). The United States is engaged in an effort to place astronauts on the moon and return them to the earth prior to the end of this decade. This article describes the plans for making the necessary maps of the moon to support the enterprise. These consist of unmanned probes and landing projects, and a manned programme.

The unmanned landing programmes are Ranger and Surveyor. The Ranger programme is to provide limited optical imagery and surface measurements at several points on the moon's visible face. Television sensors will transmit a nested series of images as the hard-landing spacecraft approaches the moon. Three Rangers have been launched to the moon without providing the planned imagery or surface measurements. Nine more Rangers are scheduled through 1964. The Surveyor programme will follow the Ranger. It is planned to "soft-land" data acquisition instruments at selected lunar sites. Measurements planned for Surveyor include high-resolution television imagery of the area surrounding the landed space-craft and wider and more precise measurements of surface characteristics (such as soil mechanics and mineral analysis) than will be possible with the lighter-weight Ranger. The first Surveyor is scheduled to be launched in 1964.

The object of the manned programme Apollo is to land two members of a three-man crew on the moon, sustain them there for at least one day, and return them together with the third crew member safely to earth. The outline details of the way in which it is hoped to achieve this are given.

The article also includes an account of the methods in use for mapping the moon from earth based photography and telescopic observations.

Military Engineer Training at West Point by Lieut-Colonel Beverly C. Snow, Corps of Engineers. A description of the engineer training given to all cadets at West Point during their four years course, there are also notes on special courses given to cadets likely to be commissioned in the Engineer Corps. The amount of training given is striking but it must be remembered that the course is very much longer than that at Sandhurst.

Seismic Warfare by Jack de Ment. A "seismic bomb" is a superyield, thermonuclear explosive which sets in motion the release of accumulated stress energies within certain sections of the earth's crust, or a weapon which acts as a prime mover of extremely large masses of earth or water. The author goes into the alarming results which can be expected from the use of such devices and also the possible peaceful uses to which they can be put. How to use them as a weapon is not made clear.

NEW RUSSIAN MILITARY BRIDGE by Major Paul D. Neftstead, Corps of Engineers. The standard Russian floating bridge is very similar to other pontoon bridges. The article starts with a brief description of it with illustrations. The new Soviet floating bridge is a radical innovation. It consists of a series of pontoons joined together without an intervening water gap and with the superstructure built in as an integral part of the pontoon. Each pontoon is carried on a truck folded accordion-like into a package 10.5 ft wide, 6.5 ft high and 22 ft long. This provides a 20-ft roadway. The equipment can be assembled and used as a ferry. Four bridge sections can carry about 80 tons. There are clear pictures with the article and a summary of the advantages and disadvantages of this equipment.

INDUS BASIN PLAN by Lieut-General Emerson C. Itschner, United States Army (Retd). The Indus Basin Settlement Plan is an immense engineering project designed to store the waters of the western rivers in Pakistan and convey them to the eastern rivers. In this article the author gives a clear and comprehensive outline of the plan, illustrated with sufficient maps and tables. The international aspect of the financing of the work is brought out and the part played by the World Bank in negotiating the agreement between Indian and Pakistan. There are technical details of construction and interesting photographs. An excellent picture of the whole plan is contained in a very short article.

PORTABLE NUCLEAR POWER SYSTEMS by Joseph F. O'Brien. This is an account with a great deal of detail of the design, construction and performance of two nuclear power systems which are in operation, one at Wyoming in the US and the other at McMurdo Sound in the Antarctic. They were primarily constructed to provide a service test for an air transportable nuclear power plant. In both cases the installation was carried out by service crews supervised by the manufacturers. There are good diagrams and illustrations.

KISIMAIO PORT by Colonel Arthur C. Nauman Corps of Engineers, US Army and James L. McCall Jun. Construction work will soon begin on a modern port for Kisimaio, Somali Republic, to serve the expanding trade in the potentially rich agricultural region of the Giuba River. The project is part of the United States foreign aid programme. An account of the scheme with maps and photographs is given in this article. There are many constructional details with diagrammatic illustrations and there are many references to the administrative side of the work.

JULY–AUGUST 1963

MILITARY ENGINEERING AS A WEAPON IN THE COLD WAR by Colonel R. L. Clutterbuck RE. In this article the author, who was the Chief of the British Section at the US Army Command and General Staff College at Fort Leavenworth, shows how subversion by communist guerillas can be countered by making it clear to villagers and tribesmen that both their security and the prospect of increasing their prosperity can be assured by the provision of facilities such as good communications which will open markets for their produce. He gives examples from Malaya and Aden to support the contention that Engineer Troops can provide just that assurance and that the Civil and Military power are helping the people to better their conditions of living and not just seeking their domination; and it is this which in the long run turns their sympathies away from the Communists. The article is of special interest to Royal Engineers for its accounts of the Corps' part in dealing with trouble spots. There are good maps and photographs.

SYMPOSIUM-ENGINEERING MANAGEMENT. At the symposium held as part of the Annual Meeting of the Society of Military Engineers on 20 May 1963, several papers were presented of which three are published in this issue. They all deal with the development of methods of planning and progressing large projects using computors. The articles are "Computerized Project Network Analysis" by Glen L. White. "What

Electronics can do for Management" by Sydney S. Green and "Technical Excellence in Research and Development" by Ralph O. Vieullemuir. These articles describe methods which are being increasingly followed in large scale engineering.

MILITARY ENGINEER FIELD NOTES

The notes in this number include a brief account of road, bridge, and airfield construction by South Vietnam Engineers which might have been used as an illustration to the point raised in the first article referred to in this review. Other notes deal with bridge construction in Korea and river control in the Yukon.

CONTINUOUSLY RE-INFORCED CONCRETE PAVEMENTS by R. K. Shafer. This is an account of the performance of various specifications for continuously reinforced pavements included in the construction of selected highways in Pennsylvania. The results of the tests are given in the form of recommendations. The article is illustrated by photographs.

THE ROAD DIVISION by Major-General Ralph E. Haines, Jun, United States Army. ROAD stands for Reorganized Objective Army Division. It was formed from the 1st Armoured Division and the 5th Infantry Division (Mechanized). The author says that basically there are few innovations in the ROAD; it is the combination, for the first time in one division, of several previously developed concepts. The aim has been the attainment of flexible divisions that can be tailored to meet varying world-wide requirements.

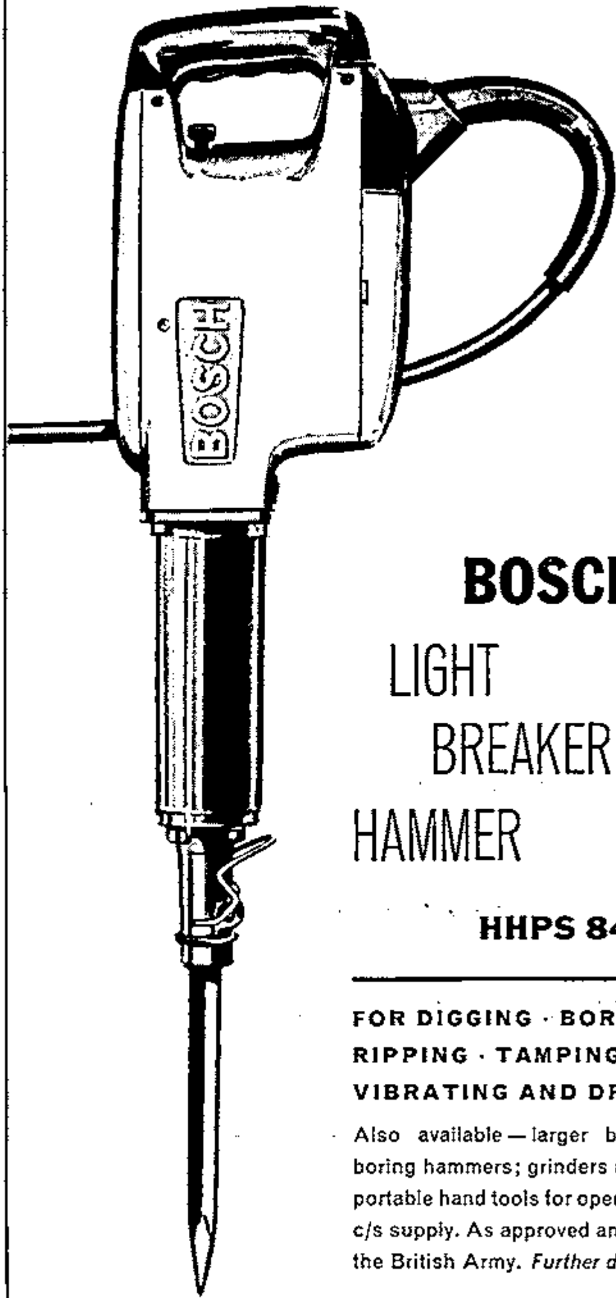
The Division, in addition to the various arms and services to be expected, contains a strong aviation battalion to provide support in such activities as aerial surveillance, air mobile operations, and armed aerial reconnaissance. The bulk of the aircraft are of the rotary wing type. The engineer battalion is 1,000 strong and very fully equipped and maintains an atomic demolition munition.

The account of the Division's organization and handling is very full. It is a very powerful formation.

MATERIALS FOR THE SPACE AGE, by Colonel James E. Harper, Jun, Corps of Engineers, United States Army. The rich natural resources of the United States have been used so extravagantly that other sources of supply of many raw materials are being actively sought. In this article the author refers to many of the materials in question and describes the new sources being tapped and the substitutes which are being developed.

VICKSBURG, THE MISSISSIPPI AND THE US ARMY, by Major-General Ellsworth I. Davis, US Army. An interesting well illustrated article describing the development of navigation and flood control on the Mississippi from the earliest times to the present day, with a brief account of the fighting for control of the river which the possession of Vicksburg brought to the Federal armies in the American Civil War.

J.S.W.S.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