THE ROYAL ENGINEERS JOURNAL—JUNE 1964

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THE ROYAL ENGINEERS JOURNAL

Vol LXXVIII JUNE 1964 No 2

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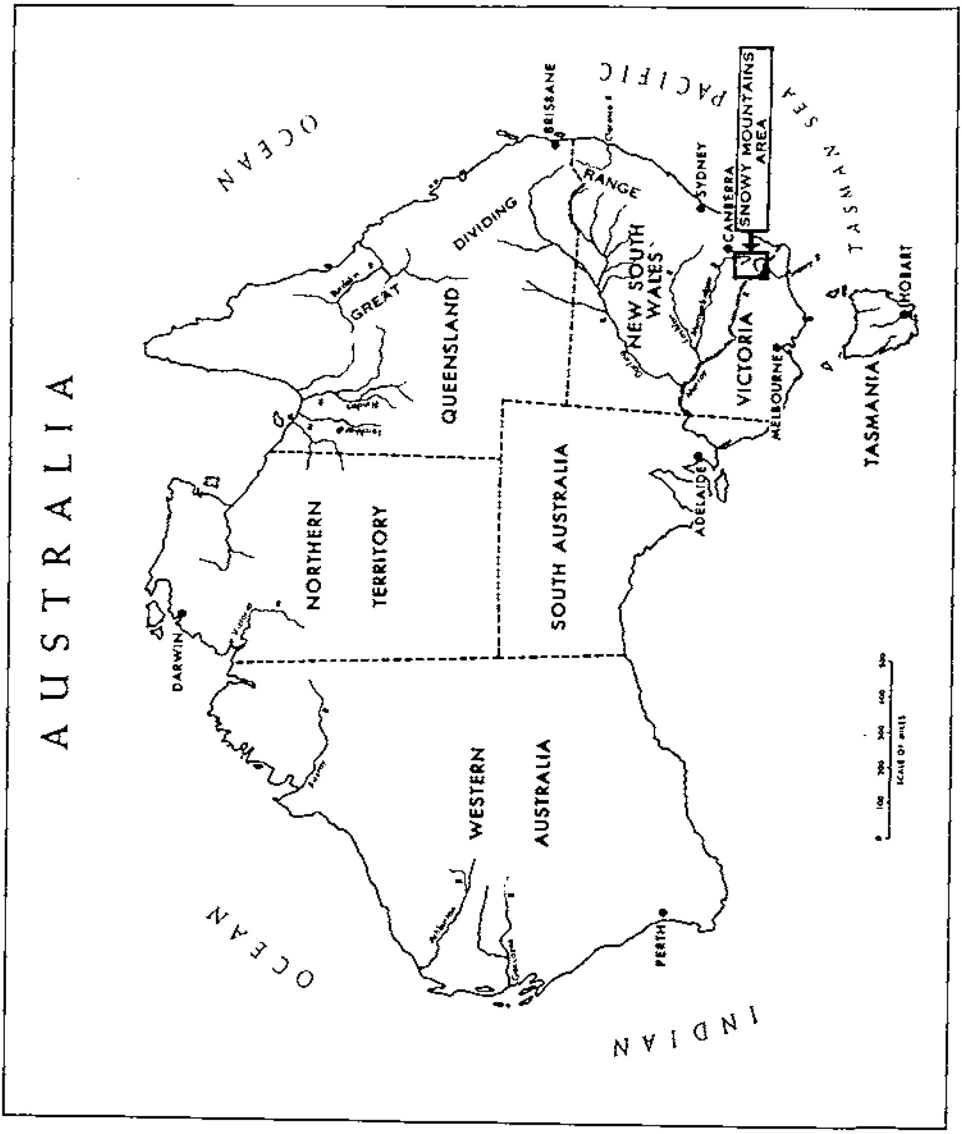
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Fig. 1

Two Years in the Snowy Mountains

By Captain P. L. Dell, RE

Introduction

Periodically a letter is sent to RE units asking for volunteers to serve a two year tour with the Snowy Mountains Authority. I answered such a letter and was posted to the SMA in August 1961. My intention in this article is to describe in very general terms some of the work and experiences of those two years.

Several articles on the Snowy Mountains Authority have previously appeared in the *Journal*. To avoid reference to these a little of the background information is repeated in this article.

The Snowy Mountains Area

It would not be right to write an article on the SMA without mentioning the wonderful country surrounding the scheme.

The mountains are snow-covered for nearly half the year, giving a snow area almost the size of Switzerland. There is good skiing. In the spring and summer one can walk or ride in the mountains, fish for brown or rainbow trout in the reservoirs and streams, or sail and water-ski on Lake Eucumbene. The scenery is superb; the area large enough to avoid crowding; whilst apart from Australia's traditional animals, the birds range from the magnificent wedge-tailed eagle through colourful parrots and cockatoos to miniature wrens.

It is true that living in the area does have certain disadvantages, but these are far outnumbered by the advantages.

The Snowy Mountains Authority (SMA)

The Snowy Mountains form part of the Great Dividing Range. They lie in south-east Australia, partly in Victoria and partly in New South Wales, and contain Australia's highest peak, Mount Kosciusko at 7,314 ft. They are snow-clad for five to six months of the year.

These mountains contain the sources of three major rivers—the Murray, the Murrumbidgee and the Snowy. The Murray and the Murrumbidgee flow west through dry fertile plains which rely on their water for irrigation. They finally join together and enter the sea near Adelaide. The Snowy flows south through an area which already receives sufficient rainfall for its needs, and then wastes itself in the Tasman Sea. (Figures 1 and 2.)

In 1884 a proposal was made to divert some of the unproductive waters of the Snowy into the Murrumbidgee for irrigation purposes. This was followed by a series of similar proposals to utilize the waters of the Snowy for both power production and irrigation. Between 1944–48 an intensive survey of

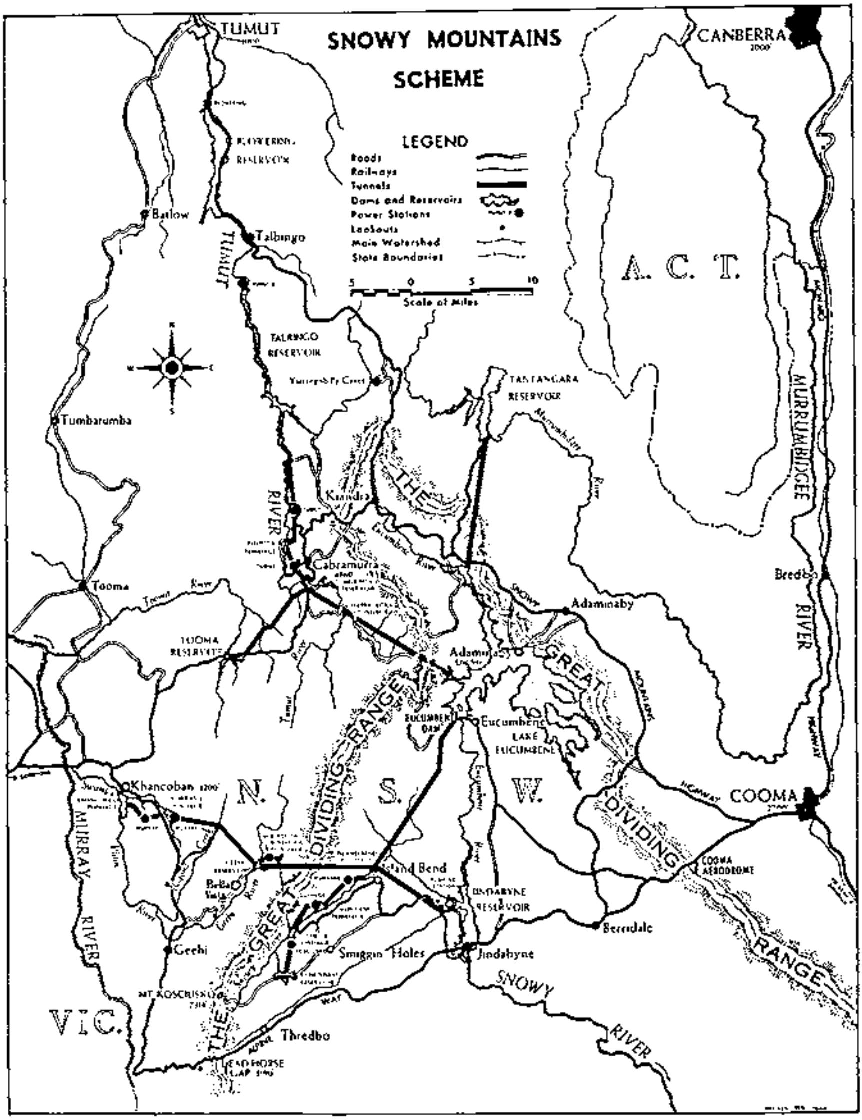
SNOWY MOUNTAINS
SCHEME
LEGEND
Roads
Railways
Tunnels
Dams and Reservoirs
Power Stations
Lookouts
Main Watershed
State Boundaries
Scale of Miles
TUMUT
CANBERRA
A. C. T.
Batlow
Talbingo
TALBINGO RESERVOIR
Tumbarumba
Kiandra
Cabramurra
Tooma
TOOMA RESERVOIR
Adaminaby
Eucumbene
LAKE EUCUMBENE
EUCUMBENE DAM
Khancoban
N.
S.
W.
COOMA
COOMA AERODROME
Island Bend
JINDABYNE RESERVOIR
Berridale
Jindabyne
Geehi
Smiggin Holes
Thredbo
MT. KOSCIUSKO
V.I.C.
MURRAY RIVER
MURRUMBIDGEE RIVER
Bredbo
SNOWY RIVER
THE GREAT DIVIDING RANGE
TUMUT RIVER
TANTANGARA RESERVOIR

Fig. 2

the area was carried out and preliminary layouts were prepared. A joint power production-irrigation scheme was shown to be economically possible. In July 1949 the nucleus of the present scheme was approved by the Commonwealth and State Governments. Later the same year the Snowy Mountains Authority (SMA) was set up by the Federal Government with the task of implementing the scheme.

Since 1949 the SMA has grown into a large organization and is responsible not only for the execution of the scheme in general, but also for the majority of the preliminary investigation, detailed design and contract supervision. In addition, the SMA has acted as consultant to other State authorities and also to other countries under the Colombo Plan. To carry out these varied roles the SMA is organized into a number of Groups and Divisions each responsible for a particular field of operations. The two Groups to which a RE officer is normally attached are Civil Engineering Design and Scientific Services (CED & SS) and Major Contracts (MC).

The CED and SS Group is responsible for all the detailed design, laboratory investigation and materials control of the projects in the scheme. This work includes the preparation of drawings, contract documents and estimates. Some design work has been completed for outside authorities. Most of this work is carried out by the Group in the SMA's head office at Cooma.

The MC Group is responsible for the control and construction, both financial and technical of the major projects of the scheme. These projects are contracted to engineering firms after advertisement on an international scale. The head of the Group, with a small staff, is situated in the SMA head office at Cooma, but the SMA area is further divided into two sub-areas east and west of the Great Dividing Range, each controlled by a Senior Resident Engineer (SRE). The SRE'S offices are at Khancoban and Island Bend. (Figure 2.)

The RE Officer in the SMA

Both Royal Australian Engineer and British RE officers are attached to the SMA for periods up to two years. The Australians normally work with the road-building forces of the Field Construction Division, whilst the British as already mentioned, divide their time between CED and SS, and MC.

This division of his two years allows the British Sapper to produce work which can lead to Associate Membership of the Institution of Civil Engineers. In addition, it probably gives the broadest possible experience which the SMA can provide in two years, since it covers both design and construction.

Which year comes first depends entirely on how busy the two divisions are when the officer arrives. From the personal point of view it is preferable to spend one's first year with CED in Cooma. The town has all the amenities one requires and being in head office enables one to meet far more people. From the professional point of view it is probably easier to spend one's first year with MC since site work is more similar to military engineering and is a gentler re-introduction into the civil engineering world than design work.

Civil Engineering Design and Scientific Services Group

When I joined the SMA in September 1961 I was told by the Commissioner, Sir William Hudson, that I would spend my first year in CED division. This division is divided into four branches responsible for the design of dams, tunnels and aqueducts, power stations and structures. I went into Dams

TABLE I—*Dams currently under design or construction*

Dam	River	Type	Height (ft)	To be Completed
Island Bend	Snowy	Gravity concrete	150	1964
Geehi	Geehi	Rockfill, vertical earth cove	300	1965
Khancoban	Swampy Plain	Earth fill	65	1965
Jindabyne	Snowy	Rockfill, sloping earth cove	220	1967

Branch as had Majors Woolcott and Hutton before me and as Captain Holland did after me. The other Sapper officer then with the SMA, Captain Dennis, was already in Power Stations Branch.

When I entered the office there were four major dams under design, the characteristics of which are shown in Table I. Two of these, Island Bend and Geehi, were in the detailed design stage. Tenders for the contract had been called and the successful contractor was about to be announced. Meanwhile work continued in the office on the preparation of detailed construction drawings and the design reports. Photographs 1 and 2 show recent views of these dams under construction. The other two, Jindabyne and Khancoban, were still in the preliminary design stage. The exact orientation of the dam on the site was not yet certain, although in general the site area and dam type had been decided.

The design of concrete dams seemed to offer more knowledge of direct use to the military engineer than the design of earth and rock dams. Modern civilian earthmoving equipment is becoming extremely large, making it impossible to move by air unless it is dismantled and in many cases it requires good tracks to ensure its mobility on the ground. Thus concrete construction methods would seem to be more applicable to the modern air transportable army than those requiring large-scale earth-movement. Consequently, whilst in the office I worked on concrete gravity and arch dams and the concrete spillways of these dams and of an earth dam.

The detailed work carried out in the branch is of little interest to anyone not directly involved, but there were a number of features in the various designs which gave an indication of current developments.

In several dams use was being made of pre-stressed concrete anchorages for the spillway gate trunnions. This gave a saving in space and also in cost. In concrete arch dams increasing use was being made of the SMA's digital computer, a useful tool also for slip-circle analysis of earth dams. The earth and rockfill dam at Geehi incorporates a very beautiful bell-mouthed spillway on which Captain Johnson is at present site engineer. Also at Geehi, use is being made of chemical grout to continue the water seal beneath the impervious zone in the dam. Design was not only limited to common types of dam mentioned above. Some designs incorporated steel-faced rock dams, hollow concrete gravity dams and hinged concrete arch dams. Allied to the design of the dam itself increasing attention was being paid to the growing knowledge of the foundation rock which the relatively new science of rock mechanics allowed one to use.

The drafting of a design report brought my year in the Branch to a close. It was with very great regret that I left. The work, although containing inevitable minor frustrations, was the most satisfying I had ever done. On the social side I had made many good friends and learnt a great deal about Australia.

Major Contracts Group

Spring in September found my wife and I on the move again, complicated by the recent arrival of our Australian son and some uncertainty as to where we were moving. Our final destination proved to be Eucumbene.

Lake Eucumbene forms the main reservoir for the entire scheme. The dam is a 381-ft rock and earth dam forming a reservoir with a capacity of 3,860,000 acre-ft. Photograph 3 shows the dam and entrance to the tunnel. Two tunnels already enter the lake (Figure 2), and the third tunnel connecting the Snowy River development with the reservoir is currently being driven. This is the 15 mile Eucumbene-Snowy Tunnel. I went to Eucumbene as site engineer. The contract at Eucumbene came under the SRE at Island Bend.

The tunnel runs from Eucumbene reservoir to the reservoir on the Snowy River at Island Bend. It is being driven on three headings, one from Eucumbene and two from an adit four miles from Island Bend. At Eucumbene the tunnel, a 21 ft horse-shoe, connects with the original diversion tunnel that was built when the dam was constructed.

The method of tunnelling used is the well established one of air powered drills rigged on a rail mounted jumbo incorporating a rear hoist ("cherry picker") for car passing. The muck car trains pass beneath the jumbo on a smaller gauge track to be loaded by an electrically driven Conway mucker. The mucker is shown in Photograph 4. All the locomotives are diesel. The explosive used is ammonium nitrate mixed with diesel fuel supplemented by AN60 gelignite. Fume extraction is by an extractor fan line in the crown of the tunnel.

The American contractor, Utah and Brown and Root Sud-Americana Ltd (UBR), was working on a three eight-hour shift six-day week. His best weekly progress on the Eucumbene heading was 420 ft, but I believe this has since been raised in better rock to 508 ft. His worst week was one in which no progress was recorded. This latter case is interesting. A major fault was known to cross the tunnel line. On the surface this showed as a very marked stream bed giving reduced cover to the tunnel. There were also several other related faults in the area. The tunnel line had been chosen in the light of an extensive geological exploration to give the best line through the faulted zone. When the tunnel struck the fault it was several hundred feet earlier than expected and consisted of a wide zone of crushed and altered granite intersected with basalt dykes. Some flows of water were encountered, none severe, but enough to cause the tunnel face and roof to fall away. Excavation by conventional means to the full tunnel profile was impossible, so small tunnels or drifts, to accept wall plates, were commenced. Photographs 5, 6 and 7 show these drifts and give an indication of the type of support required. This type of ground continued for over 300 ft and some parts required support as heavy as 8 in × 6 in BSB at 2 ft 6 in centres with 8 in × 6 in BSB invert struts embedded in concrete. Very little explosive was used in this section. Nearly all the excavation was carried out by hand using pneumatic tools. Once the initial setback was overcome the extremely difficult conditions were

Photo 1. Island Bend Dam, showing the central spillway

Photo 2. Geehi Dam, showing the excavation prior to placing the fill

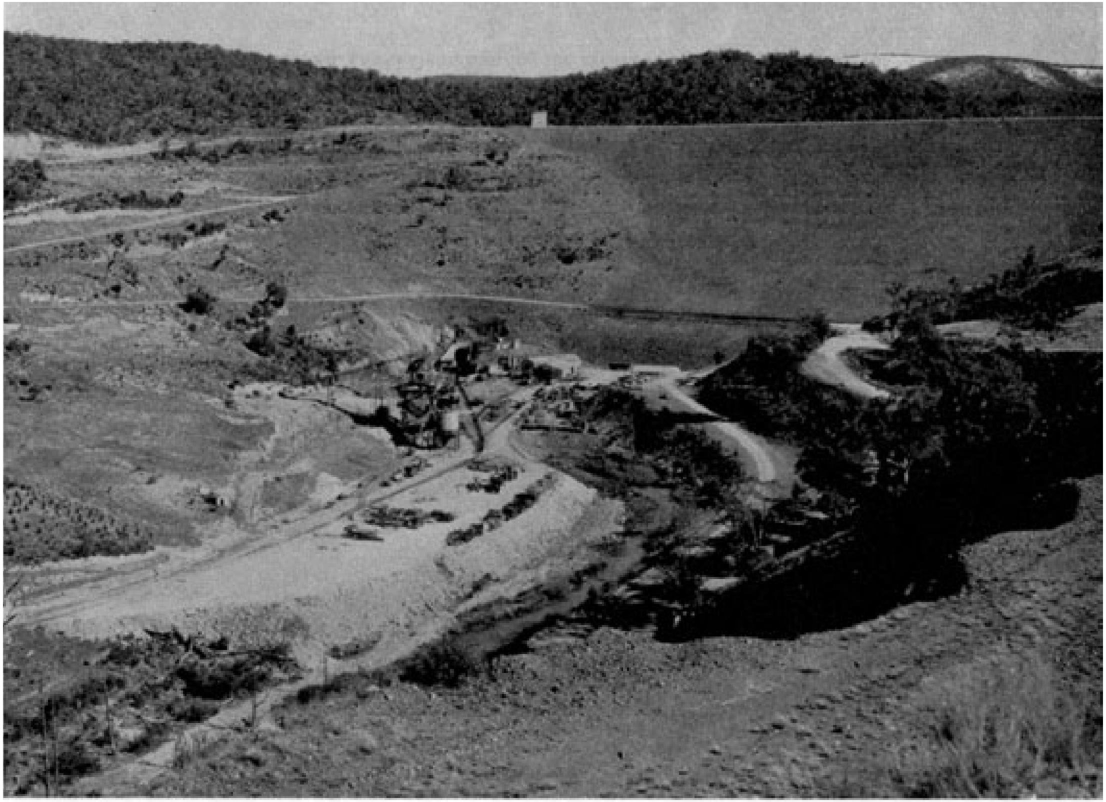

Photo 3. Eucumbene Dam, showing the tunnel portal

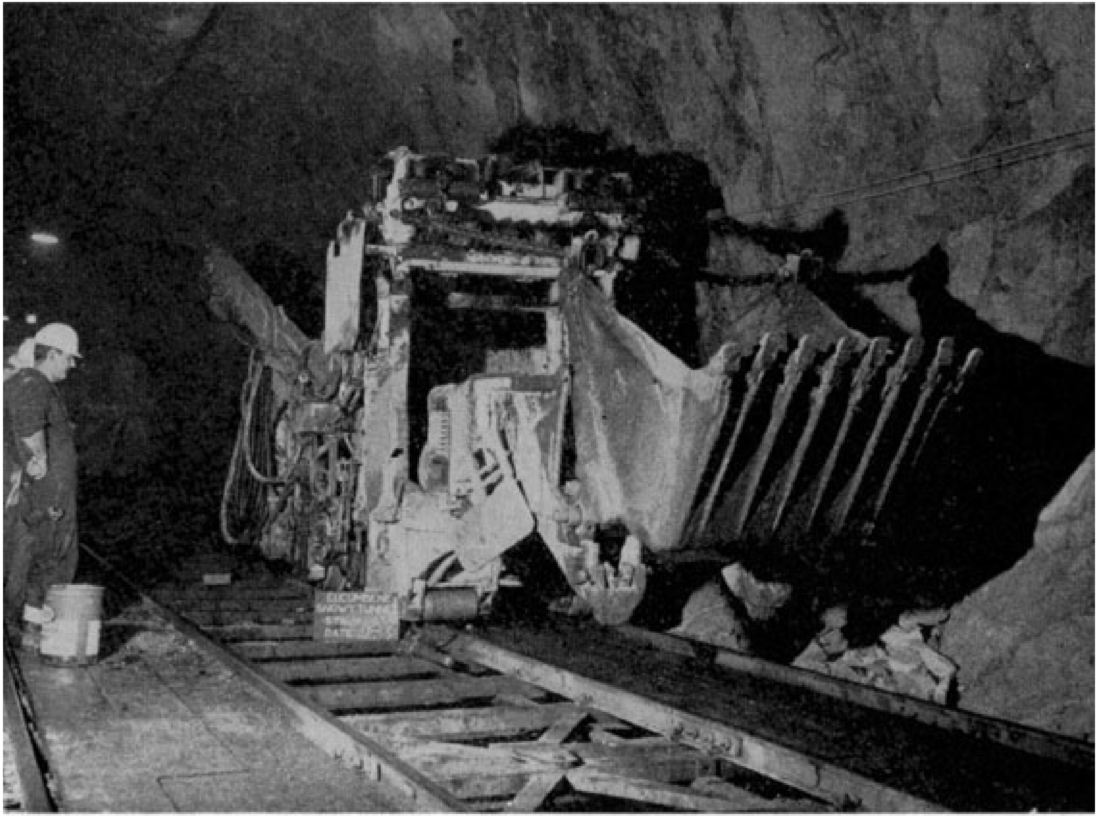

Photo 4. A Conway mucking machine

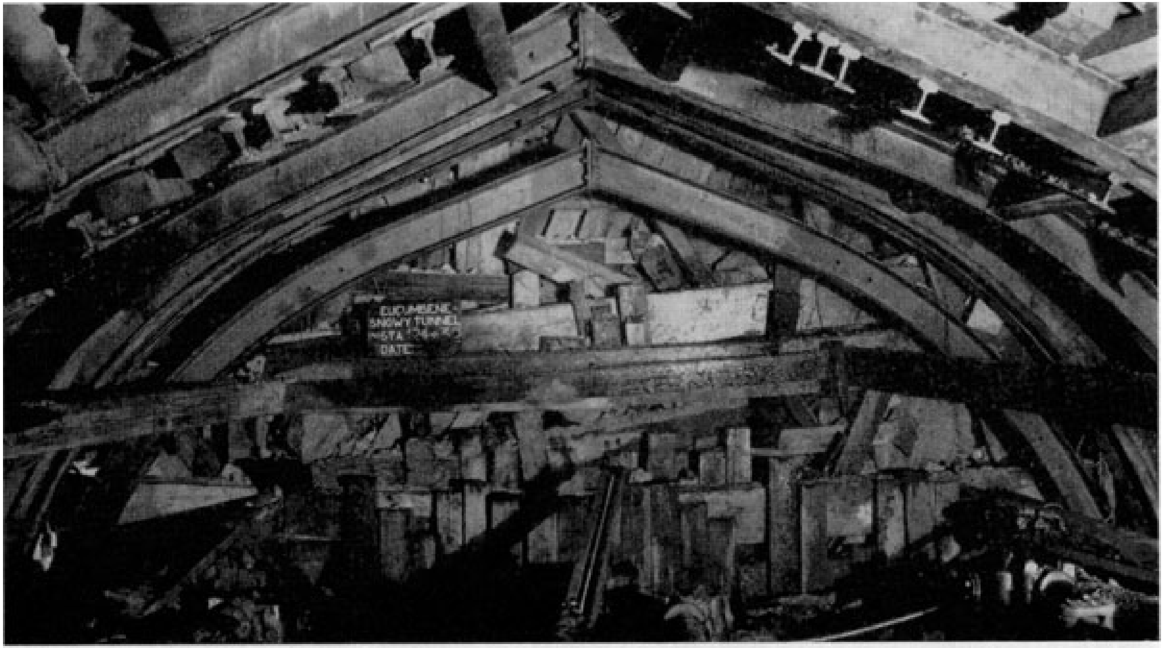

Photo 5. Face at Sta. 124 + 32, showing breastwork, spiling, and false steel set erected for further spiling

Photo 6. Face at Sta 127 + 17, showing the wallplate and crown drifts

Two years in the snowy mountains 6

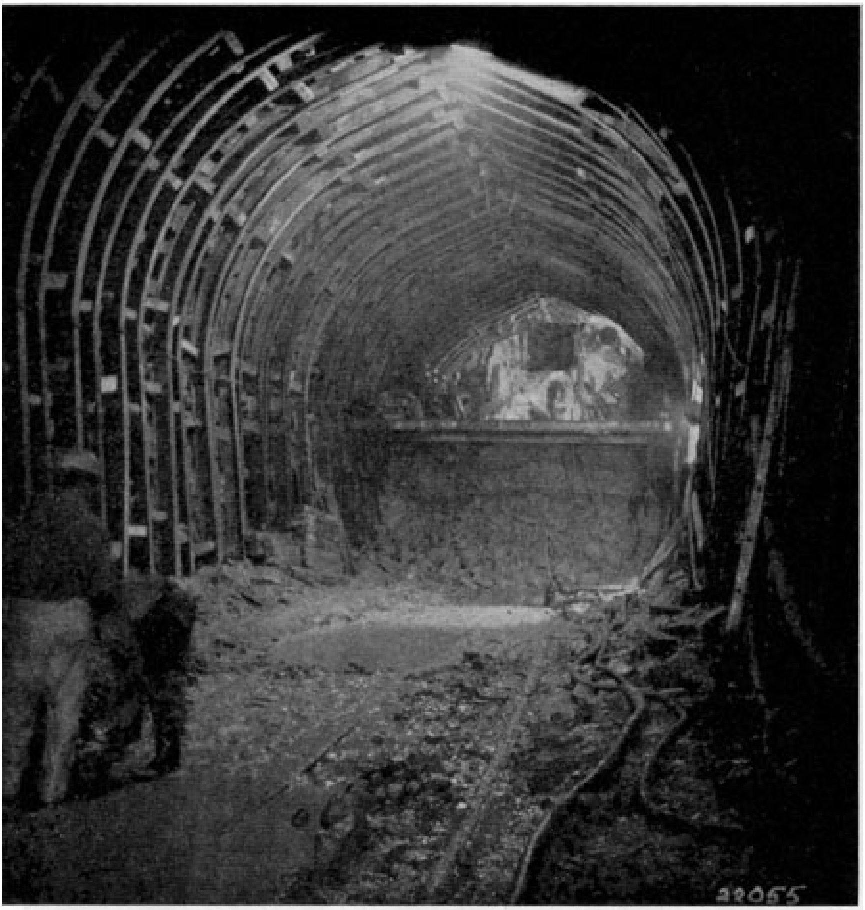

Photo 7. General view of tunnelling in the faulted zone showing the drifts being driven from a false deck

tackled very ably by UBR who were able to achieve advances of 40 to 50 ft a week.

The type of work involved on this contract is fairly typical of the duties of a site engineer with the SMA. His main duties are to see that the contract is executed correctly from the technical aspect, that the standards required are achieved and that correct payment is made for the work done. His success seems to depend chiefly on two points: one is the ability of his team of inspectors and surveyors to control the work coupled with his ability to manage them so that they always give of their best; the second is to maintain firm but cordial relations with the contractor, thus ensuring that the contract is completed quickly and efficiently.

There are two factors on the financial and quantity control sides of the contract upon which the SMA insisted, which did a great deal to assist the site engineer achieve the two points mentioned in the previous paragraph. The contractor was paid at the end of each four-weekly period for the work completed in that period. The quantities for the various items were agreed during or at the end of the period and were exact quantities. Thus, once the quantity bills signed by both parties left the site there need be no future measurement carried out. The second factor was that as each item was finished the actual amount was reconciled with the estimated amount and a final payment made, after which the item was closed. This system meant that arguments over quantities were settled on the site when the points in dispute were fresh in everyone's mind. This resulted in better relations between the two parties and the elimination of a long period of negotiation over final quantities once the contract was completed. On the debit side these two factors led to a good deal more work for the site staff; but the benefits, including the following consequence, far outweighed the extra work.

The inspectors' reports which we used were laid out so that the man-hours spent by the contractor on each task could be extracted. Subsequently, this information was used by the Estimates Branch of CED during the design and planning stages. This information, coupled with the exact knowledge of the contractor's earnings and a fair knowledge of wages, enabled a reasonable estimate to be made of costs versus earnings. Apart from the obvious interest of this information, it was very useful when discussing with the contractor alternative ways of carrying out a certain feature to have the costs at one's fingertips. Best engineering practice sometimes coincided with the cheapest method, a convincing argument to a contractor.

Summary

I hope that the contents of this brief article will give some idea of the type of work performed during a two-year attachment to the SMA. Perhaps it will help any RE officer considering applying to decide in favour of going. He should not regret such a decision. He will finish his two years with a far wider knowledge of engineering and a much deeper knowledge of his fellow men. Many of his prejudices and traditional ideas will be shattered and in their place will have grown a more balanced and genuine set of values. All this should help to make him a better RE officer.

In addition he will have learnt a great deal about how a large civilian engineering authority, the SMA, controls a very complex and widely spread scheme. Much of this learning can be applied direct to military organization and engineering problems. It also seems likely with the present size of the Corps that large-scale engineering tasks in limited war are likely to have to be completed by AER units or civilian firms. If this is so it will be very useful to have officers with some experience of the civilian approach.

ACKNOWLEDGEMENT

Finally I would like to thank the Snowy Mountains Authority for permission to publish this article and also for providing the photographs and figures.

A Field Squadron in England

By MAJOR R. E. WILLIAMS, RE

LOOKING back through past *RE Journals*, I have noticed that articles range over a wide variety of subjects. Some are purely technical while others are historical; some recommend how we should reorganize ourselves as a Corps, and much has been written on operations and emergencies abroad.

Nothing appears to have been written recently about the day to day activities and training of a field squadron, which is after all our basic unit; so I thought it might be of interest to describe how 20 Field Squadron, part of 36 Corps Engineer Regiment, spent the year 1963. We were based on Maidstone, and although we were part of the Support Echelon of the Strategic Reserve, we were not called to take part in any operations. None the less it was an exciting year, and for me it dispelled the idea that it is necessary to serve abroad to get any fun out of soldiering. I think the NCOs and Sappers enjoyed it; they certainly developed well.

At the beginning of the year the Squadron was fifty under strength, and we had just spent a period of four months with only four officers. This was trying as it meant scratching around to find enough soldiers for any task. One troop had been commanded by a Staff Sergeant who had done the job admirably but was beginning to find it a strain. During April 1963 RE Records built us up to full strength, and thereafter things became much easier.

We started the year with an Administrative Inspection in January, and finished it with another in December. The January inspection was held in the bitter cold weather, and for it we were required to do a drive past in vehicles. Snow had to be scraped off the square with a grader, and one of the practices was done at 14°F; pipes were frozen up throughout the barracks. More I shall not say except we got a good ticket!

For the remainder of January and February the majority of the Squadron went on upgrading courses either in the Regiment or at the RSME. There was specialist training and education. A party of thirty went to the British Legion Hut in Aviemore, Inverness-shire, for a week's skiing, where the snow conditions were as good as in Switzerland, although one had to work harder for one's pleasure. Twelve others joined the Regimental party for winter warfare training with the Norwegian Army in Norway. A section of 2 Troop (Captain Thompson) was called out to blast ice on the River Colne to clear a passage for shipping, and we did other snow clearance tasks.

During March the Regiment, consisting of 20 and 24 Field Squadrons, Eastern Command Plant Troop, and various RASC units took part in Exercise Hotspur. This was a bridging gallop from Scotland to the Thames organized by the CO, Lieut-Colonel G. T. E. Westbrook, OBE, RE. It was an ambitious affair lasting three weeks for which preparations in Regimental Headquarters had been going on for the best part of six months. I believe 650 letters had been written to land owners asking for the use of private land, and to formations and units demanding vehicles, equipment and administrative support. Scores of preliminary recces were done.

20 Field Squadron built two heavy ferries on Loch Ryan and we ferried our transport across to the old military port at Cairn Ryan. This went well except that there was some difficulty navigating the 2-mile passage in a fog. The squadron then moved down to Newark to build a light floating bridge near the place where cadets from 140 OCTU used to build FBE bridges in the last war.

Leaving a troop behind at Newark to sort out a farmer's fields which had been dug up during the bridging operation, the remainder of the Squadron went south to build a light assault raft on the River Crouch. This was a failure due to a variety of reasons; bad weather, a restricted site, children manipulating bridging signs, refusal of outboard motors to work, and a general lassitude from a lack of sleep. We got a 3-ton vehicle across the mud at low tide, but this did not really absolve us.

The climax of the exercise was two crossings of the River Thames near Henley. Both squadrons built a LFB and two heavy ferries each in turn. Our efforts were much more successful this time. We built our LFB in the pouring rain with an army of pressmen and photographers watching, but I do not think they got so much satisfaction out of it as we did. The heavy ferry operation was done during a wireless silence, and went with less hitches and heartburn than any of the other operations. There must be a moral here somewhere.

This was a physically hard exercise carried out in snow, cold and wet conditions. We lived out for the three weeks in bivouacs and a few tents, and wet clothes were dried by wearing them. It gave the Squadron a great sense of achievement. It was the first time we had used the new class 30 trackway dispensed off a 3-ton vehicle. It is undoubtedly the best bit of equipment that the Corps has developed for many a year.

I intend to skip lightly over the early summer because more interesting training took place in the autumn. In April we licked our wounds from Exercise Hotspur, and at the end of the month 1 Troop (Lieutenant Fisher and Lieutenant Milsom of the Royal Warwickshire Regiment) went to Canada with 24 Field Squadron for six weeks, where they constructed a road. 2 Troop (Lieutenant Howgate) and 3 Troop (Lieutenant Bosomworth) did some demolitions, and spent the best part of a month on the RE Demonstration at Gordon Barracks. This was better training than one would at first imagine.

After the RE Demonstration, and the return of 1 Troop from Canada, we launched forth into an airportability exercise in barracks. We packed our G 1098 in light-weight boxes, and prepared all the documentation for an air move. This was useful as it gave the second in command (Captain Garnett), the SSM, SQMS, Chief Clerk, Troop Commanders and Troop Storemen a chance to get their heads together to work out facts and figures. It was followed by some unit self help to improve our accommodation and stores. We fired our annual range course for ten days, paid another visit to Aviemore for adventure training, and departed on August block leave.

In the spring the Squadron had been warned for service in Christmas Island to undertake a POL project and certain works services for six months. By July we knew most of the details. A total of 148 men were required to fly out in November and December. A depreservation party was to take vehicles and plant out of moth balls, and an advance party was needed to start the POL project off before the main body arrived. The majority of men were specified tradesmen and there was to be only a small administrative Squadron Headquarters. The RAF were paying for our services, and each man's pay and air passage was costed. This all meant that the squadron would have to be reorganized at some time in the autumn into a POL Troop, Works Troop, Project Support Troop (drivers, fitters, plant operators, etc) and a Headquarters administrative element.

Digressing from the story, this necessity to reorganize for works projects or operations involving a specified number of men for aircraft is unfortunate. I had had to reorganize a troop to go to British Honduras in 1962, 1 Troop were reorganized to some extent to go to Canada in April, and further reorganizations were required for the exercises in the autumn which I will mention later. I feel that reorganizations have to be accepted in the Strategic Reserve, but that efforts must be made to build-up the spirit and loyalties of the new troop quickly. On the other hand, those who order these projects and employing agencies must not be too rigid in their demands; a Sapper is a versatile gentleman.

During the last two weeks of August we planned for the autumn training and for Christmas Island in detail. As soon as we had nominated the men for Christmas Island, we could decide who were to go on the two exercises in North Africa in November. Not until that was done could we say who was to go to Stanford Practical Training area and on the bridging Exercise Marsh Harrier. Nominal rolls were published saying who was going where, and these were kept up to date as changes occurred. There were other administrative problems. Each man nominated for the Island had to have a passport, and he also had to go to the dentist before leaving England because the nearest one to Christmas Island is in Honolulu. This proved a formidable task, which disrupted training and was not entirely finished until early in December. The Army now fights with its teeth, or gums, if it has not got any; it no longer marches on its stomach.

We did not go to a bridging camp this year, but trained in watermanship on the Medway and bridged in a quarry at Wouldham. Each troop in turn practised with heavy girder equipment and EWBB. It was interesting to discover that only about six men in the Squadron had ever done EWBB before.

On 23 September we started Exercise Marsh Harrier, which was set by the CO for each Squadron. A heavy girder bridging column was made up from new drivers for 60 Field Squadron, just forming, and vehicles came from the Reserve Army Pool. With the bridging column we set forth for five days in the Romney Marshes. Our first bridge, 100-ft DS, was constructed over the Grand Military Canal, and the whole operation took a night and a day to complete. This may sound long, but there is a world of difference in using a virgin site and off-loading from vehicles, than playing about at some well worn bridging gap. A lot of Sommerfeld track had to be put down, and the bridge site had to be prepared and levelled during the night, which was not easy. During the afternoon, 1½ in of rain fell and we were within an ace of the Coles crane sinking through the Sommerfeld track altogether. The second bridge, 87 ft 6 in SSR, North of Rye, over the River Rother was completed more quickly. After an initial mishap with a crane on its side in a ditch everything went smoothly. This bridge was built by Lieutenant Milsom who had taken over command of 1 Troop from Lieutenant Fisher. He was in the process of transferring to the Royal Engineers, but had not been Gazetted. He is probably the only infantry officer to have been in command of the construction of a heavy girder bridge.

After a few days in Maidstone we hurriedly reorganized into the formations required for North Africa. We departed for Stanford Practical Training Area on 2 October where the new troops shook themselves down quickly. We did a few days infantry training on our own, and carried out a series of exercises set by the CO in riot drills, cordon and search and anti-terrorist activities. Regimental Headquarters turned out in force as some particularly belligerent looking rioters and terrorists, whom we took pleasure in rounding up. A troop of 24 Field Squadron joined us for a minefield exercise and 2 Troop left to prepare for North Africa. We laid a mixed minefield about 2,000 yds long and at places, which had been suitably booby-trapped, each troop breached at night. This was all standard stuff except for an approach march across a bog carrying the required gapping equipment less wire, which produced some interesting results. We finished our time at Stanford with a two-day battle against the 2nd Battalion Coldstream Guards. They put in a series of attacks against us and we withdrew along an axis. This was good sport as well as excellent training. At least two Sappers claimed to have shot their CO!

2 Troop flew to Benghazi on 13 October for Exercise Quickstrip, taking their G 1098 as freight. They were required to construct a light air strip in Wavell Barracks for the 14th/20th Hussars. The troop prepared a patch of desert with plant and laid PBS. The criteria for the strip was as follows:—

Main strip	
Length	1,272 ft
Width	48 ft
Over runs	200 ft and 150 ft
Cross strip	
Length	778 ft
Width	48 ft
Over runs	200 ft and 150 ft

Both had a camber of 3-ins either side of the centre line. There was also a taxi strip and a fuel point.

There was some trouble over the PBS arriving by ship, so the project was not finished in time for the troop to join our other Exercise Longreach farther along the North African coast. They had in fact to be reinforced. No difficulty was met in laying PBS, and there was an expert, Mr Colquhun, to advise. This exercise was very good value for the troop, especially the troop Commander who was acting as the contractor to the GWO, and was his own master.

Exercise Longreach from 1 to 11 November was probably the most interesting one we did during the year. We were flown out to El Adem by the RAF, and trained in the desert for ten days, using stockpiled vehicles. For the time we were in the desert we had no administrative support other than the provision of water and fresh bread. Planning started in August after the Second-in-Command of the Regiment (Major Moss) had visited various Headquarters round the Mediterranean. Thereafter we reverted to paper work, and had to deal with fifteen different formations and Headquarters.

The Regimental Quartermaster (Major Whitehead) took out our advance party on 14 October and set up a base camp on the shores of the sea at Bomba, 90 miles West of Tobruk. He took over vehicles from 3rd Division after their Exercise Triplex West, and laid in stocks of food and POL. Plant, engineer stores and some wireless sets came from Cyprus and Malta by sea. It was fortunate that the Quartermaster led this advance party as they met difficulties which required a strong arm to sort out.

The Squadron was depleted by 2 Troop in Benghazi, and 3 Troop who were going on embarkation leave for Christmas Island, so we were reinforced by a troop from 24 Field Squadron. We flew out in four Argosies from RAF Benson and took with us 15,000 lb of freight, 1,000 lb of explosives and a Michigan Light Wheeled Tractor (15,694 lb) in the aircraft. The Michigan was delayed at Malta, but duly arrived a few days late and the driver brought it the 90 miles up the coast road on his own. I believe this was the first time a Michigan has been carried by an Argosy for such a long distance.

Our main task was to improve a desert track from a place called Umm Er Rezum to Umm Hafien for the benefit of local villagers, whose patience had been stretched by previous exercises in the area. We used the plant and explosives on this. We did a series of desert patrols in Landrovers to practice navigation and to search for water, culminating in a two-day trip of 120 miles. In looking for water we were guided by Major F. Moseley's article in the *RE Journal* of June 1963, called "Fresh water in the North Libyan Desert". Although we did not find much in the places he suggested, primarily because we did not have the proper search or well boring equipment, we did develop a source sufficient to supply a troop living near it. We finished with a desert march. The stockpile vehicles worked well, and with some improvization we kept the plant going. I regret though that it will have taken more than improvization to repair a compressor belonging to CRE Cyprus which careered down a wadi bed after shedding its front wheels whilst on tow. My humble apologies to him!

We left the shores of the Mediterranean, and returned to England on a bleak mid-November evening with a 70-knot wind gusting across RAF Benson runway. 2 Troop from Benghazi joined us for the return flight, for which we had six Argosies. Lieutenant Milsom and a small party remained behind to clean up the vehicles and return stores to Cyprus.

Exercise Longreach was expensive in money and effort, but it was well worth doing. The more training we get like this in the Corps the better; Sappers thrive on it.

On our return from North Africa there was an intensive period of cleaning up and preparing for the administrative inspection. The final reorganization for Christmas Island took place on 18 November, and the three parties left by air on the dates shown in the programme. I saw the main body off in a Britannia of British United Airways fom Stanstead airport shortly after midday on 30 December, having handed over to Major Negus. So ended 1963.

I do not have any profound conclusions to make, and readers may draw their own. This is the story of one field squadron in peace time in England, but I should like to say three things:

a. I definitely favour the regimental system of grouping field squadrons. I have not said much about Regimental Headquarters as this is primarily the story of 20 Field Squadron, but they did the majority of the forward planning for the major exercises. It would not have been possible to carry out nearly so much collective training as an independent field squadron under conditions prevailing in England at the present time.

b. At the end of the year we were in a better state of training than we were at the beginning of it. The soldiers had matured, especially the NCOs, for whom there had been a lot of promotion even to the extent of twice in the year for some of them.

c. I hope that the taxpayer had his money's worth.

Cromwell's River Crossings

By Lieut-General Sir Charles King, KBE, CB

In Buchan's *Life of Cromwell* the author gives a few glimpses of operations involving crossings of large waterways. These operations were obviously of some magnitude and they invited further study. The County Library produced several books covering the operations in general, but none gave any detailed technical information. Eventually the standard work—Fritz Hoenig's *Oliver Cromwell*—was produced in three massive volumes and equally massive German.

It was clear from the bibliography in his book that Hoenig had consulted a very large number of the original documents. Unless more information has been unearthed in the last fifty years, it is unlikely that any further detailed information is available. With true Teutonic thoroughness, Hoenig gives innumerable references to Cromwell's own letters. The translation of Cromwellian English into modern German may well lead to imperfect rendering. The re-translation into English by one whose German is rusty in the extreme could produce a result differing widely from the original version. This sketch makes no pretence to historical research. It takes Hoenig's word as correct without any check on original documents for which the writer has no opportunity or knowledge.

The description of the operations gives very limited technical information, but it is sufficient to arouse a sharp curiosity of the ways and means by which these difficult operations were successfully carried out.

Cromwell undertook three major crossings, excluding the invasion of Ireland which falls into a separate category and is not discussed here.

The three operations were:—

(i) The crossing of the Humber at Hull.

(ii) The crossing of the Firth of Forth at Queensferry.

(iii) The crossing of the Severn at Worcester.

These were opposed crossings and by any standards major operations.

Cromwell's own letters were terse in the extreme. In his letter of 21 July 1651 to Speaker Lenthall he says, "We were directed (by God) to send a party to get us a landing on the Fife coast by our boats." After this comment, Cromwell takes it all for granted.

In another letter to the Speaker written from "Near Worcester 3 September 1651 (10 at night)", Cromwell starts by saying he is so weary and scarce able to write. This is hardly surprising as he had been fighting all day "as stiff a contest for four or five hours as ever I have seen". Cromwell's report on the bridging operations is "We built a bridge of boats over Severn between it and Teme about half a mile from Worcester and another over Teme within pistol shot of our other bridge".

There is some difficulty in estimating correct numbers. Hoenig complains somewhat peevishly that he has found discrepancies even in contemporary letters. The Parliamentary Army was organized in regiments of horse and foot regiments nominally 1,000 strong. Each regiment appears to have had ten squadrons or companies of 100 strong. At times, these figures were liable to great variations as Hoenig complains. Field guns are mentioned, but information on the organization or establishment is missing. One of the most remarkable omissions is the apparent absence of transport for food and ammunition.

The Crossing of the Humber

In August, 1643, part of the Parliamentary Army was shut up at Hull under the command of the older Fairfax. Cromwell was collecting a new army round Cambridge. He advanced into Lincolnshire, drove back the Royalists and joined up with General Willoughby's force. He then turned his attention to the problem of getting Fairfax's army out of Hull. The Royalist Army investing Hull was of superior strength to Cromwell's forces. Cromwell disposed his forces in a semi-circle round Saltfleet, a town on the Lincolnshire coast some thirty miles from Hull.

On 26 September 1643 Cromwell and Willoughby "climbed" into a boat at Saltfleet and set out for Hull, where they arrived safely on the same day. Hoenig makes a remark that, even with a favourable wind and tide, it was a day's sail from Saltfleet to Hull. Cromwell discussed ways and means with Fairfax. "So many boats were available in Hull that all the Cavalry could embark in one trip. A successful issue was to be hoped." Thomas Fairfax agreed at once, but his brother hesitated for some time. It was eventually decided that D-day should be the 27 or 28 September. On one of these days (dates are vague) 21 Squadrons of Cavalry and Dragoons were embarked. The fleet was dispatched and arrived safely at Saltfleet and disembarked. The boats then sailed back to Hull. The Royalist Cavalry tried to interfere with the landing but the disembarkation was safely accomplished. Cromwell concentrated his army early on the 29 September.

There are many gaps in the story. To embark twenty-one Squadrons—nominally 2,100 men and horses—in the face of any opposition is a formidable task and there are many details one would like to know.

Crossing of the Firth of Forth

In December 1650 Cromwell had made all the necessary arrangements for the resumption of hostilities against the Royalists under the command of General Leslie who was at Stirling. Cromwell realized that there was little chance of manoeuvring him out of his strong position. Cromwell asked the authorities in London for a part of the Navy. He specially asked for large flat-bottomed boats to enable him to carry out a landing on the South Coast of Fifeshire, thus turning his opponents' position. Unfortunately Cromwell was sick for four months and it was not until March 1651 that he was able to proceed with his plans. It is interesting to note that Cromwell at no time divulged any of his plans even to the highest authorities. No trace, or even a pointer, could be found in any letters to his wife, his family or even to the Council of State in Parliament. He reported his action only when he had started to carry out his plans.

In June 1651 Cromwell appreciated the situation and amongst various possibilities was this item: "In case of failure (ie to cut off the Stirling force by land) to cross the Firth of Forth. In this purpose, specially designed boats would be necessary." General Deane, the Fleet Commander, had brought twenty-seven such boats to Cromwell. A further number had been found in the Firth of Forth and had been captured from the Scots (these are hardly likely to be special design). By the middle of June, the requirements of boats had been met, though numbers are not mentioned.

Cromwell concentrated his army of 25,000 men on the Pentland Hills. Offensive operations against Stirling were undertaken but without any success. Cromwell was convinced that the crossing at Queensferry was the only solution.

The problem was formidable: the proximity of Leslie's force at Stirling, the fortification on the Fife coast, the necessity for surprise, the state of the tide. All these problems were reproduced in far greater measure in 1944. Cromwell decided to despatch the flotilla at night from Queensferry in order to carry out the actual landing in the early morning. Cromwell appointed General Lambert in command and put at his disposal three Regiments plus four companies of foot and three Regiments of cavalry—a total of 6,000 men, assuming that the units were up to strength. At the same time, a force under Colonel Overton, consisting of one Regiment and four companies of foot and one Regiment of cavalry, marched off on 17 July from Queensferry to join General Lambert's force which remained in a position of readiness.

Colonel Overton had the task of returning to Queensferry as dusk was falling, to embark in the boats and to sail as advance guard. A formidable task for tired men. Cromwell remained with the rest of his army, demonstrating against Leslie's force in order to divert his attention from the main operation.

Little is known about weather conditions, but it appears that they were not unfavourable.

There were sufficient boats for the advance guard to embark in one flight. Incidentally, they carried spades and shovels to dig in immediately on landing. Coastguards discovered the approach of the flotilla and small arm fire was exchanged. Gun fire is mentioned but appears to have had little effect. Without serious opposition, the force landed. The infantry at once advanced to attack Inverkeithing, which was evacuated by the defenders who abandoned their guns and weapons. The force formed a bridgehead at the North

Ferry with a protecting line of entrenchments. After disembarkation the flotilla returned to Queensferry where Lambert reported his success to Cromwell. Cromwell immediately ordered all to cross and by the evening of the 18th Lambert with three Regiments and four companies of Foot and three Regiments of Horse were at Inverkeithing. No mention is made of casualties.

Bridging the Severn

In 1651 Prince Charles (afterwards Charles II) landed on the West Coast of Scotland and raised an army. He decided to invade England in the rather forlorn hope of obtaining support from his sympathizers. He marched south on the western side of England, while Cromwell hurried down the eastern side to overtake. He caught up with the Scots at Worcester and was faced with the problem of crossing the Severn in order to bring them to battle. The Severn is here about 100 metres wide and makes a formidable obstacle. Some 1½ miles south of Worcester, the River Teme joins the Severn. The Teme was bridged at Powick, some two miles below Worcester. This was in the hands of the Scots. In addition, there was a bridge over the Severn at Upton, some eleven miles south of Worcester. This bridge was destroyed by the Scots, who were occupying a position covering the site.

In spite of the destruction, a beam was found long enough to bridge the gap. A party of Lambert's Cavalry arrived and dragged the beam over the gap and crossed "sitting astride the beam". They then replaced the bridge, crossed with their horses and took up a covering position, reporting their action to General Lambert. He sent help and the Scots were driven back. Hoenig comments, "This glorious and forever outstanding cavalry action took place on August 29th."

Cromwell decided that Upton was too far from Worcester, as it needed a day's march to cross the river at that point. He, therefore, formed a bridging train, presumably from the material which Lambert had collected. His intention was to bridge the Severn just south of the junction of the Teme with the Severn.

Early on 3 September Cromwell's dispositions were complete, and he started the work on the bridge, which "proceeded rapidly because of these careful preparations". At midday on the same day, the work was completed. Hoenig comments, with every justification, "Before this a similar operation had never been carried out with such rapidity."

Fairfax had been ordered to bridge the Teme as soon as the bridge over the Severn was complete. For this purpose, special boats had been prepared. They were hurried up to the site. Owing to various difficulties, they only arrived on site at 3 pm, but the bridge was completed by 5 pm on the same day. The battle began at 5.45 pm led by Fairfax over the Teme bridge.

Conclusion

There are so many gaps in the information. The ineffectual action of the Royalist Army seems inexplicable. On the technical side, it would be interesting to know many things. How did the horses embark and disembark? There must have been great congestion in the boats, which presumably were towed. The design of the bridge over the Severn would be interesting, and many other problems.

Perhaps this short sketch may stimulate curiosity for proper research, or even for a trial run by a unit instead of a Bridging Camp.

Repair of Light Alloy Bridging Equipment

"Here's Metal More Attractive" (*Hamlet Act 3 Sc. 2*)

By Colonel W. G. A. Lawrie, MA, AMICE

The object of this paper is to discuss the use of aluminium alloys for military bridging equipment and to suggest lines of action which should be followed if full use is to be made of their potentialities. The views expressed are my own, and not necessarily Army policy.

Historical Background

"Bailey Bridging made an immense contribution towards final victory in World War II. As far as my own operations were concerned with the Eighth Army in Italy and with the 21st Army Group in North West Europe, I could never have maintained the speed and tempo of forward movement without large supplies of Bailey Bridging."

Montgomery of Alamein,
Field Marshal, CIGS.

Immediately after the last war the tendency was for military loads to increase. The obvious temporary solution was to strengthen the Bailey Bridge, but as various heavier expedients were introduced they imposed an ever-increasing strain on transport and manpower.

At the same time the introduction of the nuclear weapon demanded smaller concentrations of troops and vehicles, and fulfilment of our limited war commitments necessitated the development of air-portable equipments. The designers naturally turned to aluminium.

The outstanding property of aluminium is its lightness; its specific gravity is only about one-third that of steel, zinc or copper. In its pure state it has little strength, but the addition of small quantities of other elements such as copper, magnesium, manganese or zinc produces alloys which are comparable to mild steel. This gives a strength/weight ratio very much in favour of aluminium, but at the same time its other properties may be affected. Stronger alloys are correspondingly more difficult to manufacture, and in some cases their corrosion behaviour is less satisfactory.

Metallurgical Principles

Before we can understand the reasons for the selection of a particular alloy for use in a military equipment, or appreciate the difficulty of maintaining it in a serviceable condition, it is useful to know something about the metallurgical principles involved. To begin with, an alloy is actually a solid solution. Just as an iceberg is a solid solution of salt in water, so we can have a solid solution of copper or various other elements in aluminium. Furthermore, copper and aluminium also form the chemical compound $Cu\,Al_2$ which may be present in the alloy. This is known as an intermetallic constituent; other elements may react in a similar way.

The various changes of state which take place when an alloy is heated are illustrated in the Aluminium-Copper Equilibrium Diagram (Fig 1). This shows that for any given percentage of copper the structure of the alloy will change with variations in temperature.

For example take the case of an alloy containing 3 per cent of copper. The state of the alloy at different temperatures will be as follows:—

Over 650°C	The alloy is in a completely liquid and homogeneous state —a liquid solution of copper in aluminium.
650°–600°C	As the alloy cools it becomes a pasty mixture of liquid and solid solutions until it solidifies completely at 600°.
600°–460°C	As the temperature falls some of the copper is precipated, forming $Cu\ Al_2$
below 460°C	The alloy is now a solid solution interspersed with crystals of $Cu\ Al_2$.

When the alloy is heated again to a temperature between 460° and 600° the $Cu\ Al_2$ dissolves into the solid solution, and if it is suddenly quenched in water, some of this $Cu\ Al_2$ remains in solution. This artificially enriched solid solution is unstable and excess $Cu\ Al_2$ tends to precipitate. A similar process can take place when other elements are alloyed with aluminium and the possible variations are many indeed, using different percentages of different metals. However, the underlying principle is the same—it is the presence of excess intermetallic constituents dispersed throughout the solid solution which sets up strains within the crystalline structure of the alloy and, thereby, gives it its extra strength and hardness.

Heat Treatment

When we talk about the heat treatment of an aluminium alloy we refer to solution treatment, precipitation treatment and full heat treatment. Solution heat treatment is the process of heating the alloy to a certain temperature, then suddenly quenching it. In order to obtain maximum strength the greatest possible amount of intermetallic constituents must be held in solid solution. This will be achieved when the solution treatment temperature is as high as possible without exceeding the solidus. In some cases precipitation of excess intermetallic constituents takes place at room temperature. This process is termed natural ageing. In other cases the temperature has to be raised to between 150°C and 200°C. This accelerated form of ageing is called precipitation treatment. Maximum strength is obtained by prolonged ageing at room temperature rather than by rapid ageing at high temperature. If heating is carried on too long or at too high a temperature the material "over-ages" and starts to become softer again. Full heat treatment of course means that both solution treatment and precipitation hardening are carried out. Heat treatable alloys are those which are capable of being strengthened by one or both of these processes.

Some alloys are described as non-heat treatable. They do not respond to the processes described above but can be strengthened by work-hardening. Cold working of any metal by rolling, drawing or pressing disrupts the crystal grains, which are of regular atomic structure, into a large number of small crystals and crystal fragments. At the same time the number of planes of easy slip diminishes and resistance to plastic flow of the metal under stress increases. The metal has now been work-hardened. It can be annealed by heating it to a particular temperature, when the crystals reform, and the metal is restored to a soft condition capable of further cold working.

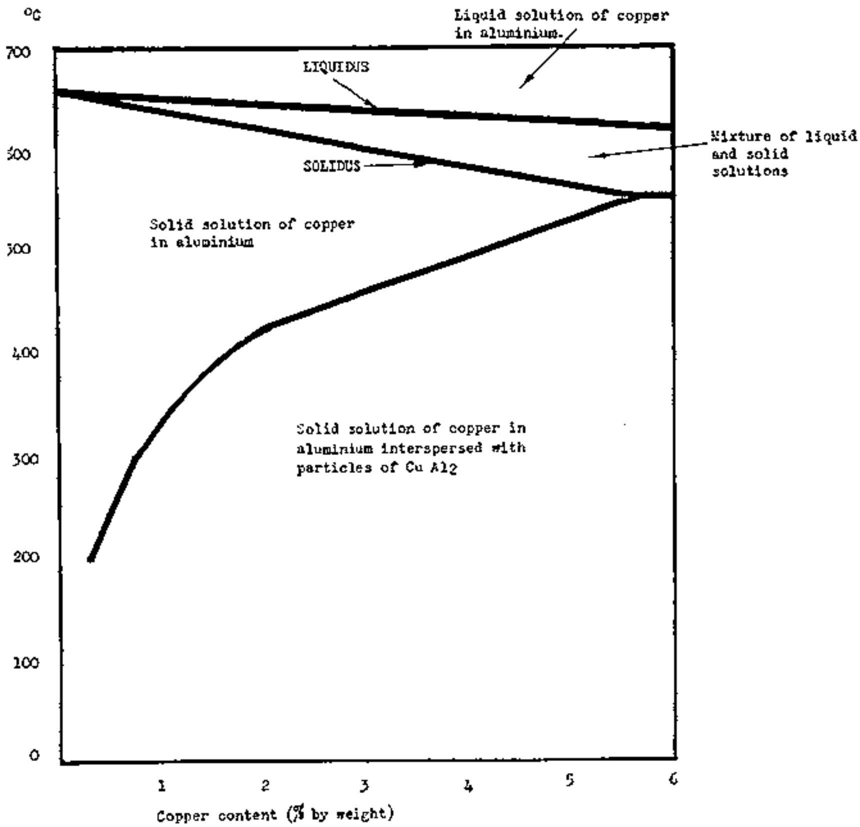

Fig. 1. Aluminium-Copper Equilibrium Diagram

LIMITATIONS AND ADVANTAGES OF ALUMINIUM ALLOYS

It is evident that aluminium alloys are highly susceptible to temperature changes, unless they are used in the fully softened or annealed condition. A rise in temperature above a critical point may completely alter their physical properties. Strength lost in this way can only be restored partially or very slowly. This is the first limitation to be borne in mind when considering the manufacture or repair of military bridging equipment.

At this point it is appropriate to consider another limitation to which aluminium alloys are subject. Certain alloys are highly susceptible to electrolytic corrosion, which may be intensified by contact between dissimilar metals, including different aluminium alloys, and is often intercrystalline in character. This is especially marked when the metal becomes wet by moisture containing salt, acid or any other electrolyte. When dissimilar metals are in contact one metal will dissolve preferentially; it is said to behave anodically and is termed an anode, the other metal of the pair being designated the cathode. The combination of anode and cathode constitutes a galvanic couple. A variation of mechanical properties brought about by different degrees of mechanical working of the surface of the metal can also give rise to electro-chemical dissimilarity.

Metals may be arranged in order of electrode potential as under:—

Noble end	gold
	silver
	mercury
	copper
	lead
	tin
	nickel
	cadmium
	iron
	chromium
	zinc
	aluminium
Base end	magnesium

In the case of any pair of metals or alloys constituting a galvanic couple that metal which is more base will function as the anode and will, therefore, undergo corrosion, whilst that which is more noble will function as the cathode and thus receive protection. It is clear that alloys of copper with aluminium are more likely to suffer electrolytic corrosion than those of zinc or magnesium, which lie next to it on the electrochemical scale.

Some aluminium alloys exhibit a condition known as stress corrosion which may lead to failure. The causes are slightly different in the various classes of alloys but it can be described in general as an intensification of electrolytic corrosion when the member is subjected to tensile stress.

Having pointed out that aluminium alloys have to be treated with respect, there is no doubt that they possess considerable advantages as compared with steel. These can be summarized as follows:—

(*a*) *Design advantages*

- (i) Extruded sections of any desired profile can be used for structural members. Since overall costs of dies are comparatively low we are not restricted to standard sections as in the case of steel.
- (ii) The strength and elongation of aluminium alloys are unaffected by low temperatures, with no tendency to brittle fracture.

(*b*) *Weight advantages*

- (i) Aluminium alloy equipments are easier to transport by land and air compared to similar equipments made of steel.
- (ii) They can be constructed with smaller working parties.
- (iii) Reduction in dead weight simplifies base-plate and grillage design.

(*c*) *Maintenance advantages*

- (i) Painting is not required.
- (ii) Atmospheric corrosion can be eliminated.

Current Bridging Equipments

Over the years research has been undertaken in many countries in an effort to find alloys with the best combination of properties for particular purposes. In many cases military requirements have formed the spearhead behind which wider civilian applications have followed. Research into various aspects of aluminium alloys still continues. One difficulty is that there is no international code of design or even of nomenclature. In June 1963 a symposium on "Aluminium in Structural Engineering" was held in London. It was attended by eminent professors from America, Germany, Belgium and Switzerland as well as British experts. They were all carrying out advanced research in their own countries but lamented the difficulties of co-operation imposed by the absence of a common code of practice.

Thus when designers at the Military Engineering Experimental Establishment (MEXE) were asked immediately after the last war to design a new family of bridging equipments they turned to aluminium alloys which were known in this country or in the United States. The results of their efforts, which included both steel and light alloy components, are listed below:—

Equipment	Design period	Prototype ready	Under trial	Introduced into Service
Heavy Girder Bridge	1946–49	1950	1951–53	1954
Light Floating Bridge	1946–50	1951	1952	1956
Heavy Ferry	1946–51	1952	1954	1957
Heavy Floating Bridge	1951–54	1955	1956–58	1962

Repair Techniques

Some of these equipments have been in use for nearly ten years and have inevitably been damaged on numerous occasions by accident or through normal wear and tear. Engineer workshops at all echelons have improvised and developed a variety of techniques to keep them operational, although no official repair manuals have yet been issued, and even the provision and replenishment of essential maintenance spares has never been satisfactory. In order to put right this situation the RE Repair and Maintenance Advisory Team was authorized in 1963 and they have already drafted several repair pamphlets for issue in 1964. RERMAT have a difficult task if they are to catch up with ten years back-log of work as well as keep abreast of new developments. They have, however, the advantages of direct access to MEXE design staff and a considerable body of user experience in the field and in workshops on which to base their doctrine, both in regard to current equipments and those still in the design stage.

It is worth examining the basic repair techniques which have been evolved in the last ten years, and which are described in detail in the new repair pamphlets, including their particular application to each equipment.

(a) Emergency repair kits

Special kits are supplied with all floating equipments containing various items which can be applied by any intelligent Sapper to stop them sinking. They include various sizes of bung which can be used to plug bullet holes, screw-on patches and a supply of epoxy putty (also called epoxy dough). Holes up to 4 in diameter in wood, steel or aluminium alloy hulls can be repaired with epoxy putty. This consists of epoxide resin with an inert filler to which a hardener is added. After 8 hrs the filling is completely hard and can be sanded and painted, but in an emergency the pontoon can be relaunched in 2 hrs. Holes larger than 4 in across can be repaired by building up layers of epoxide resin and glass fibre or wire gauze on a backing of light alloy sheets. This method has been used successfully under certain circumstances to make good damage to structural members. Epoxy putty which is abrasion-resistant can be used for building up badly worn extrusions as long as structural strength is not required.

(b) Bolted or riveted metallic patches

These are used for larger holes and provide more permanent repairs. They are much slower to execute and require a certain amount of skill and knowledge to design and apply. Standard rivets are available in various alloys, with different types of head, and in different lengths and diameters to suit different thicknesses of plate. There are a large number of proprietary fastenings on the market, all of which require more or less special tools and a wide range of rivets to cover every case.

In an emergency "fitted" bolts can provide a simple method of repair. Holes in patch and plate are hand drilled to a diameter slightly less than that of the bolt, which is then driven in, swaging the holes to the exact diameter.

There are also various patent types of bolt which have been used for bridging repairs. "Huckbolts" consist of a bolt with a protruding tail and collar. A special pull-gun applied to the tail causes the work to be tightly clenched together until the collar is swaged into lock grooves. The tail of the bolt then breaks off. "Jo bolts" are used where only one side of the work is accessible. They consist of a high-tensile steel bolt and nut and a stainless steel sleeve. The whole assembly is inserted into the hole and the special driving tool causes the sleeve to be drawn up hard against the blind side of the work. At a predetermined torque the tail of the bolt breaks off flush with the head of the nut on the outside of the work.

Self-tapping screws provide a satisfactory method of fixing patches, using the minimum of tools, provided there is no possibility of independent movement.

All these methods are being tested by RERMAT in order to compare their efficiency under controlled conditions. But their introduction as standard methods of repair would involve the scaling and cataloguing of all the fasteners and special tools, and the holding of spares at all echelons in the supply chain.

(c) Welding

Modern techniques and equipment permit the safe welding of certain alloys provided the members involved are not stressed beyond 8 tons per sq in. The article entitled "Fusion Welding of Aluminium Alloys" by Major D. L. Jones, RE, which appeared in the *RE Journal* for June 1961, gave a very clear outline of the methods and equipment used. Since then the LYNX 500 MIG welding set and the QUASI-ARC SIGMETTE light welding set have been authorized for the RSME and Engineer Base Workshops at home and overseas, and tradesmen will be acquiring experience in their use.

The Properties of Different Alloys

This experience is essential because of the many complications introduced by the physical properties of aluminium alloys. Although their melting points are low (520°–650°C) their high latent heats require welding temperatures which destroy the extra strength obtained by heat treatment. In addition, their high conductivity is liable to cause a rise in temperature over a much wider area than in the case of steel. Fig 2 shows that, although the weld was only ½-in wide, a 6-in strip of metal has been seriously affected. Apart from loss of strength, ductility in the overheated region is reduced, which may cause cracking on cooling.

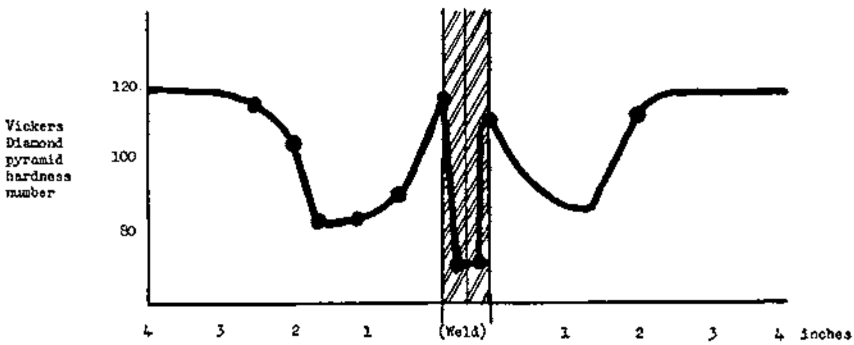

Fig 2. Variations in hardness across a welded alloy plate

(The original alloy was naturally aged after solution treatment and the hardness was tested four days after completion of welding).

Aluminium alloys also expand twice as much as mild steel on heating, so to avoid buckling, allowance must be made for expansion during welding and subsequent shrinking.

Many of these difficulties would be eliminated if "eutectic" or low temperature welding could be applied to the alloys used in military bridges. This process utilizes the phenomenon that certain alloys melt at much lower temperatures than either constituent metal. For example copper melts at 1083°C and aluminium at 660°C, but the melting point of an alloy containing 33 per cent copper and 67 per cent aluminium is only 548°C. Unfortunately this particular alloy has no military application and no way has yet been found of using this principle to weld high strength aluminium alloys at temperatures low enough to avoid weakening.

Some alloys quickly regain much of their strength if the appropriate heat treatment is applied. In the case of Constructal 21/51 for example, the parent metal starts with a 0.2 per cent proof stress of 16 to 23 tons per sq in, depending on the heat treatment it has received. The strength near a weld falls to 6 to 8 tons per sq in. After 7 days the strength recovers to 9 to 10 tons per sq in, and after 30 days it reaches 12 to 14 tons per sq in. But under operational conditions it will not be possible to wait for natural ageing to take place. A small electric blanket is now being developed which would maintain a temperature of 100°–120°C in the welded region, giving a strength of 11 to 13 tons per sq in in 24 hrs.

The proof stress mentioned above is taken to be the point in the stress/strain curve where plastic flow is commencing. It sets the limit to the ultimate load a structure can withstand. If working stresses during the design stage are based on a 0.2 per cent proof stress, the allowable permanent distortion is limited, thus ensuring interchangeability of components. 0.2 per cent proof stress is found from the stress/strain curve by drawing a line parallel to the straight line portion of the curve through a point on the strain axis representing an extension of 0.2 per cent (see Fig 3).

The welder's task is complicated by the fact that current and forthcoming bridging equipments include about twenty different specifications of alloy, each of which may be affected by heat in a different way (see Table I).

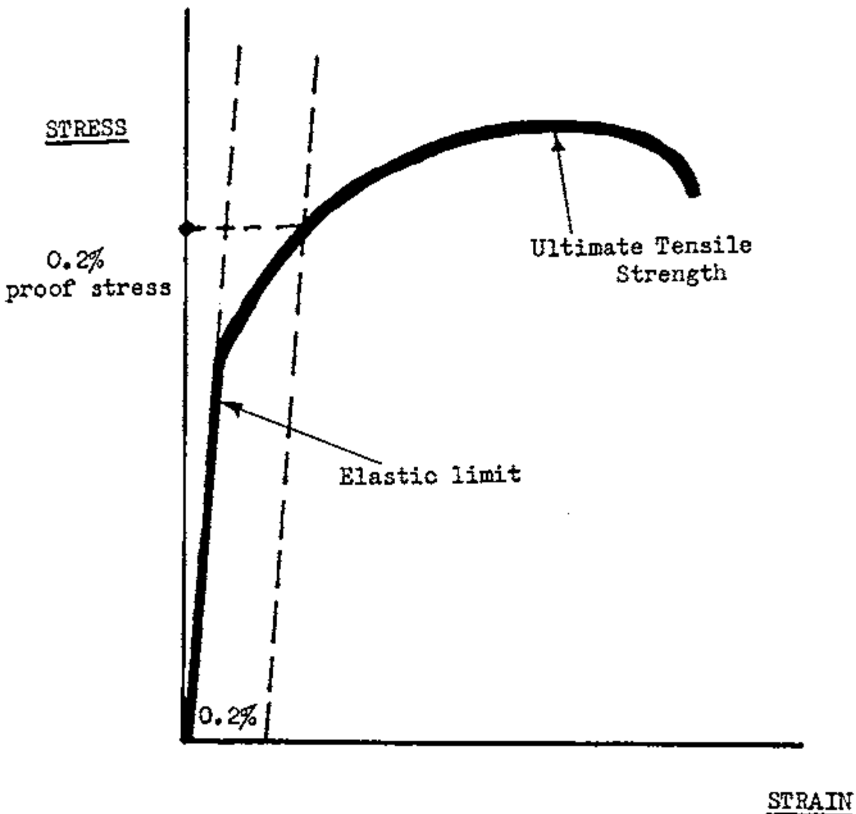

Fig.3 Typical stress/strain diagram for aluminium alloy

The Problem

We have a large number of aluminium alloy equipments made up of a variety of different alloys and scattered throughout the world. They have been damaged and repaired in an *ad hoc* manner from time to time, but no clear policy exists to define the repairs that may be carried out at each

TABLE I—*Alloys used in current and future bridging equipments*

Equipment	Sheet	Plate	Extrusions	Castings
Heavy Girder Bridge (decking)		HP 30-WP	HE 30-WP	
Light Floating Bridge	HS 30-W NS 6-O NS 6-W NS 6-½H		HE 15-WP HE 30-WP HT 30-WP	LM 6M LM 10W
Heavy Ferry		HP 15-WP HPC 15-WP HP 30-WP NP 6-M	HE 11-WP HE 15-WP HE 30-WP	LM 6M LM 10W
Heavy Floating Bridge	NS 6-½H	HP 30-WP NP 5/6-M	HE 15-WP HE 30-WP	LM 6M
M2	Constructal 21/51			
Medium Girder Bridge and Class 16 Floating Bridge	Impalco 720 and Hiduminium 48			

Notes 1. A complete guide to the British Standard code for aluminium alloys was given in Major Jones's article, but for ease of reference the essential points are repeated below:—

Initial letter) (Heat-treatability)	Second letter (Physical form)	Number (Chemical composition)	Final letters (Treatment carried out)
H = strength can be increased by suitable heat treatment N = heat treatment produces no increase in strength	E = extrusion LM = casting P = plate PC = clad plate S = sheet T = tube	For meaning of numerical code see Table II	½H = ½ hard temper M = as manufactured O = annealed W = solution treated P = precipation treated

2. Constructal 21/51 is the trade name of a German medium strength weldable light alloy. It has been developed from Unidal, also of Continental origin, and is an aluminium-zinc-magnesium alloy. British versions include Impalco 720 and Hiduminium 48. These have not yet been given BSS numbers.

TABLE II—*The composition of aluminium alloys used in military bridging equipments*

	Castings		Sheet, Plate and Extrusions			
BS Code	LM 6	LM 10	6	11	15	30
Copper	0.1	0.1	0.1	1.5	4.3	1.0
Magnesium	0.1	10.0	5.0	0.8	0.8	1.0
Silicon	12.0	0.35	0.6	1.0	0.9	1.0
Iron	0.6	0.35	0.5	0.7	0.7	0.5
Manganese	0.5	—	1.0	1.0	1.2	0.7
Nickel	0.1	—	—	—	—	—
Chromium	—	—	0.25	—	—	0.3
Zinc	0.1	—	—	—	—	—
Lead	0.1	—	—	—	—	—
Tin	0.05	—	—	—	—	—
Titanium	—	0.2	—	—	—	—
Aluminium	86.35	89.0	92.55	95.0	92.1	95.5
Ultimate tensile strength in tons/in²	12.0	20.0	17.0	24.0	30.0	19.0

Notes 1. The percentages given are typical. The BSS allows variations within certain limits.
2. Strengths are approximate, depending on heat treatment received.

echelon in peace or war, nor, if welding is to be one of the authorized methods, have we the equipment or trained Sappers to carry it out in the field.

It is suggested that the problem be considered from several angles and in the following order:—

(*a*) Organization—How will the equipments be deployed in operations? What damage capable of repair is likely to occur? What are the correct methods of repair and what organization and equipment is required to enable these repairs to be carried out?

(*b*) Training—How many skilled tradesmen are required to implement the decision on organization? What training is required by personnel of field squadrons, field park squadrons and RE base workshops?

(*c*) Spares—How does the fact that a particular component can, or can not, be repaired affect spares scaling? How can we ensure that spare parts are ordered for the planned life of an equipment during the main production run?

Proposed Organization

It is safe to assume that in any future war whether in Europe or elsewhere movement will be an even more critical factor than in the past. There will be no large dumps of bridging equipment from which replacements can be drawn, nor will it be feasible to switch equipment from one front or route to another. This means that a formation will have to make do with its original allocation of bridging for each phase of the war, whether it is a matter of days or months. It will, therefore, be vitally important to keep equipment serviceable and to repair damage immediately.

From what has been said already it will be evident that many components are impossible to repair under field conditions. Welding temperatures might reduce the strength of a stressed member in a particular alloy to a dangerous figure or cause unacceptable distortion. Such items must be covered by providing an adequate proportion of sub-assemblies and component spares. This applies to nearly everything in the nature of a girder or strut. Skins of pontoon hulls, which are the items most susceptible to damage and most difficult to transport, can often be repaired fairly easily. Every field squadron engaged in bridging operations should carry the necessary stores and every field squadron NCO should be trained to use them.

There will, however, be cases where more extensive repairs are required. Should we go for riveted or bolted patches, or welding or both? In spite of the inherent difficulties involved I believe we should decide on welding, for following reasons:—

(*a*) By the time any decision is implemented more and more equipments will be coming into the Service made of "weldable" alloys such as Constructal 21/51.

(*b*) There is no repair that can be carried out by patching that cannot be done quicker and more efficiently by welding.

(*c*) Light alloy welding equipment will be needed for the repair of other engineer equipments besides bridging—e.g. piping and trackway. It can also be used for welding ferrous metals.

In short the light alloy welder is the tradesman of the future. The Corps should realize this and take appropriate action now.

In 1961 it was suggested and agreed that "forward repair teams" should be established in BAOR. They were to be equipped with a formidable array of kit including:—

Electric sawing, shearing and drilling tools.
Portable welding set with generator and alternator.
Pneumatic drilling, grinding and riveting tools.
Hand riveting tools with a full range of rivets, bolts, screws, etc.
Light alloy sheets, plates and extrusions.
Epoxide resins, glass fibre and wire gauze.

It has taken so long to obtain approval and assemble the equipment that the first team will only be ready to operate on an experimental basis this year. Even then I do not think that this will be found to be the best answer. Given the right tradesmen and tools the field park squadrons should accept responsibility for the field repair of equipments being used by their formations. The thirty or forty different emergency repair kits now in existance, all of which have had to be scaled and catalogued, should be augmented or replaced by bulk stocks of items such as epoxide resins, glass fibre and alloy sheets to be held by the field park squadrons in the same way as they held solder or glue. In general, then, no special organization is required, but the field park squadrons must be brought up to date in tools and tradesmen, and *ah hoc* repair teams must practise moving rapidly from one bridging site to another across country or by helicopter.

The amphibious squadron is a special case. Their vehicles are not made like Meccano. Quite minor damage may put a £50,000 vehicle out of action. This might well be so vital to the success of an operation that the squadron must have a built-in welding capability. Fortunately the Germans have constructed the vehicles of one "weldable" alloy throughout (Constructal 21/51), although the difficulty of providing jigs and gauges in forward areas will necessitate replacement of complete components.

Training Policy

It has been said that "the making of a weld can truly be described as the whole of metallurgy in miniature". Modern push-button equipment has made many trades easier in the last twenty years, but welding light alloys now demands not only greater manipulative skill than ever before, but much greater knowledge and intelligence.

Consider for a moment what a welder has to do before he starts work.

He must identify the parent metal correctly and decide how severely it is stressed. The new pamphlets will tell him this if they are to hand, or we may adopt the German practice of painting highly stressed areas a distinctive colour. Then he must design a suitable weld joint, which involves knowing the operating conditions required of the part under repair. Next he must decide the composition and thickness of the filler wire, hence the current required, the speed of welding, and the correct rate of flow of the argon shielding gas. All these require precise adjustments to the delicate mechanism of the welding gun, including several intricate electrical connections. He will then have to prepare and clean up the work and start up the portable generator. Even if he carries out the weld efficiently, avoiding the many possible errors, his work is not finished. He must estimate the effect of heat on the parent metal and if necessary apply the correct heat treatment to restore as much of its strength as possible in the time available, or alternatively weld on additional aluminium alloy "splints".

At the moment this kind of work is carried out in civilian firms under controlled conditions by highly skilled men who have been doing it every day for many years. We cannot expect Sappers to achieve satisfactory results during operations in the field after a short course at the RSME. Even in our own base workshops most of the welders are civilians. Suitable men must be trained at the RSME; they should be attached to civilian firms for a period and then employed continuously at their trade in engineer base workshops and bridging camps world wide. This is the only way in which we can build up experience and know-how in the Corps, and if we start now it will take at least five years to achieve satisfactory standards.

The number of men required in this trade should be based on at least 4 per field park squadron, plus others in base workshops. We should cater for something of the order of 50, and light alloy welding certainly merits upgrading to the status of an "A" trade.

A very important aspect of training which has been neglected so far is to teach units to look after their equipment intelligently. In operations every piece of equipment will have to be carefully preserved from unnecessary damage because replacements will not be forthcoming. It is, therefore, thoroughly bad training for war to launch heavy ferry pontoons by pushing them into the river sideways with a dozer, which has been common practice in BAOR in recent exercises and has resulted in serious damage.

Spares Provision

The provision of spares for bridging equipment is closely tied up with repair policy. Once it has been decided by RERMAT what items can be repaired and at which echelon, it is possible for the assessors to produce an estimate of the probable annual consumption of each spare part.

When a contractor sets up his production line it is cheap and easy for him to provide an extra quantity of any item. This means that the assessors must work out the requirement of spares from the drawing board. The annual consumption figure must then be multiplied by the estimated number of years the equipment will be in service, a point on which the Engineer-in-Chief's Branch is most reluctant to be dogmatic. When the spares bid is calculated it may well amount to 30 per cent, or more, of the total cost of the new equipment, and it is very difficult to confront the financiers with a demand of this size based on a whole series of guesses. We have never yet succeeded in getting what we want when we want it.

The financiers apparently hope that the equipment will become obsolete in a year or two and that no more money will be required for spares. What is actually happening is either that quantities of expensive equipment lie idle because there are no spares for their repair, or else that several short term buys are made during the life of the equipment at vastly enhanced prices.

Conclusion

In order to escape from the deadlock and confusion involving our light alloy bridging I would like to suggest the following lines of action:—

(*a*) At the design stage:—

(i) Continuous research to find the best alloy.

(ii) Close liaison between RERMAT and the designers to ensure that repair considerations are given full weight.

(iii) Full requirement of spares for the planned life of the equipment to be calculated for inclusion in the initial production run.

(iv) Repair policy to be formulated by RERMAT and promulgated in pamphlet form as the equipment comes into service.

(*b*) By E-in-C's Branch:—

(i) Lay down a definite period for the life of each equipment on which planning can be based and time its introduction to coincide with the availability of spares.

(ii) Decide on the repair organization required, particularly in BAOR, and arrange trials.

(iii) Accept the consequent requirement for highly skilled welders and modern equipment, and arrange adequate training facilities.

(iv) Persuade the finance branches to agree on the grounds of overall economy to a one-time spares buy.

(*c*) By field units:—

(i) Take greater care of bridging equipment during training.

(ii) Ensure that personnel are familiar with standard emergency repair methods.

ACKNOWLEDGEMENTS

An Introduction to Metallic Corrosion by U. R. Evans.

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Proceedings of the Symposium on Aluminium in Structural Engineering 1963.

Critical Path Techniques

By Colonel P. S. Baines, MBE

In the *Royal Engineers Journal* of March 1964, Major J. R. Johnson gave a very clear and concise description of the Critical Path Method of planning and organizing work. The aim of this article is to offer some further thoughts regarding the techniques which should be followed in the practical use of the Method. These are based on the author's experiences during a year's attachment to the Civil Engineering Company of a contracting firm, when he was invited to help in the development of Critical Path techniques to fit the Company's requirements and used the Method in earnest in the course of initial tender planning, subsequent contract planning, detailed planning of individual structures and control of work on the site.

The reader is assumed to have read Major Johnson's article, or at any rate to have a rough knowledge of the Method; reference will be made to it and the same simple reinforced concrete beam and slab bridge will be used for illustration.

The Need to Simplify Techniques

The advantages of the Critical Path Method can be summarized as follows:—

(*a*) It enables, indeed forces, the planner to take two bites at the cherry: firstly, he considers in isolation the basic logic which must govern his plan, closing his mind to the worrying effects of time and resource limitations; then, with this logic firmly in the background, he superimposes the time and resource limitations which will determine the eventual scheduling of the job. By separating planning and scheduling he makes the cherry more digestible and arrives at his answer through more precise channels of thought.

(*b*) As a means of presenting thought it shows, in Major Johnson's well chosen words, "which jobs are critical, the amount of free time in non-critical activities and the inter-relationship of activities throughout the project. It, therefore, forms a clear and simple visual aid for briefing, issuing of orders and hand-over of duties."

(*c*) It is designed so that it can readily be fed into electronic computers.

Now the times when Civil Engineering problems require computers are comparatively rare. In a particularly complex project, such as the diverting of services during the construction of the new Victoria underground, a computer will save days of work by engineers with wet rags round their foreheads, but the great majority of Civil Engineering problems boil down to planning the application of force in a reasonably sensible way over a period of time. In a project such as a section of motorway with its attendant bridges, or a dam, or the foundations for a nuclear power station, the major trains of resources can be numbered on less than ten fingers and can readily be levelled by eye. This applies even more to Military Engineering. For the ordinary user the present teaching of the Critical Path Method, as introduced by Mauchly Associates Ltd, concentrates too much on advantage (*c*) at the expense of advantages (*a*) and (*b*), and this partly accounts for the inertia which still has to be overcome, in both Industry and the Services, before the Method is adopted from top to bottom as a standard way of presenting thought about anything which could formerly have been presented in Bar Chart form. If the planner sticks slavishly to an unnecessarily complicated technique he makes his own task more difficult and may well take longer to produce his answer than he did formerly; and the people for whom he is working may find this extra time unacceptable, or may think his method of presentation too difficult to understand and so not take the trouble to master it. In either case, however well he may understand it himself, the planner's medium will have failed. The theme behind the following thoughts on technique is the need for simplicity. We must treat the Critical Path Method as a useful and adaptable servant rather than a tiresome and rigid master.

The Arrow Diagram

The arrow diagram is the planner's tool for sorting out the main factors which will determine his answer. It is not the final means of presenting the answer, nor (except when computers are needed) does it lend itself to the levelling of resources, both of which demand a time-scale diagram. It is, as it were, the rough work which need not be sent in with the examination paper. As in examinations, speed is all important. The first effort is usually very rough indeed, because it is seldom easy to find the best lay-out at the beginning. As the planner's free-hand pencil races to keep up with his brain a very untidy network usually develops; arrows run backwards across the page, lines cross over each other by means of improvised bridges, firm lines have to be changed to dotted lines, and so on. A fair copy is generally needed before durations and event times are added.

At this stage it pays handsomely to consider how the final presentation will be set out and to adjust the fair copy of the arrow diagram to anticipate that form. The lay-out in Major Johnson's Fig 3 conforms with current teaching and is thoroughly confusing. There is no apparent rhyme or reason behind the directions which the various lines take; and the alphabetical system of job numbering, requiring reference to a separate Table, is most irritating. It is perhaps not surprising that experienced men, set in the way of the Bar Chart system, decline to be bothered with this sort of thing. Compare Fig 1. The arrow system is identical, but the geographical nature of the lay-out and the brief title above each job give an immediate picture of the whole project to anyone who speaks the same simple engineering language.

The figure also illustrates a further simplification. If, as in this and many other cases, the Critical Path can easily be found by eye from the Earliest Event Times, and if there is no intention to use computers, then there is no virtue in entering the Latest Event Times on the diagram. The available float will automatically show up in the next process, when the arrow diagram is drawn out to time-scale; the additional figures merely confuse the picture. And if in this case one finds it easier and quicker to scribble circles rather than squares around the numerals, then let circles be used. There is no merit in using squares simply because the technique of the Mauchly Associates Ltd lays this down; this rough work is for one's own use and is not going to be seen by the examiner.

The "Activity Inter-relationship" set out in a column (3) of Major Johnson's Table I is a useful aid to instruction when explaining the system to students. It should not be used after the first lesson. The whole point of the Method is that one uses lines and arrows as a form of shorthand to express what otherwise takes many words, and one's brain must be using the arrow system as the medium of thought. Moreover, words in themslves can be dangerously ambiguous. "Follows Job B" is loosely used to mean "Cannot start until Job B is finished" and can have no other reasonable interpretation; but does "Is concurrent with Jobs C and F" mean "must be" or "may be" concurrent? Major Johnson's arrow diagram shows at once that the design of his bridge evidently permits the latter interpretation. It is only the wording in the Table that has given rise to any doubt.

A last point about the Arrow Diagram, which concerns method rather than technique. It is important at this stage to consider only the basic logic and not to be influenced by any preconceived ideas about resource limitations. If events can logically take place simultaneously, or can overlap with each other provided the resources are available, then they should be shown like that. Resource and time limitations are to be handled during the second bite of the cherry. It is, therefore, a sound general rule to make the arrow diagram show the tightest programme that logic will reasonably permit and to open this out later if resource limitations so dictate, of if the time available allows a more economic use of resources. The design of Johnson Bridge appears to be such that the concrete for the cantilevered footwalks cannot be poured until after that of the main deck, and this may also apply as a matter of logic to the reinforcement; but does it necessarily apply to the soffit shuttering? Or has the staggering of the shuttering been introduced only in order to level the resources to the one gang with three carpenters? Three days (or one-sixth of the total time for the bridge) would be saved if the shuttering could be done simultaneously. One must, of course, use common sense in applying this general rule. If it is known that whatever happens only three carpenters will be available, then it would be a waste of time and effort not to accept this at the arrow diagram stage.

The Time-Scale Diagram

Major Johnson shows very well how resources are levelled by drawing the arrow diagram to a time-scale. At this stage the planner must give up his scribbling and resort to slightly more sophisticated techniques—a drawing board, T square, set square, H pencil, stour eraser and a set of coloured pencils being the simple tools needed. There is no advantage, indeed many a disadvantage, in complicating the process by using the vectorial techniques as shown in Major Johnson's Figs 4, 5 and 6. Let the lines be horizontal and vertical, which both suits the tools and makes for a tidier and clearer final presentation. Fig 2 corresponds to Major Johnson's Fig 5. Note how the lay-out has been anticipated by the Arrow Diagram at Fig 1.

In drafting the time-scale diagram it is best to pin squared graph-paper on to the drawing-board and to surmount this with good quality tracing paper; the former provides a convenient background for the time-scale and the latter will stand the rubbing out which will be needed as scheduling develops. Tracing paper has the advantage that prints can be run off at any time. These may well be needed to keep the planner's colleagues or clients informed of the current state of planning. They are also useful for the process of trial and error involved in the levelling of resources. Coloured pencils are a great help in this, the horizontal lines (and their floats) being boldly overdrawn in different colours corresponding to the main trains of resources, eg, concreting in yellow, earth movement in blue, pavement work in red, work by other agencies, such as sub-contractors, in pink, and so on until the colours are exhausted. The use of prints for this rough work saves the master copy from being unduly mangled, so that with luck it will survive in good enough shape to provide prints of the final programme without a fair copy having to

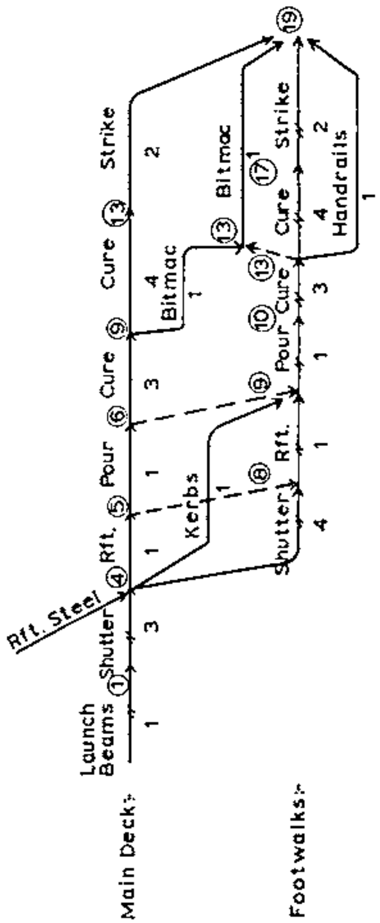
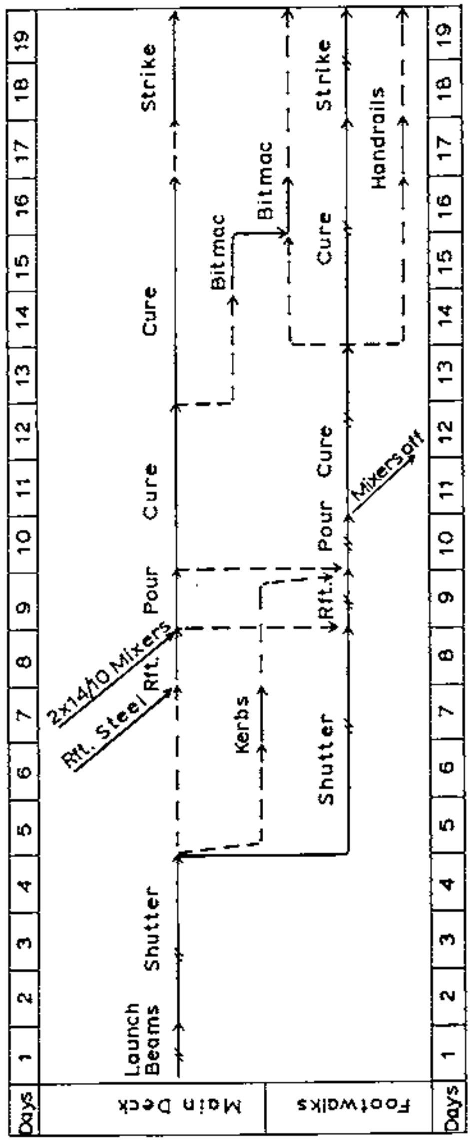

Main Deck
Footwalks
Launch Beams
Shutter
Rft. Steel
Rft.
Pour
Cure
Cure
Strike
Kerbs
Bitmac
Bitmac
Shutter
Rft.
Pour
Cure
Cure
Strike
Handrails

Fig. 1


Days
Main Deck
Footwalks
Launch Beams
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Rft.
Pour
Cure
Cure
Strike
Kerbs
Bitmac
Bitmac
Shutter
Rft.
Pour
Cure
Mixers off
Cure
Strike
Handrails

Fig. 2

be drawn. These final prints can also with advantage be coloured so as to make the presentation clearer. A useful little technique, which helps in subsequent analysis when changes are needed in the light of events, is to put the appropriate colour on the heads of arrows which represent only resource restraints, leaving in black those that form part of the basic logic and which should be immutable.

In any go-ahead concern the planner will always be working against the clock, and this particularly applies to the Services. Processes must, therefore, be made to overlap. In a large project it will normally happen that whilst the duration of some jobs can quickly be inserted on the arrow diagram, others will have to wait for more data to be found or for more complicated calculations to be made. In a motorway project, for example, timings for the earth movement can be quickly calculated by current rules of thumb for plant outputs (and see p. 79 of the same March *Journal*: "Excavation Earth—6,943 yds of Solid Digging which is imagined 500 men well employed would throw up in Ten Days"); but timings for the bridges and culverts will need a detailed analysis of their particular designs. The preparation of the outline programme to a time-scale should not be held up until the latter has been completed. A guess, based perhaps on the total amount of concrete and reinforcement steel involved, can be made—that one structure may take say 17 weeks, another say 23 weeks. Pending confirmation, these figures should be used to allow the outline programme to begin to take shape, so that the levelling of resources in other simpler parts of it can get under way. Beating the gun like this will more than compensate for the time spent later with eraser and pencil in expanding or contracting the programme when the duration of the structures has been more accurately assessed. The development of the time-scale diagram is thus a continuing process rather than a one-time operation. We are using the Critical Path Method as a servant in the gradual development of our plan.

A golden rule in the interests of speed and simplicity is that the diagram should not attempt to show more detail than is necessary for the level of planning for which it is intended. Let us assume that Johnson Bridge is part of a project for a new main road and is intended to carry an existing B road over the new road so as to eliminate an awkward cross-roads (it would then need to be a somewhat larger structure—but never mind). The embankments for Johnson Bridge are to be formed from near-by cut for the new road. The abutments are to be piled by a sub-contractor. The B road is to be kept open to traffic throughout, so a temporary diversion must be made while Johnson Bridge is built on the existing alignment. In this setting the detailed arrow diagram at Fig 1 will be needed (as rough work) at an early stage, in order to establish the factors which affect the overall plan—the time required, the plant involved and any major supply limitations. The time-scale diagram at Fig 2, however, will not be required for the overall plan but will be prepared much later by whoever is responsible for executing that particular part of the project. In the overall plan, of which an extract drawn to a time-scale of weeks is shown at Fig 3, the decking of Johnson Bridge takes a humble place as a 3-week job; it is not even on the Critical Path; but a 6-week delay in the supply of reinforcement steel has been treated as a factor worth recording in respect of the first structure to be built.

When choosing the unit for the time-scale one must bear in mind the space needed for writing the description of a job of only one unit's duration, for which ½-in will be found to be about the minimum. At this spacing, a sheet

EXTRACT OF AN IMAGINARY PROGRAMME FOR A NEW ROAD

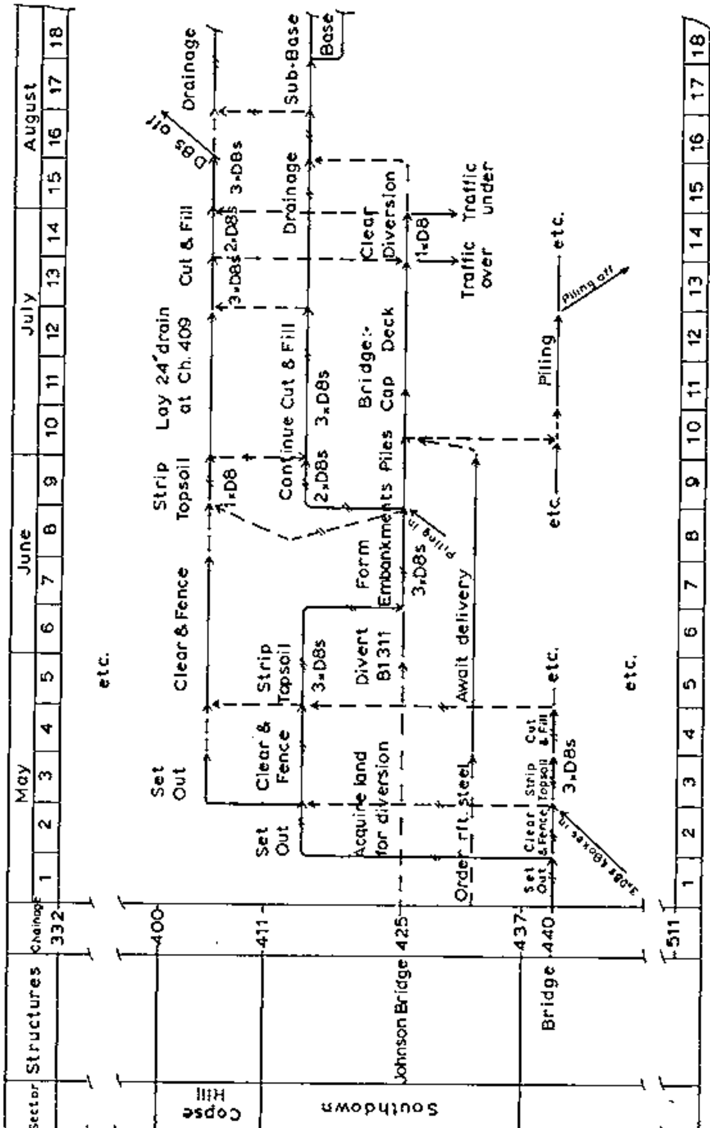

Fig. 3

of paper of drawing-board size will allow a project of something under two years' duration to be set-out to a time-scale of weekly units. For obvious practical reasons it is undersirable for the size of the diagram to be more than that of a drawing-board. The recommended technique is to choose a time-scale which can be fitted on to the board, restrict the detail to what can then be shown without confusion, and prepare subsidiary diagrams to a larger scale for such parts of the overall programme as need more detailed presentation. It is a fair technique, in the interests of simplicity, not to show overlapping processes when the scale will not readily permit this. For example, the piles for Johnson Bridge abutments will be driven first on one side, then on the other; while the latter are being driven the cap for the first set will be being placed; Fig 3 merely shows the part of the capping process which overlaps after the piling is finished.

In the confident belief that lines and arrows can convey thought better than words, other points about the techniques used in Fig 3 are left to the reader's perusal. Different colours for the different processes would make it more immediately understandable to the layman.

Recording Progress

Little need be said about this, because as Major Johnson points out the Critical Path time-scale programme can be used in exactly the same way as a Bar Chart to record daily or weekly percentage completion, a string hanging down vertically to show the current date. Its great advantage, however, is that the effects of unexpectedly fast or slow progress are immediately apparent to the viewer, so that he is encouraged to make early decisions regarding future adjustments. Consider, for example, the effect of a week's delay, because of a stubborn farmer or dilatory solicitor, in acquiring the land for the diversion road which is needed while Johnson Bridge is being built. It looks as if the Drainage from Week 13 onwards may be the job on the Critical Path where "crash action" can most economically be applied, but in the meanwhile, unless we are to pay for standing time, the piling sub-contractor must be told to turn up a week later than was planned. This might not have been nearly so apparent from a Bar Chart presentation.

In Conclusion

The Critical Path Method is only a means of ordering one's thoughts and presenting them to others. It is not a wonderful new gimmick which will enable the idle or the ignorant to solve an engineering problem. If the engineer has a sound knowledge of how the job should be done, what resources are needed and how long each part is likely to take, then any system will work but the Critical Path Method will work best. If his academic qualifications, ability to use the text books and practical experience do not quite match up to the problem, then the use of the Method will at any rate show himself and others, far more clearly than will a Bar Chart, how far he has managed to get, what mistakes he may have made and what gaps need to be filled in. The Corps will always hold many who are Jacks-of-all-Trades and who may expect to find themselves teased when faced with a specific technical problem. We cannot afford not to adopt the Critical Path Method as a standard drill in planning and organizing work. If foremen in the Civil Contracting Industry can understand it and use it, so can Sapper Corporals. The prevailing bogy that it is something esotevic and connected with computers must be dispelled. The encouraging theme behind our system of indoctrination should be simplicity.

The History of AG7

By Brigadier A. G. Peart, OBE, AMICE

Introduction

Most officers of the Corps of Royal Engineers must have heard of AG 7 and doubtless know that it is a Branch which has charge of their personal affairs and careers and which posts them round the world. Many may have visited the office of the AAG and have seen the imposing portrait gallery from which look down no less than 34 previous holders of the office stretching back to 1821. Some may realize and wonder that AG 7 is not a Branch of the Engineer Directorate at all but in fact comes under the Adjutant General, while only a few may be aware that the Other Rank policy of the Corps is also laid down by the same AG 7. A glance at page 1 of the *RE List* and at the "Yellow Book" will show that the AAG RE is an Ex-Officio member of the Corps Committee and of almost every other Committee dealing with Corps affairs.

What is the history of this Branch, and why is it placed where it is in the Army machine?

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The history of personnel administration of the Corps falls into three distinct periods:—

(*a*) Up to 1855–56, being the period up to the abolition of the Board of Ordnance, the move of the Royal Sappers and Miners Depot from Woolwich to Chatham and the amalgamation of Officers and Other Ranks into one Corps.

(*b*) 1855–56 to 1902–05, the period terminated by the Esher Committee Reforms and the establishment of a separate and distinct Record Office.

(*c*) 1902–05 to the present day.

This paper considers each period in turn and each is divided into three parts, officers, other ranks and comment.

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Period to 1855–56

From the time of William the Conqueror there has always been a King's Chief or Principal Engineer who has been called by many differing titles through the ages, but nevertheless the forerunner of the present E-in-C, who was charged with the giving of military engineer advice to the Monarch or Commander and with subsequent execution of engineer work. Clearly he had to have subordinate Engineers and equally clearly only he could choose or recruit them. The first time we find this responsibility defined is in a Warrant, dated 25 July 1683, which includes under "Instructions to our Principal Engineer" the following specific duties:—

"To endeavour to provide for our service good and able Engineers, Conductors and Work Bases, and not to recommend any to the employ of an Engineer but such as are sufficiently qualified to be so, which that it may be known, he is to examine what skill the person that sues to be employed both in the mathematicks, and particularly in Fortifications, what works he hath undertaken or managed, in what campaigns he hath served, at what sieges he hath been, the manner of trenches and of the offence and defence, and having gone through this or such like examination then to give his report thereof in writing to us or the Master General of our Ordnance."[1]

Work in connexion with Officers grew. In 1757 Military Ranks, carrying relative status throughout the Army, were granted to Engineers. Commissions were issued by the Sovereign on the advice of the Master General of the Ordnance who was himself advised by the Principal Engineer. Officers of the Scientific Corps were promoted by seniority and not by purchase. The RMA Woolwich, established in 1741, included in its charter:—

"An annual examination to be held and scholars classed under certificates from the Chief Engineer, the Commanding Officer of Artillery and the Chief Master of the School. . . ."[2]

To compete with these, and doubtless other requirements, it is obvious that there must have been a growing amount of staff work but there is no evidence of a Personnel Staff Section, as such, under the Inspector General of Fortifications. In evidence given by the IGF, General R. Morse, at the inquiry on the Board of Ordnance 1811,[3] the organization of the IGF's office was given as IGF, D/IGF, Major of Brigade and Adjutant, the latter being attached to the Corps of Royal Military Artificers, shortly afterwards to be renamed Royal Sappers and Miners. The words used by General Morse leave no doubt as to the authority of the IGF:—

"I have command of the Corps of Royal Engineers, of the Corps of Military Surveyors and Draughtsmen, and of the Corps of Royal Military Artificers; and all orders to these Corps, or to the individuals, pass through me. . . ." . . . "The Major of Brigade assists generally in all these duties but more particularly in the duties relating to the Military Corps before mentioned."

He also said:—

"The selection of Royal Engineer officers for appointments . . . is generally made by me."

An A/IGF was added in 1807 and the post of D/IGF lapsed in 1830 being replaced by a second A/IGF. Those officers dealt with technical matters. The post of Brigade Major was upgraded to AAG in 1846. At that time there was no "G" Staff as we understand it today. The Adjutant General was responsible for training and establishment matters as well as personnel questions. "AAG" was the normal title for a non-specialist staff officer of the rank of Lieut-Colonel or Colonel dealing with such subjects. The letters of Sir John Burgoyne from the Crimea, 1854, addressed to Colonel Matson, then the AAG RE at the office of the Board of Ordnance[4] contain scarcely a reference to personnel problems. He is treated rather as what we would now call a "Colonel E". While, doubtless, the IGF made most selections, it is inconceivable that he handled all officer administration entirely by himself, and it seems virtually certain that his AAG did that as part of his normal duties. No change is discernible in the administration of RE officers until the abolition of the Board of Ordnance on 6 June 1855.

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The first Company of Soldier Artificers was raised at Gibraltar in 1772 and a second company was raised there later. RE Officers were appointed to command these units by the IGF but Other Rank recruiting was by obtaining volunteers from units in the garrison. The numbers to be recruited were governed by the Board of Ordnance and the units were under the command of the Master General through the IGF.

On 10 October 1787 the "Corps of Royal Military Artificers" was formed, consisting of six companies of 100 men each. The growth of the Corps, combined with the tendency for men of poor character (although possessing requisite trade skill) to be recruited by the system of seeking local volunteers,[5] led in May 1795 to the establishment of a Corps Depot at Woolwich. An Adjutant RE was appointed to run this Depot and all recruits passed through it, receiving basic military training, and being posted and generally administered from there. Command was still vested in the Master General of the Ordnance, through the IGF, and the Adjutant belonged to the Staff of the IGF and had his official office in Westminster although obviously spending much time at Woolwich. The post of Adjutant was regraded Adjutant and Quartermaster in 1807, upgraded to Brigade Major in 1814 and further upgraded to AAG in December 1855, immediately prior to the move of the Depot to Chatham in January 1856. This post is not the same as that mentioned earlier as dealing with Officers. The two posts were held:—

Bde Major Staff Officer to the IGF Westminster	*Bde Major i/c Woolwich Depot with office at Westminster*
1802–06 John Rowley	1814–30 Rice Jones
1806–21 John Handfield	1830–31 Frank Stanway
1821–42 Charles Ellicombe	1831–41 Edward Matson
1842–46 Edward Matson	1841–48 Henry Sandham
then upgraded to AAG	1848–54 John Walpole
	1854–56 F. A. Yorke
	then upgraded to AAG

At the time of the upgrading of the Depot post to Brigade Major in 1814 a Quartermaster, and in 1835 an Assistant Adjutant, were added as subordinate officers.[6] In December 1855, when the Brigade Major was upgraded to AAG there were present an Adjutant and an Assistant Adjutant and a Quartermaster and in January 1856, on completion of the move to Chatham the Assistant Adjutant was upgraded to Adjutant (making two) and a second Quartermaster was authorized.[7]

On 4 August 1812 the Royal Military Artificers were restyled "Royal Military Artificers or Sappers and Miners" and on 6 March 1813 the title was shortened to "Royal Sappers and Miners". On 17 October 1856 the Queen was "graciously pleased to direct that the Corps of Royal Sappers and Miners shall hence forward be denominated the Corps of Royal Engineers". The rank and file, originally termed "artificers" and later "privates of the Royal Sappers and Miners", now became "Sappers". All these changes must have caused much administrative work.

From as early as 1783 documentary Records of Service were compiled in the Westminister office of the IGF from "Variation of Service" returns rendered monthly by the Officers Commanding Artificer Companies. These returns were later called "Casualty Returns" and are now known as "Part II Orders". Three "Records of Service" were maintained, one by the OC Artificer Company, one in the Westminster office and one was attached to the original Attestation Paper. It is believed that the Attestation Papers were held by the Paymaster in London and that routine checks were made periodically between his office and that of the IGF. Although the Paymaster may have been subordinate to the Principal Engineer or IGF prior to 1856 it is clear that from this date he was to all intents and purposes a civil servant subordinate only to the Finance Department.[8]

Comment on this period

Until its abolition on 6 June 1855 the Officers of the Royal Engineers and the Other Ranks of the Royal Military Artificers/Royal Sappers and Miners were under the command and administration of the Board of Ordnance. The Board was powerful, efficient and unpopular. It looked after its subordinates (who in many ways were privileged in relation to other personnel in the garrison and were not under the command of the local military Commander) remarkably well and it withstood every investigation of its methods. It was its unpopularity which eventually caused its abolition. The Board was advised on all Engineer matters, including engineer personnel questions, by the Principal Engineer, later Inspector General of Fortifications, who also issued executive orders, his advice having been accepted. There is no evidence of the existance of a personnel staff section dealing exclusively with officer administration. It is reasonably certain that officer matters were handled by the "G" Staff of the IGF as part of their duties. The Brigade Majors, later AAGs, at the IGF office in Westminster were Staff Officers. The Adjutants, later Adjutant and Quartermaster—Brigade Major—AAG, at the Depot Woolwich dealt exclusively with Other Rank questions and also had an office in Westminster as part of the staff of the IGF. It is possible that these officers could be regarded as the ancestors of the present Officer in charge of RE Records but they were almost certainly subordinate to the IGF through his principal "G" staff officer who had wider duties. The two earliest portraits in the office of the AAG RE are of Charles Ellicombe, Brigade Major (Westminster) to the Corps 1821–42 and Edward Matson, Brigade Major 1842–46 and AAG (in the upgraded Westminster post) 1846–55. The date 1821 has no evident significance; Captains Rowley (1802–06) and Handfield (1806–21) earlier held the Brigade Major post. Perhaps Ellicombe's was the earliest photograph available when the portrait gallery was started. Matson had been Brigade Major at the Woolwich Depot before coming to the similarly graded staff post in Westminster in 1842 and his knowledge of Other Rank administration must have stood him in good stead when the changes came in 1855–56. The office of the IGF was at 3 Abingdon Street, Westminster until 1810 when it moved to 84 Pall Mall.

Period 1855–56 to 1902–05

When the Board of Ordnance was abolished 6 June 1855 the administration of the Officers and men of the Royal Engineers (Royal Sappers and Miners to 1856) was made to conform to that pertaining to the rest of the Army, that is, the Cavalry and Infantry. From 1793 the Staff of the C-in-C comprised the Military Secretary, the Adjutant General and the Quartermaster General. The Office of Adjutant General was one of great antiquity. Before the appointment of a Commander-in-Chief in 1793 the Adjutant General had confined himself to the Army in Great Britain and the discipline of troops in the field, other matters being sent to the Secretary at War. But from 1795 his department assumed wider duties, including the collection of special and confidential reports on the conduct of each Regiment and each officer, issues of General Regulations ensuring one code of discipline and the collation of accurate returns so that information might be supplied to Parliament through him.[9] In 1807 the office of Inspector General of Recruiting was abolished and its work transferred to the Adjutant General. The Adjutant General was also in large measure responsible for staff duties connected with establishment and for military training.

In 1855 the Adjutant General became executively responsible for all these aspects of the Royal Engineers. The IGF, who had previously wielded these authorities in the name of the Master General of the Ordnance, became advisor only, but remained, in somewhat varying degree, responsible for technical efficiency. To enable the Adjutant General to exercise these new powers he was given an Engineer section on his own staff headed by a DAG RE. The office of the DAG RE was at Army Headquarters in the Horse Guards, close by that of the Adjutant General; that of the IGF was in Pall Mall.

In 1862 a Circular Memorandum decreed:—

"The Inspector General of Fortifications was to be in future designated the Inspector General of Engineers and Director of Works. He was to be considered as a General Officer on the Staff of the Army, holding the position of a Divisional General as regarded his own Special Corps, whilst at the same time he was to be departmental officer and the head of the barrack fortification and other works branches. He was to be in direct communication with the Commander-in-Chief as Inspector General of Engineers and with the Secretary of State as Director of Works."[10]

This position of authority did not continue as far as personnel matters were concerned. In discussing the retirement of Colonel Harness in 1865 from the post of Commandant the "RE Establishment Chatham", the forerunner of the RSME, General Collison says:—[11]

". . . it must be borne in mind that the great reform of the War Department had just been completed, under which control of the Chatham School passed from the IGF to the C-in-C. The Duke of Cambridge, who was then C-in-C, considered that in dealing with that establishment his proper advisor was the DAG of Engineers as in the case of all matters connected with the military service of that Corps. Harness, on the other hand, felt that he could not satisfactorily carry on the duties of head of so important a school . . . unless he had direct personal communication with the C-in-C, and a voice in the appointment of instructing officers, as had hitherto been the case under the IGF. . . ."

A committee appointed in 1891 by the Adjutant General and consisting of General Sir L. Nicholson (IGF), Major-General R. Grant (DAG RE), and Major-General R. N. Dawson Scott (Comdt SME)—could it be more authoratitive?—recorded the relative responsibilities as follows:—[12]

"The Inspector General of Fortifications is charged with the construction and maintenance of fortifications, barracks, and store buildings; with the custody of War Office lands and unoccupied buildings; with the design, inspection, custody, and issue of Royal Engineer and submarine mining stores; and, in concert with the Quartermaster General, with preparing the annual estimates for the above services. As Inspector General of Royal Engineers he will advise as to the general distribution of the Corps; as to the appointment of Officers to or their removal from responsible positions in connection with Works. He will inspect the Corps of Royal Engineers and advise on all questions relating to its technical instruction. . . .

"The DAG RE is directly responsible to the AG for the efficiency of the RE officers and men, for their distribution and mobilizations, for their equipment and technical instruction, and for the efficiency of the School of Military Engineering. On the question of instruction he is responsible that the various courses are carried out in accordance with the approved schemes. Further, that any alterations in the course of instruction proposed by the DAG, or in any other quarter, are submitted to the IGF and approved by him before submission to the AG. As regards distribution, that this is carried out in accordance with the scheme approved by the IGF, and that no officers employed in responsible positions on the works are moved without the concurrence of the IGF. He is responsible to the Military Secretary for all questions relating to the appointment, promotion, and retirement of Officers RE, for submitting selections for appointments, and for custody of confidential reports, and further that in all cases where necessary, the approval and concurrence of the IGF has been obtained before submissions are made to HRH. He keeps the roster for foreign service and is responsible that no exemptions are made unless authorized by the Commander-in-Chief, to whom for this, questions of appointments, and other regimental matters he has personal access. He is also responsible that in all engineer questions not specified under any of the above headings the opinion of the IGF is obtained where necessary."

Shortly afterwards (in 1896) the title of "Inspector General of Fortifications and Royal Engineers" reverted again officially to "Inspector General of Fortifications". It is interesting to compare the wording of these responsibilities with the clear authority of the earlier period quoted previously in this paper.[1,3] There is no doubt that a diminution of power and division of responsibility had occurred. Equally it is clear that the DAG RE held a position of very considerable influence. His staff at the time was an AAG, a Staff Captain and a Lieutenant attached from the Coast Battalion.

From 1856 to 1885 the DAGs RE were senior Colonels. Colonel J. Stokes was promoted Temporary Major-General in March 1885, remaining in post. He was succeeded in 1886 by Colonel R. Grant who became T/Major-General in December 1889 and remained in post. In May 1891 Grant was succeeded by J. M. H. Maitland who was made T/Major-General on appointment and was himself succeeded by Major-General Salmond who was DAG RE until July 1902. In line with the Esher Committee reforms the post was then downgraded to AAG RE and has been held by a Colonel ever since. Apart from the short period March to July 1886, whenever the DAG RE was a Major-General, the IGF was a Lieut-General or General. In 1870 the Indian Establishment was incorporated into the Corps without increase in the staff of the DAG RE. The numbering of AG branches dates from 1888. That of DAG RE was called AG 6 from 1888 to 1905 when, on renumbering, it became AG 7 and has remained so to the present time.

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The DAG RE was in all respects responsible for administration of Other Ranks of the RE throughout this period.

From as early as 1812, when the SME was formed at Chatham, numbers of NCOs and some Sappers had gone there for engineer training but it was not expedient to move the Depot until the railway had been extended and Chatham was more accessible. In January 1856 the Depot moved there. About 1864 a battalion organization was adopted for command at Chatham covering also the Other Ranks of the SME staff but the actual administration of personnel remained with the DAG RE office in the Horse Guards. The Corps Paymaster opened an office at Brompton in 1857 and attestation papers were kept there. The Paymaster with one of his clerks journeyed quarterly to the Horse Guards taking the whole of the attestations with him for cross check with the records in the DAG RE office.

In about 1878 copies of the original attestations, obtained from the Paymaster for the purpose, were made in the office of the DAG RE and to the copy was attached a Military History Sheet prepared from the Records of Service. The duplicate was then issued to OC Units to be substituted for the Records of Service in their custody. By 1880 it was clear that the system caused a great deal of unnecessary clerical effort and a proposal was made that a Record Office be established in London but there were difficulties over accommodation. Provision was eventually made in Army Estimates for 1883–84 with a QM as superintending officer and suitable clerical staff but the proposal failed. At length in 1884 Lieutenant (QM) Hills was appointed Assistant Superintendant RE Records, the Superintendant being the DAG RE. Hills was sent to Chatham and placed under the Paymaster with a view to taking over the original attestations and making preliminary arrangements for the formation of a Record Office.

For two years the Record Office was over the Guard Room in Brompton Barracks and was moved in 1886 to 3 Garden Street, Brompton. It was always a part of the War Office and to make this clear in 1884 a ruling was given that the Record Office, although temporarily located at Chatham, was part of the DAG RE office at Horse Guards. Lieutenant (QM) Hills was empowered officially to deal direct with the DAG RE.

Although due for retirement in 1900 Captain (QM) Hills was retained supernumerary because of the South African War but was succeeded by Lieutenant (QM) Waldron who remained in charge after Hills' eventual retirement in 1901. On 6 January 1905 a Special Army Order was issued for the reorganization of Commands and Staff in the United Kingdom. This Order—now included in Queen's Regulations—provided for the appointment of Officers of the rank of Colonel to take charge of the Records of the various arms of the service, and this is the start of the independent Record Office now in existance.

Comments on the Period 1855–56 to 1902–05

The growth of responsibility of the DAG RE through this period followed generally the growth and improving organization and methods of the Army in the sphere of the Adjutant General and is indicated by the rank and seniority of the officers appointed to the post. It is intriguing to find that at the head of the *RE List*, issued with the first *RE Journal* dated 1 August 1870, the DAG RE and his AAG RE are placed above the IGF and DIGF. The entry was rectified in time for the second issue, 1 October 1870, when the order reads IGF, DAG RE, AAG RE, DIGF! The position of IGF as head of the Corps was, of course, acknowledged by all but it is hard to escape the conclusion that real power in military (as distinct from technical) matters had passed to the DAG RE.

Most Corps activities were initiated, or put on a firm footing, in this period. The Library Committee, started much earlier, possibly in 1813, was merged with the Committee for the Professional Papers in 1873 and the two came under the control of the Committee of the Institution of RE in 1876. The Museum was started in 1875, the Widows Fund Committee enlarged in 1879, the Charitable Fund started in 1866 and the Games Fund set up in what is roughly its present form in 1885. It is logical that the DAG RE, who was one of the most senior and most influential RE officers serving centrally in London, should be appointed, *ex officio*, to those Committees and this tradition has continued.

As far as Other Ranks were concerned, actual command of the Depot was exercised at Chatham by the Commandant SME but all policy and all administration remained with DAG RE in the Horse Guards. Continuous efforts were made to improve the efficiency of the administrative system and these culminated in the establishment of the separate Record Office under a Colonel in 1905.

Period 1902–05 to the Present Day

Reforms resulting from the recommendations of the Esher Committee were widespread and took some years to put into effect. In the context of this paper they comprised the abolition of the post of Commander-in-Chief and its replacement by an Army Council of four military members. Each Army Councillor was served by a number of Directors responsible for various fairly closely defined subjects. All Directors were reduced in rank to Colonel and all officers then serving in these posts, and who were senior to that rank, were required to resign. A considerable diminution of power and complication in advisory responsibility resulted for the new DFW (Colonel), Inspector RE (Colonel) and for the AAG RE (Colonel), although much of the latter's Other Rank responsibilities were transferred to the new OIC RE Records (Colonel) in 1905.

A timely appeal for continued unity was made in the farewell address of the last IGF, Major-General Shone, to his staff on 16 February 1904:—[13]

"We realize the drastic nature of the reforms now in progress when we recall the names of the distinguished men who have held that appointment, and reflect that there will no longer be at the head of the Corps a Royal Engineer officer holding the high position of the IGF to advise on the many important questions connected with Military Engineering as well as those concerning the Corps and its technical work and training. . . . In the future it seemed that the various branches of Military Engineering would be administered by several separate heads instead of as here-to-fore by a single Chief. Officers should, therefore, regard themselves as even more bound to maintain union in the future than in the past. . . ."

The forecast lack of authoritative control shows up in the large number of Committees later convened to examine Corps matters. At least three major examinations[14] of Corps Organization and training took place between 1904 and 1911 and there were many minor ones—pay, motor cyclists, postal, etc. These must have caused immense work for the AAG RE and his Staff of two officers in December 1904, one in April 1906 and two in August 1911.

Another, perhaps more obviously needed, investigation was made in 1919 under General Sir Henry Rawlinson after the end of World War I.

In 1904 Engineer work in the War Office was divided between three Officers, Inspector RE, DFW and AAG RE, of whom the AAG RE was responsible for advising the newly established General Staff on all questions of organization and training of RE Units. On the personnel side the AAG RE was responsible to the Adjutant General through the Director of Personal Services and the Director of Recruiting and to the Corps in the person of the Inspector RE. All those mentioned (except the Adjutant General) were Colonels. Very soon they all crept upward in rank except the AAG RE who has been a Colonel ever since. From 1904 until 1940 when the post of Inspector RE disappeared, the acknowledged head of the Corps—the DFW —does not appear to have had responsibility for personnel.[15] The individual selection and promotion of Staff Officers was carried out by Members of Council in respect of their spheres of interest and by a Board, under the presidency of the Inspector General of the Forces with the Military Secretary as secretary, for other officers.

The Division of duties and responsibilities for the selection of officers between the Selection Board and Army Council was:—[16]

"(*a*) The Selection Board will submit to the Secretary of State the names of Officers whom they consider for divisional, district and brigade commands, Royal Artillery and Royal Engineer commands, commands of grouped regimental districts, commands of regiments and battalions, or other analogous appointments, and all promotions to ranks up to and including that of Major General.

(*b*) Selections for the higher commands of the Army, such as Commanders-in-Chief . . . and promotions to the rank of Lieutenant General, will be made by the Secretary of State from a list of those Officers whose professional qualifications render them in the opinion of the Section Board, eligible for such appointments or promotions.

(*c*) Recommendations to the Secretary of State for the appointment of Officers to staff and departmental posts will be made by the Member of Council concerned. (Then follows a list of Members of Council and the appointments in their sphere of interest.)

(*d*) Should any appointment made under (*c*) involve the promotion of an officer to higher rank, the fitness for promotion of the officer recommended will, in the first instance, be submitted to the Selection Board."

All Confidential Reports, which had previously been held by the DAG/AAG RE under his charter,[12] were transferred to the Military Secretary.[17]

The Inspector RE was present at the Selection Board when RE officers were being considered.

During both World Wars, selection and promotion of Officers, except the most senior, was necessarily delegated to Commanders in the Field and to Directors in the War Office but when the wars were over Selection Board procedure was again introduced. Since the end of World War II selection of Staff Officers by Members of Council has been discontinued. MS are responsible for all Lieut-Colonels and above and for Staff Officers Grade 2 and AG 7 for all others. The AAG RE is present when promotions to Lieut-Colonel are being considered,[18] and has thus taken back the function performed in this respect by the Inspector RE from 1904.

The post of Inspector of RE has been instituted three times and each time has lapsed after a short period. It was held as an additional title by the IGF from 1862 to 1896, as an independent appointment by a Colonel or Brig-General from 1904 to 1919, and as an additional responsibility by the Commandant SME from 1932 to 1940 (contributing to the rank of Major-General for this post). The idea behind the post of Inspector is that there should be a senior officer who, of his own knowledge and independently of command or administrative responsibility, can advise on the state of efficiency of the Corps and any measures needed for improvement. The post is superfluous when the E-in-C is in effective control, as was the case up to 1855 and is so again now, and it was not essential when the responsibility for efficiency was squarely placed on the DAG RE. But in the period from 1904 to 1940, at times when there was no Inspector, the difficulty of getting proper advice must have increased considerably the work of the AAG RE.

It is interesting to compare the strength of AG 7 against the Corps build up in the two World Wars:—

WORLD WAR I[19]					WORLD WAR II[20]				
Date	Strength of the Corps		Staff of AG 7		Date	Strength of the Corps		Staff of AG 7	
	Offrs	OR	Offrs	OR		Offrs	OR	Offrs	OR
Aug 1914	1,569	23,521	1	9	Sep 1939	2,879	54,362	3	16
Aug 1915	4,311	121,856	3	18	June 1940	5,715	123,997	12	40
Aug 1916	6,823	202,361	3	31	Jan 1941	9,471	167,796	17	60
Aug 1917	8,886	286,782	3	31	Jan 1943	15,101	196,897	25	113
Aug 1918	11,830	225,540 plus about 80,000 Tn	3	37	Jan 1944	18,714	226,553	25	117
					Jan 1945	21,036	243,174	20	121
					and later:				
					Jan 1947			17	77
					Jan 1950			10	21
					Jan 1961			7	21

"The fact that only three officers carried on the work for the first three years of the (First World) War no doubt accounts for Colonel Curtis being invalided in 1917 and Lieut-Colonel Brown dying in 1919. It must be remembered that AG 7 was also dealing with the great expansion and organization of the Signal Service."[21]

The similarity in build up of Corps strength is remarkable. The corresponding Staff strength of AG 7 in World War II shows that a lesson had been learnt. It is obvious from the figures of build up what a tremendous task was achieved in the Second World War too.

Although the Royal Corps of Signals was formed as a separate entity in 1920 its personnel administration remained with AG 7 until the formation of AG 11 in September 1939. The office of the AAG RE was at the Horse Guards until 1906 when it moved to the newly constructed War Office building across the road in Whitehall. After the declaration of war in 1939 it moved to Hobart House, SW1; in the spring of 1940 to Cheltenham, back to Hobart House in 1942, to Lansdowne House, W1, in 1945, and out to Stanmore, Middlesex, in 1946, where it has remained to the present day.

Turning now to Other Ranks, the principal Depot at the beginning of 1905 was at Chatham and was under the command of the Commandant SME. There was a second Depot, which trained drivers for mounted units and the specially enlisted men of the Bridging units, at Aldershot under the CRE of the Aldershot Command. Both depots were controlled by the AAG RE as regards recruiting and drafting.

When it was decided to appoint a Colonel as OIC RE Records he was also appointed to command the Chatham Depot. This was in line with the Infantry and Cavalry arrangement. Experienced clerical staff were transferred from the AAG RE office to Chatham with all Records. The situation in which command at Chatham was vested in two Colonels one of whom (Comdt SME) was responsible for training the other's personnel did not work smoothly! Towards the end of 1906 after a personal visit by two Members of the Army Council to Chatham it was decided to restore command to the Commandant SME who was upgraded to Brig-General. The administrative portion of the Records Office was moved to Gravesend. Within a few years the two portions were joined again at Chatham but the OIC Records was regarded as working directly under the War Office and excluded from the chain of command. The Depot command has remained with the Commandant RSME to the present day except during the period 1940–58. The Record Office moved from Chatham to Brighton in 1939.

Comment on this period

From the start of the period in 1902 until the outbreak of war in 1939, the AAG RE continued to cover the majority of functions previously carried out by the DAG RE. AG 7 was the Staff Branch of the Corps through which were channeled and co-ordinated all advices from the many parts of the Corps concerning individual officers, unit establishments, recruiting and drafting. The AAG was the Corps spokesman on all these questions at Committees and to the Staff Directors but he did not exercise the power of decision of his predecessors in the previous period. He was the Staff servant of the Corps rather than its master. Today the task of AG 7 is confined to formulation and promulgation of policy for RE Officers and Other Ranks, administration of RE officers in all its forms, and the various Corps functions arising from traditional membership of nearly every Committee. The Record Office is a unit whose OC is a Colonel in command. It is a functional machine designed to carry out orders and is not organized to frame the policy governing the orders. AG 7 is a Staff Branch of the War Office designed to evolve policy and empowered to promulgate it in the name of the Adjutant General. It is an essential complement to RE Records for Other Rank administration.

Corps History lists in Volumes II to IV the names of DAG RE and AAG RE to 1913. The appendix with this paper brings these lists up to date and adds the names of the Officers in charge of RE Records from 1905.

Conclusion

This paper has covered the history of personnel administration of the Royal Engineers from early times to the present day. More particularly it has shown how AG 7 originated as a Branch under the Adjutant General in 1855 and has remained so ever since and it has indicated how the AAG RE has inherited his position in Corps matters from his illustrious predecessors of Victorian times.

AG 7, as it now exists, is responsible for expression, in the name of the Adjutant General, of all Corps policy in respect of Officers and Other Ranks and conversely for ensuring that Army personnel policy can accommodate Corps needs. AG 7 must speak with the authority of the Adjutant General because this is binding on Commanders-in-Chief; instructions issued from a Branch of the Engineer Directorate can be addressed only to Chief Engineers. AG 7 is also responsible for detailed administration of individual officers RE and especially for ensuring that their own best interests and the Corps needs are compatible. RE Records performs this latter task for Other Ranks. All other functions exercised by AG 7 at various times in the past have now been transferred to others, but mostly to the E-in-C.

The history has fallen naturally into three well defined periods. It seems a safe prediction that a fourth period is now starting. The present decade is one of considerable change and intensive Committee investigation. Works Services have been largely removed from the Corps, conscription is over and the Nye and McLeod Committees have recommended major changes—at the moment of writing, *sub judice*.

If it be accepted that the first period of this history commended effectively about 1795 when Officers and Other Ranks were first administered centrally, each period has been some sixty years long. There is obviously no justification for assuming that the new fourth period will last sixty years but we should certainly start it with a knowledge of past dangers and all pull together for the good of the Corps. It seems fairly clear from this history of AG 7 that the Corps has been healthy when the E-in-C has been in central control and therefore powerful but weak at other times. This is the main lesson from the past.

ACKNOWLEDGEMENT

The author is indebted to Lieut-Colonel E. E. N. Sandeman, OBE, Librarian, RE Corps Library, Chatham, for help with the early period, in which nearly all evidence is conflicting, and to Colonel A. W. Stokes, DSO, MC, for his generous readiness to discuss his own experiences as AAG RE between the wars, a period in which there is little recorded material.

APPENDIX

NAMES OF AAG RE SINCE 1913

(earlier periods covered in *Corps History*, Vols II to IV)

1913–17	Colonel R. S. Curtis
1917–19	Colonel T. A. H. Bigge
1919–23	Colonel R. H. H. Boys
1923–27	Colonel P. E. Hodgson
1927–30	Colonel G. H. Addison
1930–32	Colonel E. E. B. Mackintosh
1932–36	Colonel A. W. Stokes
1936–39	Colonel H. B. W. Hughes
1939–40	Colonel B. K. Young
1940–40	Colonel M. Luby
1940–42	Colonel B. C. T. Freeland
1942–45	Colonel W. D. Robertson
1945–47	Colonel A. Crichton-Mitchell
1947–50	Colonel L. O. Clark

1950–53	Colonel I. G. Loch
1953–56	Colonel G. C. Clark
1956–59	Colonel B. S. Armitage
1959–60	Colonel A. P. Lavies
1960–64	Colonel A. G. Peart
1964–	Colonel R. L. Clutterbuck

NAMES OF OFFICERS IC RE RECORDS SINCE 1905

1905–09	Colonel G. H. Sim
1909–11	Colonel E. Agar
1911–12	Colonel H. Huleatt
1912–17	Colonel B. R. Ward
1917–18	Colonel E. A. Tudor
1918–22	Colonel H. B. Jones
1922–26	Colonel A. M. Henniker
1926–30	Colonel A. J. Savage
1930–34	Colonel N. D. Noble
1934–38	Colonel H. F. Moore
1938–41	Colonel E. Bradney
1941–43	Colonel J. K. Tickell
1943–43	Colonel H. A. Bleach
1943–47	Colonel W. H. Blagden
1947–49	Colonel R. A. V. G. E. S. Monteith
1949–53	Colonel R. M. A. Welchman
1953–56	Colonel J. E. Marsh
1956–59	Colonel T. Wright
1959–62	Colonel T. Burrowes
1962–	Colonel R. O. H. Carver

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[1] *Corps History*, Vol. I, p. 50.

[2] Clode: *Military Forces of the Crown*, Vol II, p. 458.

[3] Fifteenth Report of Commissioners 1811. Approximately pp. 344, 345.

[4] *Life and Letters of Sir J. Burgoyne*, Vol II, p. 10 footnote.

[5] Connolly 1855, Vol I, p. 92.

[6] Connolly 1855, Vol I, p. 201 and Vol II, p. 294.

[7] Extracted from evidence given by Colonel H. Sandham, RE, before "The Commissioners appointed to consider the best mode of reorganizing the system for training officers of the Scientific Corps". Report HMSO 1857, p. 378.

[8] Clode: *Military Forces of the Crown*, Vol II, p. 302.

[9] Clode: *Military Forces of the Crown*, Vol II, p. 341.

[10] *Corps History*, Vol II, p. 95.

[11] Collinson: *General Sir Henry Harness*, p. 244.

[12] Report of a Committee on Organization of the Royal Engineers 1891, p. 5.

[13] *RE Journal*, 1 March 1904.

[14] Under Major-General Franklin, December 1904—Duties and strength of Officers of the Corps.

Under Field Marshal Sir Evelyn Wood—Organization of the Corps, April 1906.

Under Field Marshal Viscount Kitchener, August 1911—Organization and training of the Corps.

[15] Except that DFW was in every respect responsible for personnel of the Establishment for Engineer Services until the end of World War II when it passed to AG 7(W) and in June 1946 to RE Records. There is also some evidence that he was consulted about Works appointments for Officers which would seem logical and correct during that period.

[16] Statement included in most War Office Lists; quote is from that of 1912.

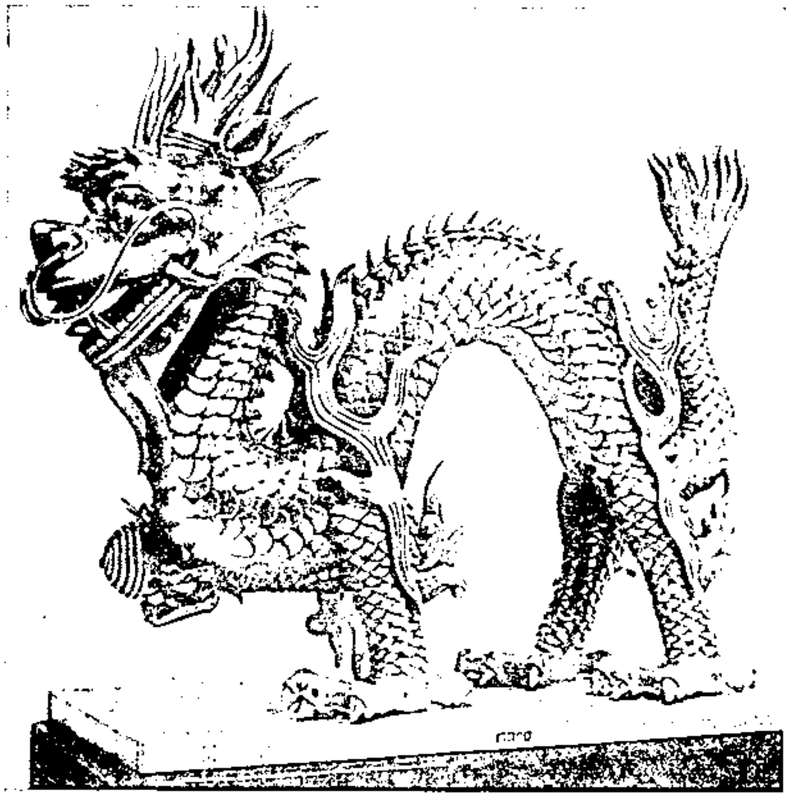
[17] Report of Committee on Organization of Corps of RE 1906, p. 30.

[18] See note to No 3 Board, Army List 1961, p. 7.

[19] Figures from *Corps History*, Vol V, p. 30.

[20] Figures from AG 7 *War Diary*.

[21] *Corps History*, Vol V, p. 31.



April 1964 Corps Guest Night

THE Corps Guest Night, held in the Headquarters Mess, Chatham on 16 April last was a unique and historic occasion.

The Chief Royal Engineer, General Sir Frank Simpson, GBE, KCB, DL and three serving Colonels Commandant Royal Engineers, General Sir Charles Jones, KCB, CBE, MC, Major-General A. J. H. Dove, CB, CBE, this year's Representative Colonel Commandant, and Major-General T. H. F. Foulkes, CB, CBE, were present. The Engineer-in-Chief, Major-General G. W. Duke, CB, CBE, DSO, also attended. The official guests consisted of Rear-Admiral I. L. T. Hogg, Flag Officer, Medway and his Flag Lieutenant, Lieutenant Lord Rathdonnell, RN, Captain V. Lamb, ADC, RN, The Dean of the Royal Naval College, Greenwich; Lieut-General Sir Geoffrey Baker, KCB, CMG, CBE, MC, Vice-Chief of the General Staff, Major-General L. H. Atkinson, OBE, Director, Royal Electrical and Mechanical Engineers and Major-General R. G. S. Hobbs, Lieut-Governor of the Royal Hospital, Chelsea; Sir Cecil Mant and Mr E. H. A. Stretton of the Ministry of Public Buildings and Works; Dr G. F. Gainsborough, Secretary of the Institution of Electrical Engineers; Sir William Carron, KSG, MA, FRSA, President of the Amalgamated Engineering Union, Mr George Woodcock, CBE, General Secretary of the Trades Union Congress, Mr J. Cooper, JP, General Secretary of the National Union of General and Municipal Workers and Mr E. J. Hill, General Secretary of the United Society of Boilermakers, Blacksmiths, Shipbuilding and Structural Workers.

The distinguished Trade Unionist guests had made a comprehensive conducted tour of the Royal School of Military Engineering during the afternoon.

The real uniqueness of the occasion, however, was the presence of a large number of "Sapper Fathers and Sons" dining in Mess that night. The idea of such a novel family reunion stemmed from the Commandant, Royal School of Military Engineering, Brigadier J. G. Carr, ADC. The senior "Pater-Filiusque" combination was Major-General C. H. Foulkes, CB, CMG, DSO, Colonel Commandant, Royal Engineers (retired) and his son Major-General T. H. F. Foulkes, CB, OBE, Colonel Commandant, Royal Engineers. To mark the occasion the Chief Royal Engineer ceded the honoured place of President at Dinner to Major-General C. H. Foulkes, and Major-General Tom Foulkes (Junior as the Americans would say) acted as "Mister Vice", a position seldom filled by a Colonel Commandant, but it was a very special occasion.

The other fathers and sons present were:—

Lieut.-General Sir Clarence Bird, KCIE, CB, DSO and his son Major P. C. Bird; Major-General Sir Horace Roome, KCIE, CB, CBE, MC, and his son Lieut-Colonel O. McC. Roome; Major-General Sir Eustace Tickell, KBE, CB, MC, and his son Lieut-Colonel M. E. Tickell, MBE, MC; Major-General W. Cave-Browne, CBE, DSO, MC, and his son Colonel J. R. Cave-Browne, MC; Major-General H. Bainbridge, CB, CBE and his son Captain J. R. Bainbridge, Major-General I. H. F. Boyd, CB, CBE and his son 2nd Lieutenant M. L. Boyd; Brigadier E. A. E. Bolton and his son Captain M. W. Bolton; Brigadier J. C. Carr, ADC and his son Lieutenant R. J. Carr; Brigadier G. L. Galloway, DSO, OBE, GM and his son 2nd Lieutenant C. C. Galloway; Brigadier J. H. S. Lacey, CBE and his son 2nd Lieutenant J. N. H. Lacey;

Brigadier F. C. Nottingham, DSO, OBE and his son Major M. P. C. Nottingham; Brigadier W. G. Nutt, CBE, MC and his son Major R. C. R. Nutt; Brigadier C. J. V. Shepherd, CBE, DSO and his two sons Colonel G. W. Shepherd and Major A. B. Shepherd; Brigadier G. O. M. Thompson, DSO, OBE and his son Captain N. H. Thompson; Colonel P. S. Baines, MBE and his son 2nd Lieutenant A. F. S. Baines; Colonel A. F. Chater and his son Captain J. K. Chater; Colonel H. L. Chesshyre and his son 2nd Lieutenant W. J. Chesshyre; Colonel E. M. E. Coghlan, MBE and his son Lieutenant R. E. M. Coghlan; Colonel H. B. Harrison and his son Lieutenant C. B. Harrison; Colonel O. Sturt and his son Major N. R. Sturt; Colonel R. T. Weld and his son Lieutenant S. C. E. Weld; Lieut-Colonel W. H. S. Travers and his son 2nd Lieutenant M. C. Travers.

It was indeed a formidable array of Sapper families but those dining in the Mess that night represented but a fraction of the total number of Royal Engineer fathers and sons eligible to attend. Many fathers were unable to come due to a variety of reasons and many sons were prevented by the stern exigencies of the service.

The evening closed with the customary singing in the Conservatory, the Engineer-in-Chief himself providing the piano accompaniment to a vociferous junior officer choir. Songs appropriate to a Trades' Union Congress were included in the programme of music for the benefit of our guests, who eagerly joined in the singing. These traditional airs were sung just as heartily as the more common after-Guest-Night ditties and with the same wild abandon, although no one was word perfect—not even our guests!

Well Done—Thank You!

By MAJOR J. H. DE WALLER, DSO, OBE, MSc, MICE

As 1964 draws to a close it will be half a century since I joined the Corps. Golly! It makes you think; and I often do think of that little spell, 4 years and 4 months, when I was a Sapper. I wasn't a real Sapper, you know, only a temporary gent, but that short period stands out in my memory with unexplainable clarity that characterizes no other time. Now and again, I meet an old Sapper and have a yarn and, of course, I get the *Journal*, so I keep more or less in touch.

I was particularly interested in an article in the December issue—"The Unconventional Sapper" by Lieut-Colonel Wilson and was specially attracted by the title because the Sappers job covers such a wide field that if it is to be really efficient he must divest himself of much of the convention that has grown up round military life. Having said that, I feel a bit nervous, butting in like this, and I don't expect everyone will agree with me—but here goes—for what it is worth. When a Sapper goes abroad, sooner or later he is almost certain to have to carry out works with local labour that is relatively unskilled—many of the men may never have been on a job or even have worked in a gang before. As for materials little need be said for our friend will jolly well have to make do with what he is given, and that is that. Conventional practises won't take him very far and success will depend on initiative. This is particularly true with labour and, most times labour counts for well over half the final cost.

When I was seventeen, and had just scraped through matric, my Father (capital F please) asked me what I wanted to do. I said I'd like to be a mining engineer. He agreed at once but stipulated that I should become a miner before going to college. I would then be able to be sure I was on the right track. This was OK by me and in order to get "below" I started work as a navvy on a railway then being built to a new mine. It was not easy to become a miner. From navvying I became a carpenter's so-and-so (six letter word), and as surface construction was completed, I slipped underground as a trucker: after pushing that damned truck for six months I got a chance to get "into the face" and became a full-blown miner. Oh boys! Was I not pleased? Well, this all happened on the rain-sodden west coast of Tasmania. The climate was tough; the work was tough and the men were tough. There were about 150 of us all told and conditions were so tough that there were only two women on the field. (No. I'm not going to say they were tough.) I had a succession of four bosses—the navvy ganger, the carpenter foreman (an ex-ship's carpenter) and two miner bosses who were under the underground manager, himself an old miner. During the long years that have passed since I worked on "the Coast" I have frequently been responsible for the men on the job—railways and harbours principally, and it was by no means exceptional for me to cast back and try to think what those old bosses would do as my problems arose. They were all four of them real tough characters but to a man we respected them and did our best. And, this I think is the point, they were good to us in that they never failed to show appreciation for work well done. When I think of the class of man they had under their charge I simply marvel at their success. In my three years there, not an hour of strike and hardly ever was a man sacked—and I'm telling you really hard work was the order of the day.

Years later an old man told me that the four most important words in the language were "well done" and "thank you!" I don't know, but he was right.

Now comes something I don't like putting in words, but needs must.

Too often I have watched, in backward areas, army men—not always Sappers—handling local gangs of "natives" and too often, far too often, were they failing to get good results. They roared and scolded and cussed the men and the men didn't really understand and didn't try to understand—their backs were up and the moment the man in charge moved on they slacked off to a man. When the boss was strafing they never so much as glanced at him—they just pretended to be impressed. On other occasions I have seen the same type of men looking with admiration at their boss and going all out to please him. And when they pleased him, he showed appreciation. In particular I have seen this in Egypt where I found that once you had got on the right terms with the men they worked like blazes—and yet I heard officers in the Mess describing them as completely useless. The trouble was that the NCOs in charge were speaking the language of the gravel-crushing barrack square. It simply won't do.

Can it be possible that in the training of both officers and other ranks special attention should be paid to the handling of civilian labour, and in particular the so-called "native" labour? I have nothing to say about the methods that are employed in shaping the soldier. He must be taught discipline and the results of this training are there for all to see—the finest discipline in all ranks to be found anywhere. But the getting of men to do what you want on a civvy construction job is a different thing and I would suggest that in the case of the Sapper, this should be treated as a subject quite apart from normal military instruction. Just how this could best be done is a matter that wants thinking out. Shouting and strafing are not enough and they won't produce the required results. When my thoughts go back to my old mining days and those charge hands who produced such fine results with such crude material I can't help remembering a command we were given in the riding school at Chatham before we broke off. It was "*Make much of Your Horses!*" I understand you chaps nowadays have very few horses to make much of. I'm sorry about that but the motive that gave rise to that order may well have implications on the job, in some distant land and I think that in this connexion the four words which I have put at the head of these paragraphs are well worth keeping in mind.

I'll Give You a Riding Mule

By Major W. L. Sheldon, RE

'Mules,' he said, 'it's no good, you'll have to go back to mules.'

It was 1943 and as a subaltern with a troop of Indian Sappers and several hundred Nagas I was building a road eastwards from Imphal towards the river Chindwin and the Japanese. The steep-sided Naga Hills between Assam and Burma are clad with some of the thickest jungle in the world. Four hundred inches of rain a year make the area one of the world's wettest, and although the month was January, and theoretically the "dry" season, some of those 400-ins were at work dissolving my road before our eyes. I call it a road, though in truth it was little more than a jeep track, a white scar slashed with tremendous effort across the steep, green mountain side.

Still muttering "mules" my company commander squelched away and left me to it. Eventually the rain stopped and two or three days later under the hot tropical sun the road had dried out and convoys were running once more. Meanwhile, in preparation for the next deluge, a company of mules had been stationed at the bottom of the hill.

Next pay day I went down to Imphal in my jeep to collect the wages for the Nagas. This amounted to several thousand rupees, silver of course, for the Nagas had no use for pieces of paper. As I approached the hills on my way back the heavens opened. My jeep was "cleared for action"—there was no windscreen and no canopy. The outlet vents in the floor were blocked with dirt, and as I sat there in the deluge the water rose around my ankles. There was clearly no question of getting up the hills on wheels for at least a couple of days.

I slept that night curled up damply alongside my money bags on the floor of a grass hut near the mule lines. By dawn the rain had ceased and as the sun rose the ground steamed like a boiling cauldron.

"You'll never get the jeep through that lot," said the mule company commander. An authoritative statement which I couldn't dispute. "I'll give you a riding mule and you can sling the money in a couple of kitbags in front of the saddle." To this I agreed, omitting to say that I had never ridden a horse in my life, let alone a mule.

In due course my mount was produced. Army mules come in three sizes and this was one of the largest. It was truly enormous, and obviously intelligent, and from the outset I distrusted the mean look in its eye.

The money bags were duly hoisted into position and so in turn was I. The beast was then aimed in the right direction and released. A resounding welt on the backside from a "well-wisher" gave us acceleration and we were off like the wind. It took the mule about four good strides to assess my equestrian skill but I managed to stay with him and five minutes later we were back at base. The mule, seeing no future in the task at hand, had turned swiftly round in the first clearing we reached and gone home.

Our return was greeted with mild surprise, but dignity is a great thing with the young and I went over to the jeep, fiddled in the dashboard locker as a face-saver, and returned to the mule. Once more I was hoisted into the saddle, the animal was again aimed and released. The sequence of events was repeated and five minutes later we were back once more. The grins of the

Indian mule drivers made the preservation of dignity a difficult matter, but I steadfastly went through the same procedure as before and we were on our way for the third time.

This time however I was ready. I was determined to preserve what little "face" remained and as the mule made his turn I fell from the saddle keeping a firm hold on the reins. For a moment the mule stood motionless obviously astonished by such unexpected initiative. Giving him no time to recover I quickly tied the reins to a sapling and then sat down to consider the situation. The mule, somewhat mournfully, considered me.

My composure restored, I resolved that the mule should not be allowed to win hooves down. In the interests of the whole human race it was patently my duty as a British officer to bend the beast to my will.

Thus fortified and grimly determined, I unfastened the reins and prepared to mount. The mule had other ideas. Regardless of the speed of my outflanking movements the mule and I were always face to face, and short of crawling over his head I was stymied. I tethered the beast once more and considered the problem further. The mule shook his head a little sadly and munched a tuft of grass.

Leaving the mule tethered I walked round him, avoiding the hindquarters. He took not the slightest notice and munched on. I moved up close beside him and still he munched. Gradually the possibilities of the situation crystalized and reaching slowly up to the saddle with both hands I gave a jump and a heave and there I was, back on the mule again and highly delighted. The delight was shortlived however for the mule had been thinking ahead. He stopped munching, backed quietly away from the sapling to the full extent of the reins and stood motionless. He was still tethered, the knot was out of reach and it was stalemate again. I climbed forlornly to the ground.

There was nothing for it but to tow the animal the thirteen miles to my camp up the mountain so I unfastened the reins. Unfortunately I had underrated the determination of my opponent. With a jerk of his head he snatched the reins from my hands and was away up the track like an arrow. This was his only error but it proved his undoing. In the course of our antics in the clearing he had become confused and instead of heading for his base I could hear his hoofbeats fading away up the hill in the direction of my camp.

Fearing for the rupees he was carrying I set off in pursuit. It didn't take a mule as clever as mine very long to realize his mistake and presently he reappeared round a corner and gathered speed as he came towards me. It was now a case of death rather than any further dishonour, and as he went by, reins trailing, I grabbed and hung on.

This proved to be the end of the contest. The beast halted, put his ears out at right angles and adopted that rather melancholic expression peculiar to mules. At last, to my infinite relief, I had achieved a moral ascendancy. I wisely refrained from rubbing this in and putting the reins over my shoulder I set off with the mule following docilely behind. Thirteen miles farther on, many thousands of feet higher and several hours later we arrived at our destination.

It had been a wearisome day but in the course of it I had grown strangely fond of my companion, and so, I think, had he.

Paper Presented to Joint Meeting of the Institution of Royal Engineers and the Institute of Transport

By Brigadier C. A. Langley, CB, CBE, MC

RAILWAY SAFETY—PAST PRESENT AND FUTURE

A joint Professional Meeting of the Institution of Royal Engineers and the Institute of Transport held at the Royal United Service Institution on 27 January 1964.

General Sir Frank Simpson, GBE, KCB, DSO, DL, JP, Chief Royal Engineer, in the Chair.

The Chairman: It is a great honour to the Institution of Royal Engineers to join with the Institute of Transport this evening to have a discussion on this all-important matter of railway safety. We are particularly honoured that we have so many distinguished people present who have been connected with the railways and transport generally, and I should like in particular to mention Lord Robertson and Dr Beeching whom we are delighted to welcome to this meeting.

Our lecturer this evening is Brigadier C. A. Langley who is, I am sure, very well known to you all and whose reports we have read many times in the newspapers. He comes from a long line of Sapper officers who have done this very important job of Chief Inspecting Officer of Railways. He was the Chief Inspecting Officer of Railways from 1958 to 1963, and he is a member of both the Institution of Royal Engineers and of the Institute of Transport. He will present for discussion his paper, which was published in the *Royal Engineers Journal* last December, entitled "Railway Safety—Past, Present and Future".

I have very great pleasure in inviting Brigadier Langley to present his paper.

Lecture

Opening Remarks

I esteem it a very great honour to present a paper to such a distinguished company this evening, and I hope that my subject will prove of interest. It is one with which the Corps of Royal Engineers has been closely associated for the past 124 years, namely Railway Safety. It covers a very wide field—past, present, and future—and so I shall only touch on a few of the main features now, but I shall be happy to deal with any other matters during the discussion.

I would remind you that 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.

The Railway Inspectorate

With such a revolutionary form of transport, accidents were by no means infrequent. This 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 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 of Inspector

General of Railways. Thenceforward to the present day all Inspecting Officers have been drawn from the Corps in unbroken succession. A very fine and, I believe, unquestionably justified example of the Closed Shop!

Railway Safety Legislation. The Inspecting Officers' work is founded on the principles of British safety legislation which place on the Railway managements the responsibility for the safe construction, operation and maintenance of their railways, allowing them the maximum freedom to develop projects on their own initiative, and restricting Governmental control to the minimum. Let me summarize this legislation very briefly:—

Early Acts. The 1840 Act was followed two years later by another which gave the Board of Trade power to postpone the opening of a line should its condition be unsafe, but neither Act gave the Board authority to order inquiries into accidents, though these were held from the earliest days. This demonstrates the co-operation that existed so early between the Inspecting Officers and the Railway managements.

1871 Act. The next important legislative step was the 1871 Act 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, but it did not give the Board power to enforce any of their recommendations, nor does such power exist today. The policy of the Inspectorate is to rely on persuasion rather than statutory coercion.

1889 Act. During the years that followed, rail travel became more efficient and safer, but some railways continued to work their lines on outmoded 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 a continuous but 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 twenty minutes after the excursion, in accordance with the time-interval system.

The new Act 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.

Safety of Employees. Towards the end of the last century the safety of railway employees began to attract attention, and in 1900 the Railway Employment Act gave the Board of Trade power to make rules to reduce or remove the dangers and risks incidental to railway service.

So much for legislation, let us see now how safety has progressed during the last century.

Railway Safety in the Nineteenth Century

When railways were first opened for public service speeds were low, but with their rapid extension, confusion arose at junctions, and some form of signalling became imperative. The first types were boards and lamps fixed on poles.

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. The resulting accidents led to the concentration of signal and point levers in signal cabins, but mistakes could still be made by a signalman pulling a wrong lever. Hence interlocking was introduced following a suggestion by Colonel Yolland in his report on a collison at Bricklayers' Arms in 1855.

Double line working. The early railways were nearly all double line, and at first the time-interval system was adopted. It worked satisfactorily so long as trains kept to time and did not break down, but unpunctuality was a constant source of dissatisfaction and, in those days, of danger.

With the introduction of the electric telegraph the Block, or space-interval, system of working was developed. The Block instruments enabled the signalman 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 trains.

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 simultaneously to turn to the required position the instrument in his box and the corresponding instrument at the other end of the section.

Single line working. On single lines the first safety move was to introduce the staff which alone was the authority for the train to proceed into a section between boxes. This was satisfactory so long as working was balanced, but should one train be immediately followed by a second, 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 of the series.

Even so, there was delay, which was eventually reduced by the invention of the tablet or token instrument. An instrument was installed at each end of a section; it was interlocked electrically so that only one tablet could be removed at a time; the tablet had to be returned either to its own instrument or to the one at the other end 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 may be in a section at a time.

Summary. The nineteenth century was indeed an era of Railway Adventure—of invention and of rapid development of new engineering techniques. It was under such conditions that the requirements for railway safety were defined, were tested, and were adopted—at first half-heartedly, but at last universally. The period of 70 years from the opening of the Liverpool and Manchester Railway in 1830 to the end of the century saw the creation, and eventually the wholesale adoption of the three great safeguards for British railway working, namely the Absolute Block System of operation, the interlocking of points and signals, and the equipping with continuous automatic brakes of every passenger train.

Railway Safety in the Twentieth Century

The twentieth century has seen the consolidation, the further amalgamation, and, finally, the nationalization of 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.

Signalling. Safety requirements have been concentrated primarily on giving additional aids 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 techniques have made striking advances, and of these the introduction of the track circuit has probably been of the greatest value . . . it is the basis of modern signalling.

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, even mental aberration (from which most of us suffer from time to time). Various controls have been devised to prevent these mistakes, and they have been installed in many boxes where Block Instrument working is still in force—details are given in my paper.

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 which are controlled automatically by the occupation and subsequent clearance of track circuits.

Briefly, modern signalling practice is to concentrate the control of large areas into one box and so to 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 signal boxes can be abolished, reducing the numbers of signalmen, and resulting in 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 rare. With the concentration of so much work in one box, serious dislocation of traffic may arise from a power failure and consequently sources of supply are invariably duplicated.

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 his view, semaphore signalling grew more complicated, with formidable arrays of signals at large junctions and terminals. The driver, therefore, had (and still has) to acquire an intimate knowledge of the road before taking charge of a train. 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. This safeguard was first introduced by the Great Western Railway in 1906 and for many years it has been standard throughout that system, but the decision to extend it was not taken until the railways were nationalized in 1948. An inductive system was selected, however, and it was not until 1956 that the new equipment was made sufficiently reliable for wholesale adoption.

With this system, 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 a 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 and the disc is turned to black.

The Inductive and the Western Region systems are now in use on over 2,500 route miles and have proved invaluable aids to drivers, particularly in fog. During the 12 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 A.W.S. This is the case for its extension to all Main Lines.

Public Road Level Crossings. Until recently gates closing alternately across road and railway have had to be provided at public level crossings in Great Britain. The Law has now been amended to allow lifting barriers in place of gates, with the object of easing the position both for the railways and the road user. There are two main types; the full barrier protecting the complete width of the road and worked directly or remotely, and the automatically operated half barrier covering only half the road on each side of the crossing. In addition to the normal road notices, safeguards include lights that flash and gongs that sound before and during the lowering of the barriers. With automatically operated barriers, space is allowed for a vehicle to escape should it be caught on the railway as the barriers are lowered. The time between the first warning and the arrival of the train has been cut to a minimum so that motorists held up at the crossing will not be tempted to "jump the lights".

Electrification. The electrification of railways in Great Britain has had a somewhat varied history. The low voltage DC system with rail collection was adopted by a number of railways, with voltages varying from 630 to 660. The Metropolitan and District Railways and later the Underground Railways, adopted the fourth rail system. The Mersey Railway also favoured this method, but has recently changed to the third rail, which was adopted for the Tyneside, Liverpool & Southport, and the London & South Western electrification schemes, and later by the Southern Railway. The overhead 1,500 volts d c system operates on the Manchester–Sheffield Main Line; and in 1956 the high-voltage single-phase a c system was adopted as standard and is now in use on part of the LMS Main Line, around Glasgow, and on some of the Eastern Region lines.

Safety Precautions on Electrified Lines. Additional safeguards have been introduced to protect staff and public from electric traction dangers. 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 unclimable fencing is provided along 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 permament 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 a c 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, films, 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.

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 fatality rates in 1900 were distressingly high, and campaigns were launched to reduce them. Great progress has been made since then. The 1961 fatality rate for guards was only one-eighth that in 1900; for shunters, one-tenth; while platelayers fatalities were halved. The present situation is not, however, viewed with any complacency and measures to reduce accidents have been intensified.

Summary. During this century much progress has been made in the provision of safeguards of all types and high standards of safety have been achieved. During the 6-year period 1956–61, which included the Lewisham disaster where 89 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.

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 used armoured trains for inspection purposes and sometimes I regret to say took them out in the face of opposing traffic, much to the alarm of the staff, and to the detriment of safe traffic working.

Operation Dynamo. In both World Wars the Railways played a major role, but time does not permit a description of this work; though I believe it would be of interest to refer to the railway arrangements made in connection with the Dunkirk evacuation, known as "Operation Dynamo" since very little publicity has been given to this remarkable feat.

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 from France, 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. The returning troops were to be dispersed amongst the military centres throughout the country on the basis of doubling-up on the existing 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 to be 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 journey with the railway staff. A Railway Construction Group RE was based at Ashford and was 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 Railways' 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. 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 main-mainted though unorthodox methods were necessarily used.

Railway Safety in the Future

It is with some trepidation that I turn to the speculative side of this paper. What of the future?

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.

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 signals, and enable signalling to be controlled from a few widely spaced boxes. These will be at main stations and junctions, and the intermediate signals 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 routes and we shall see trains running at high average speeds with maxima of about 100 mph or possibly more.

Radar. Suggestions have been made that radar should be introduced on railways to enable a driver to get warning of obstructions ahead, but 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 metal conductors above 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. 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 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.

A selective radio of this type could, I believe, be used between controller and driver to give him working instructions and to exchange information in the event of an emergency; simple equipment might provide a link between driver and guard of a long freight train. There are, however, 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 may be needed.

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; in a car-ferry train, a thoughtless motorist may be tempted to light a stove for a meal, or be careless with cigarettes. 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 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 negligible.

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. 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 bottle-necks on existing British lines preclude the possibility of introducing on them super high speed trains running at say 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 rapid 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.

DISCUSSION

Colonel D. McMULLEN: As a member of both Institutions and having succeeded Brigadier Langley at the Ministry of Transport, I have, needless to say, greatly enjoyed reading his paper and hearing his resumé of it tonight. I should like to congratulate him heartily on covering such a wide field so ably, and in such an interesting way. There are a few points that I should like to make, that will, I think, be of general interest.

On the historical side, it may not be known that the father of all railwaymen, George Stephenson, played a large part in shaping the policies of governments towards railways. In 1840 a Select Committee considered the extent to which government should exercise control over railways, and Stephenson gave evidence before it. Afterwards he wrote to the President of the Board of Trade and the following is an extract from his letter:

> "I am quite sure that some interference on the part of Government is wanted. Perhaps I ought to be the last man to admit this (the whole system of railways and locomotive engines having been brought about by my exertions), but when I see so many young engineers and such a variety of notions, I am convinced that some system should be laid down to prevent wild and visionary schemes being tried at the great danger of injury or loss of life to the public."

He went on to suggest that "any plan for the better working of railways" should be submitted to the Engineer of the Board of Trade—that was the first Inspecting Officer of Railways. The original letter was recently found in our archives and a facsimilie of it hangs in my office. We do not get "wild and visionary schemes" put up to us now except by members of the public!

Again, on the historical side, the idea of a Railway Inspectorate, or the equivalent, for exercising varying degrees of government control over safety on railways was adopted in many other countries, both inside and outside the Empire. In India, for instance, the Inspectorate was modelled very much on our lines though the Inspectors were given greater powers, including the power to inspect maintenance. In the United States, the Inter-State Commerce Commission has powers to inspect rolling stock and an Inspector can, if he sees fit—and I am told sometimes does—stop an engine or a train set even if it is about to be used for peak traffic. In Great Britain the policy of all governments from the earliest days has been to ride the railways with a light rein. We have, as Brigadier Langley has mentioned, remarkably few statutory powers, and we rely on our powers of persuasion—I have heard it called blackmail—to attain our ends! The present high standard of safety on British Railways is, I suggest, a full vindication of this policy.

Brigadier Langley has mentioned under the heading "Railways in War" that many Sappers received their railway training on Indian Railways. The Corps had, of course, close connexions with the Indian Railways for a very long time in peace time also, and many Sappers reached the highest positions, such as Chairman of the Railway Board, and General Manager of Railways. Many of our Inspecting Officers, including such famous ones as Colonel Sir Alan Mount and Brigadier Langley himself, received their railway training or railway experience there. The Corps has also had close connexions with railways in other countries, such as Egypt, where I am proud to say my cousin, General Sir Donald, served with such distinction. During the war in the

Indian theatre, Sapper officers, some regular and many more Supplementary Reserve, were responsible for the planning and, initially, for the development of the Assam Rail L of C which worked efficiently and, generally, safely. In all these vast and varied fields Sappers undoubtedly made a large contribution to safety on railways.

Brigadier Langley has covered railway safety in the twentieth century very fully, but there is one aspect which I think deserves comment. It is the hazard of the private level crossing that is greater now than in the last century because of the growth in the size and weight of farm vehicles and machinery. British Railways have no obligation to provide protection other than gates at these crossings. The problem is a difficult one. It is not one of what should be done, but of who will pay to have something done. We hope we are now on the way to a solution.

Now for the future. I am all in favour of Brigadier Langley's proposal for a Horoscope Casting Committee!

He is entirely right in saying that the physical characteristics of the existing main lines will not permit speeds much higher than those achieved now. If the future overall transport plan is to require higher speeds for surface transport, it will be necessary to construct, at extremely high cost, entirely new lines for, say, a monorail, a hovercraft, or a conventional railway such as the new 320-mile long Tokaido Line between Tokyo and Osaka which the Japanese are constructing at very great cost. That railway is on an entirely new alignment with many tunnels and bridges to ensure easy curves and gradients for high speed. I was privileged to travel at 210 kph (132 mph) on the test section of that line recently, and it was an interesting experience. The track and rolling stock are first class. I cannot see, however, an economic justification for such a line in this country, where air and road transport has been developed so much more than in Japan.

For myself, I think that we shall continue to have conventional railways, more or less as we know them, for many years to come. But the railway system of the future will be very streamlined and probably fully, or largely, electrified with, perhaps, automatically driven trains, no signalmen and only controllers at a few points and no lineside signals. Whatever method of control may be used, a block system will still be necessary to ensure safety, but I suggest that this might be a moving block instead of the fixed block system used at present, and I shall be glad to hear Brigadier Langley's views on this.

Finally, I should like to endorse Brigadier Langley's remarks about the Channel Tunnel, with which I have been closely connected. There will, as he says, be safety problems galore. One will be whether we, or the French, should hold an inquiry into an accident half way across. Perhaps he would like to comment on that also!

Brigadier C. A. Langley (in reply): I should like to thank Colonel McMullen for supplementing my remarks so ably, and reminding us of George Stephenson. It puts me in mind of another railway pioneer who took the opposite view. I refer of course to I. K. Brunel, the brilliant engineer of the Great Western Railway, who opposed any form of government interference. You know how old traditions die hard in some places!

As regards the Channel Tunnel, I sincerely hope that Colonel McMullen, or his successors, may never have to hold an inquiry as he suggests, but, should one unfortunately be necessary, I believe it would be a joint investigation. I feel, however, that the British Inspecting Officers would have to do most of the work, since the French Inspectors, whom I have met, do not investigate accidents; they only inspect and approve new works.

I was interested to hear Colonel McMullen's views about the Japanese line. I am doubtful whether we shall ever see anything like that in Great Britain.

The moving block system which he mentioned may eventually be used here but we should be clear what we mean by "moving block". It is a system whereby the distances between trains are controlled automatically by their respective speeds, but these distances must always be sufficient to ensure that the following train will be pulled up clear should the leading one come to a violent stop through any cause.

General LORD ROBERTSON OF OAKRIDGE: On reading through Brigadier Langley's excellent paper, and having listened to him make a summary of it, it has occurred to me to raise an aspect that he does not touch on, and I quite understand why he does not touch on it. Indeed, it may seem to be rather an irrelevant or irreverant matter to raise here, although I do not think it is. It is in fact the aspect of cost in this matter.

Brigadier Langley has rightly paid tribute to the standards of safety on British Railways, and to the skill and conscientiousness of those who have managed the affairs of our railways and who still do so, and I for one entirely endorse that. I think it is something of which they can be justly extremely proud. But of course it is yet not enough. The railways are not safe enough, and the struggle for greater and greater safety must always go on so that there is no risk element at all. But this cannot be done without cost. In 1956, when the decision referred to by Brigadier Langley was taken to adopt in a wholesale way the automatic warning system, I had responsibility to British Railways then, and the decision no doubt seemed to those who read about it to be a decision in favour of the obvious. But it did not seem so to those with me who made that decision. The cost of the initial installation, according to my recollection, was £20 million, and the annual maintenance cost was £2 million. It was a decision which was made after very careful thought. It was no doubt a proper decision, for there is no way of measuring the cost of a human life or even of a limb and, therefore, any calculation to help one or to guide one in reaching a decision is clearly not possible. Yet, I should like to hear whether Brigadier Langley does not think that something should be done, for example, in the first place to give balance to the outlook of the Press and of public opinion on this matter by constantly and quietly referring to the cost question when discussing railway safety.

Similarly, when talking about the future and referring, as Brigadier Langley does so ably, to questions of better signalling, of radar and radio, and so forth, is it not as well to remember that there is not only a technical problem but a financial one also, because if we make our railways absolutely safe, it will only be by disregarding the cost factor.

Brigadier C. A. LANGLEY (in reply): I entirely agree with Lord Robertson that it is difficult to assess the full cost of a railway accident. How is it possible to evaluate human misery caused by fatal accidents and injury? The material side is fairly easy to assess, but there is a great deal more than material damage to rolling stock to be considered. There is the money spent on breakdown gangs, and so on, the diversion of trains and the effect of public reaction.

In considering this question the human factor is of vital importance. The Railway Board is fully alive to this problem and is at this moment conducting a vigorous campaign to improve still further safety on the railways. I should like to see more efforts made to assess accident costs, taking into consideration not only the financial but also the human side of railway accidents.

Mr A. R. Dunbar (Vice-President of the Institute of Transport): It may appear curious to some that a system of government inspection and inquiry, found necessary to check the railway adventurers of the early days, should still have a high place in the conduct of a responsible nationalized railway system.

Brigadier Langley has brought out some of the reasons for this. As he has shown, it is not because modern railways are a high-risk form of transport. Quite the contrary. Our system of operation on a reserved track gives special opportunities for introducing safeguards which affect us alone, and our engineers and operators have, throughout the years, derived great benefit from highly-skilled independent officers advising and passing judgment on their equipment and their practices.

There are, in fact, few senior railway officers who are so certain of the Law that they could describe with confidence the exact powers of the Inspecting Officers as defined in Acts of Parliament. To us nowadays that does not matter nearly so much as the knowledge that we have this group of safety advisers and judges ready to help us solve our problems.

The search is always for the sensible solution—not just what is absolutely safe, but what is intelligently safe. As Brigadier Langley has shown, the standards of operation on a military railway can be different from those on a main line passenger system. Likewise different methods can be applied to goods lines, ordinary main lines and high speed passenger routes, as long as they are all based on established safety principles.

We are moving forward into a new era where there will be a higher proportion of express trains, freight and passenger; when there will be fewer men employed in relation to the mileage of track and trains. I am sure Brigadier Langley will agree that the emerging re-shaped Railways present to the railway engineers and operators and the Ministry Inspecting Officers the greatest challenge they have had in this century. Would he care to comment on how they are approaching this new problem of applying high standards of safety with simplification to a streamlined railway system?

Brigadier C. A. Langley (in reply): Let me take this question in two stages; first with regard to train operation and then locomotive control.

I believe the first development will be the complete track circuiting of all high-speed lines, with automatic signals controlled by track circuits between widely-spaced signal boxes. All these lines will be equipped with the Automatic Warning System. We may see train descriptions transcribed automatically and used in association with electronic computers so as to guide the signalman in handling the traffic at busy junctions, especially when trains are running late or out of course.

Secondly, if we are to have higher speeds, we shall need some form of speed control, or possibly complete automation as has been developed, I understand, for the Victoria Line of London Transport Railways. With complete automation we shall have, I believe, some form of dual control—one control for the normal running and stopping of trains, and a "safety control" to apply brakes automatically whenever a train exceeds the maximum permissible speed and in emergency, including failure of any of the automatic equipment or power supply. With complete automation there must still be a man in charge of the train, because even the best equipment sometimes breaks down, and it will be necessary to have means of keeping traffic moving, probably at slower speeds. The first application of automatic operation to British main lines will probably be on the Channel Tunnel route where we shall undoubtedly see some system of speed control if not complete automation.

The subject of locomotive control is an interesting study. With modern electric and diesel locomotives, the ergonomics of cab design and the question of driver alertness are of paramount importance especially at the higher speeds. As a matter of fact, we have been carrying out a study of the size and shape of seats, problems of noise, ventilation, heating, visibility, and so forth. They are all matters which are being meticulously investigated at the present time. On long runs with few stops and with little action needed by the driver to control his train, his possible drowsiness is a danger which we recognize and are taking action to reduce.

The first safeguard is of course the driver himself. He must be trained to keep alert, and I believe that a great deal can be done in that direction. He should, for example, know how to take immediate steps to combat drowsiness, such as opening the window of the cab, standing up, and so on.

Then there is the mechanical safeguard. As you probably know, all diesel and electric locomotives are fitted with a device to stop the train should a driver die at the controls. It is known as the "Deadman's pedal or handle". The name is, in my view, a misnomer because it suggests a safeguard against the remote contingency of a driver dying at the controls—a contingency which no driver contemplates. What we want is a device to alert the driver the moment he begins to feel drowsy and we want his co-operation in its use. I have, therefore, suggested that the name be changed to "Driver's Safety Device". We are now carrying out experiments with a more sensitive pedal that will, I hope, meet these requirements.

Mr E. Whitaker (Institute of Transport): We have heard a great deal about streamlining the railways, and I am wondering what is being done about streamlining the safety precautions themselves, having regard to technological developments, and whether in fact some of these precautions have been outmoded and railways are losing out because of it. I think this is striking rather a different note, because all the emphasis has been on more and more safety, but I see that Dr Beeching is here and of course he has the responsibility to which Lord Robertson referred. All this costs money, and the question is how can the railways be made to pay if too much money is spent on them?

I travel on the Tattenham Corner–Purley train, and at night when we arrive at Purley, I have to get out of the train and wait on the station for the Caterham part of the train to come in. The platform is long enough for the section to come in but, I am told, it is because at night they cannot have a man with a red flag standing at the side to stop the motorman coming up to the section already there. It seems to me that is one of those cases where an accident occurred at some time, and the Inspector said that something must be done, and this was the result. I would have thought that the motorman would have sufficient intelligence to come up to the back of the other section without hitting it. I was told once that his foot might slip off the brake, but in that case what good would a man with a little red flag be? There are probably a number of other cases where the regulations might well be looked at afresh.

Brigadier C. A. LANGLEY (in reply): As a matter of fact this is the very subject which is exercising my mind at the present time. I am thinking of ways particularly in which one can simplify single-line working. I have mentioned in my paper the token system which is in force at present, but I hope that we may be able to introduce tokenless block working without any exchange of tokens, but still ensuring that there is only one train in a section at a time.

On freight lines my thoughts are going further. I am wondering whether we could not have automatic crossing stations where the crossing is so designed that the train itself unlocks the points and goes through. The train would be controlled by a central controller and that might be done by means of selective radio.

So far as the Tattenham Corner–Purley question is concerned, we are looking into the question of tail lamps on trains, and are considering whether we shall use more powerful lamps. I can assure you that we are reviewing requirements to see how we can maintain safety in the most economical way.

Mr D. S. EAST (Institution of Transport, Reading Branch): On 11 December 1958 a contractor's crane toppled into a cutting and was run into by the Manchester train which, in turn, was run into by another train. One of Brigadier Langley's officers, Colonel Reed, in his report stated that the circumstances of this accident gave ground for reviewing the advisability of adopting the flare on British Railways. I am informed by those who supply road flares to the Lancashire Police that British Railways are examining flares at Derby. Unfortunately, they are calling for 75,000 candle power which is extremely high, and the cost of equipping guards and brake vans throughout the country would be about £1 million. I read on Saturday that the Ministry of Aviation is to spend a quarter of a million pounds on research into safety during the take-off and landing of aircraft, and one feels that if consideration is given to the matter in the light of the Lewisham or Harrow rail disasters, then £1 million is not out of proportion.

Secondly, in my view we cannot afford to go on having boys in signal cabins dangling red oil lamps out of the window in an effort to attract the attention of the driver of a train. There must be very few people present who are not familiar with the Aldis lamp which has a range of 5 miles, and which is run off the mains or off batteries. I have seen them used in Germany to illuminate shunting at night, and they may be fitted with a red or a green screen. I am sure there must be thousands of Service Aldis lamps in the RAF, Royal Navy and Army depots.

I should like to hear Brigadier Langley's views on these two points.

Brigadier C. A. LANGLEY (in reply): I have not had an opportunity of using or testing the Aldis lamp, but I have made a note of the suggestion.

There is another device which I believe may go a long way towards solving the problem of giving warning to a train on an opposite line. I have asked for a simple short-circuiting device to be produced, and one is nearly ready for testing. If there is an accident on a fully track circuited line, all the driver has to do is to fix the device on the opposite line thus short-circuiting the track and placing the signals to danger.

Mr DOWNING (Institute of Transport): I think that we should not regard the Automatic Warning System entirely in the light of the lives which may be saved, important though that is. There is also the factor of less delay to be considered. The ringing of the bell in the Automatic Warning System helps in some way towards maintaining the alertness that is wanted on the part of the drivers. That, coupled with the modern signal, has made main line traffic running at 70 mph through fog very safe.

Brigadier C. A. LANGLEY (in reply): I agree about the value of the Automatic Warning System in helping traffic. Trains fitted with this system can run much more safely and efficiently than those without it. We have had many examples of trains travelling safely at 70 mph through fog with the Automatic Warning System to warn the driver of signals ahead.

During the last year I have really enjoyed myself travelling up and down the country in the cabs of diesel locomotives of various types studying the work of the drivers, and taking note of the problems connected with alertness. I have found the Automatic Warning System a wonderful help in maintaining alertness, particularly when travelling by night from King's Cross to Edinburgh!

Mr PAYNE (Institute of Transport): One of the major requirements so far as railway safety is concerned is discipline. Therefore, does Brigadier Langley not think it a matter of regret that there has not been a greater effort on the part of Longmoor to contact staff officers of the London Transport Board with a view to recruitment into the Army Emergency Reserve? There a man can have fifteen days' training, be subjected to some discipline and also have opportunities of handling equipment and taking part in railway maintenance.

Brigadier C. A. LANGLEY (in reply): Thank you for your remarks about the Corps and about Longmoor in particular. I agree that better discipline is needed, and I am quite sure that we shall see an improvement in that direction. There is a move on foot at the present time to improve the discipline on the railways, and to improve efficiency in every way.

Major T. W. TINSLEY (Royal Engineers): This is an Age of Automation. It would seem we are even to lose our railway engine drivers, with "driverless trains". While being fully aware of the needs for safety in peace, as a Royal Engineer I am interested in the capability of railways in war. I do not wish to cry woe or Whoa! But we have to think of nuclear war. The speaker has ably stated the case to keep railway wagons moving in war, but if we have fewer signal boxes, fewer and farther between, and if we need, in an emergency, to operate with "stick and string" (or "tokens", as it is termed) may I coin a phrase and ask "Whither have all the signalmen gone?" Will there only be a few very technical boffins in the very few automatic, vulnerable, signal cabins?

Brigadier C. A. LANGLEY (in reply): When, if ever, the days of complete automation arrive, there will be few engine drivers and signalmen left on British Railways and Longmoor will have to recruit and train all the staff they need to meet their war commitments.

Lieut-Colonel G. W. SHEPHERD (Royal Engineers): In his lecture Brigadier Langley referred to the possible use of radio to control trains, and at Longmoor, where I am the Chief Instructor, we are interested in this from the point of view of military railway working. We know from experience that it is highly probable in any war that all forms of communication will be disrupted, so that under those conditions normal methods of operating railways must go by the board. Again, it may be difficult to restore communications quickly over long distances. On top of that we think it may be expedient in a war—bearing in mind first that, except perhaps in Europe in a major nuclear war, military tonnages to be moved will be small and, secondly, that overseas manpower will be limited—to lengthen our sections to 20 miles, and under those conditions control is difficult. One possible answer is radio communication between signalmen, or possibly between controller and signalmen or controller and train crews. If we did this we should probably have to use military VHF sets, and these of course have their own difficulties. For example, there is a shortage of range, a shortage of frequencies, and they are not particularly selective. Furthermore, they are only limited to line sight. I should be grateful for Brigadier Langley's views on this particular matter.

Brigadier C. A. Langley (in reply): There is on the market a portable radio which has three wave-bands, and a range of about 3 or 4 miles which could be extended to 10 or 15 miles. The set is fully transistorized, and might be used for communication between signal boxes. It might even be possible to increase the range to some 20 miles, but there would be difficulty should a hill come in the way, but this could be overcome by using relay stations. Selective radio could be used between a controller and the signal box, and between boxes. If you want to get more sophisticated, and you are short of men, CTC equipment could be operated by UHF radio as used for operating the valves of the North Wales Gas Grid. There are a number of difficulties to be overcome, but it would be worthwhile to have a look at some of the latest equipment to see how it could be used for Military railways.

Dr R. Beeching (Chairman British Railway Board): The point was raised by Lord Robertson concerning the difficulty of estimating the value of safety, and Mr Whitaker rightly pointed out that it was very necessary to review the cost of some of the safety measures which are at present practiced, and to bring them up to date. I am speaking because I want to make a point which perhaps Brigadier Langley does not feel in a position to make.

His situation with us is not that of a "poacher turned gamekeeper"; nor, on the other hand, is the reverse true, he is not a "gamekeeper turned poacher". He is with us so that he can help us with our task, and his position, if I may pursue the simile, is rather that of a gamekeeper who is now shooting as a "guest on the estate". A very important part of his work with us is to help us review all the safety measures of one kind or another which have been built into the system over the course of history to see whether we cannot achieve the same safety more cheaply because, apart from the question of whether it is worth spending the money on a particular method, it is worth getting the same safety by spending only half as much if that is possible.

Mr Keith Granville (President, Institute of Transport): I should like to take the opportunity of thanking the Institution of Royal Engineers for inviting the Institute of Transport to join in this meeting tonight. It has been very valuable to members of the Institute, and we appreciate the courtesy of being invited in this way.

I should also like to add my thanks to Brigadier Langley for a fascinating and absolutely first-class paper. Each time I listen to people speaking about forms of transport which are different from my own, I think how similar they all are. The problems of safety on the railways are similar to those in the air, although sometimes there is a little difference. For instance, I could not help feeling very envious when I heard it said that when the driver of a train gets drowsy he opens a window! If we issued instructions of that kind we should lose out aircraft captains rather more quickly, and a number of fare-paying passengers smartly afterwards!

However, there are great similarities between all forms of transport, and I am sure what Brigadier Langley has had to say will not be wasted on the members of the Institute who are not necessarily concerned with railways.

The CHAIRMAN: Whenever I hear about red tail lamps I always think of one of the first coloured pictures ever to appear in the *Tatler*. It showed a large lorry on its arrival at the top of a steep hill, and the driver examining the rear of the lorry. A constable was also shown asking the lorry driver, "Where's your tail light?" to which the driver replied, "Damn the tail light; where's ruddy trailer?"

I should like to accord a vote of thanks to the Royal United Service Institution for allowing us to come here this evening and to hold the Meeting in such comfortable surroundings.

The finest tribute which can be paid to Brigadier Langley is the large and distinguished audience which has come here to listen to him talk on this vitally important subject of railway safety. It has given rise to this very interesting discussion which would still be taking place if time had permitted. I know you will all want to join me in thanking Brigadier Langley very much for all the trouble he has taken to prepare the paper, and for putting it over to us so wonderfully.

The vote of thanks was carried by acclamation, and the meeting then terminated.

The following written question was submitted by Mr W. E. GELSON:

"Having been intimately concerned with the design of vehicles and permanent way and having studied their performance in traffic I should be very interested if the author would include some information on the incidence of accidents caused by mechanical and structural failures.

There is usually a large factor of safety against derailment with twentieth century stock running on modern tracks, which remains so long as track maintenance is sufficiently good to avoid unloading of guiding wheels and provided running gear and other mechanical parts function substantially in accordance with the designers intentions. Considerable responsibility rests with those departments whose duty it is to maintain way, works and rolling stock."

To which Brigadier LANGLEY replied:

"Particulars of accidents on all statutory railways in Great Britain are given in the Chief Inspecting Officer of Railways' Annual Reports. It will be seen that in 1962 there were 115 derailments from technical defects of one sort or another. Nearly half were due to track defects and half to locomotive and vehicle defects.

I agree with Mr Gelson that safe railway operation depends to a large extent on ensuring a consistently high standard of maintenance, but in the last few years there have been a number of high-speed derailments of freight trains initiated by short wheel-based covered vans leaving the rails for no readily apparent reason.

These vehicles for the most part have relatively stiff underframes and simple spring suspensions which make them unduly responsible to comparatively minor irregularities in the track, especially under variable conditions of loading. At the low operating speeds formerly general, this was of little consequence, but the introduction of powerful diesel and electric locomotives is permitting the overall speed of freight trains to increase, especially on rising gradients, with the result that these vehicles are now running at higher speeds for longer distances than they did when steam-hauled.

Considerable research has been undertaken following a detailed examination of these derailments. This has indicated that for higher speeds there must be a proper relationship between under-frame stiffness and spring flexibility, that there must be an element in the suspension permitting controlled and suitable damped lateral movement, and that the wheel-base should not be less than 15 ft.

Existing 4-wheeled vehicles that comply with these requirements can run at speeds up to 60 mph, but the short wheel-based wagons have been restricted to a maximum of 50 mph."

Correspondence

Lieut-Colonel S. E. M. Goodall, MBE, MC, RE
Headquarters, 2nd Division
British Forces Post Office 22
12 March 1964

The Editor,
RE Journal.

ARMY REACTORS

Dear Sir,

The article on Army Reactors in your March issue by Major J. D. Isaac is a welcome addition to the previous contributions by Major A. A. Hiscock on the "The Energy Revolution". It would seem that this Energy Revolution is a field which the Corps would do well to follow most actively. As Major Isaac so rightly says the rate of advance of modern technology is so rapid that such matters as cost, weight and cooling times may well be solved long before it seems now to be possible.

The importance of all that to us, as the producers of energy for the Army, is clear to see. In our peacetime tasks of supporting the Army in minor wars, internal security and disaster recovery there will always be a requirement for energy in out-of-the-way places. Portable or even mobile reactors may well be the most appropriate answer in ten to fifteen years. Development of polar or even lunar areas will need similar engineer support should this country ever contribute to such undertakings.

In general war the MCR is probably the Army's solution for cutting out the need for POL supply in the battlefield, and powering complicated modern weapon systems. Just as there is an Energy Revolution linked to the nuclear reactor so I believe we are on the verge of another perhaps even more far-reaching one in connexion with the fuel cell and electrical propulsion.

By producing a system linking the fuel cell with portable MCRs we can have power sources which obviate the necessity for complicated POL supplies.

These are both fields in which we as Sappers should be in a position to take the lead as far as the Services' needs are concerned. They offer great scope for the traditional inventiveness and pioneering skill for which the Corps has always been noted.

There is one statement in Major Isaac's article which I should like to correct. It is a small point but one which might lead to misunderstanding. The explosion in the SLI Reactor was NOT in fact a nuclear explosion in the accepted sense. The explosion was caused by excess steam pressure in the boiling water reactor resulting from the reactor generating heat far in excess of the design rate. The size of the explosion was nothing in comparison to a nuclear explosion.

Yours faithfully,
(Sgd) S. E. M. Goodall.

Major D. C. Browning, RE (retd) AMICE, AMIMechE
76 Hartley Down,
Purley,
Surrey.
19 April 1964.

The Editor,
RE Journal.

TUNNELLING IN GIBRALTAR

Dear Sir,

Major Lauder's interesting article in the December 1963 *Journal* threw some welcome light on an aspect of Sapper effort which unfortunately gets little publicity. As a former OC of the 32nd Fortress Squadron, RE, I should like, however, to correct the impression given on page 341 that it was the 1st Fortress Squadron, RE which carried out the extensions for the power station at Calpe Hole and which drove the Episkopi Tunnel in Cyprus. These tasks were in fact the work of the 32nd Fortress Squadron. At that time (1952–55) the 1st Fortress Squadron was basically an E and M Squadron.

I was interested to see, on page 343, that skips were still being braked by jamming timber between the wheels. When the Orillon Gap tunnel was being drive in 1954 one of these "timber brakes" slipped and the resultant runaway skip narrowly missed the C.O. who was on his way up the 8 ft wide tunnel to the face at the time.

Major Lauder may also be interested to hear that Troop HQ had on a previous occasion in 1954 been set up at Little Bay. This was when parts of "I" and "P" Troops had been combined in order to make the excavation in readiness for the new swimming pool that was to be constructed by the Works Services.

Yours faithfully,
(Sgd) D. C. BROWNING

Captain J. A. Sneden, ARICS
"Strathearn,"
129 Fulbridge Road,
Peterborough,
Northants.
9 January 1964.

The Editor,
Re Journal

TUNNELLING IN GIBRALTAR

Dear Sir,

The article by Major J. G. Lauder in the December issue of the *Journal* on "Tunelling in Gibraltar" is most interesting. In his description of the preparations by the troops for the "stoping" of the Windmill Hill Shaft by the "cage" method, he makes reference to the construction in 1955, by my Company, of the St Fillans High Pressure Shaft as part of the North of Scotland Hydro-Electric Board's Breadalbane Project. Some facts on this shaft may be of interest to members.

The shaft is 600 ft deep. The 5 inch diameter diamond hole on the centre line of the shaft took three months to drill and was within 2 ft of centre at breakthrough. The average cycle in "stoping" the 6 ft pilot shaft was:

Drilling	2
Charging	$0\frac{1}{2}$
Smoke clearing	1
Travelling to and from face	1
Concreting, disconnecting and storing "cage"	$1\frac{1}{2}$
	6 hours

With a maximum number of 23 rounds per week and a pull of 4 ft on a 5 ft hole, progress should have been 92 ft per week. The average achieved was 64 ft per week with a maximum of 138 ft in the latter stages, which stages would have been the slowest by previous methods.

The shaft was enlarged to 12 ft diameter by using a platform and head gear. The platform was raised to the top of the shaft during firing and the rock spoil "mucked out" from the base of the pilot shaft through the Low Pressure Tunnel. Concrete lining to the shaft was placed in a moving shutter.

Nothing stands still in the development of engineering techniques and the "cage" system has given way to the improved Swedish type Raise Climbers, no longer requiring the centrally drilled hole. These working platforms are raised on guide rails to the face for drilling and charging and the guide rails contain all essential service connections. Advances of 8 ft to 10 ft per 11 hour shift are commonplace.

Yours faithfully,
(Sgd) J. A. SNEDEN

The Editor,
RE Journal.

Colonel R. A. Blakeway, OBE,
Military Engineering Experimental Establishment
Barrack Road, Christchurch, Hants.

1 April 1964

Dear Sir,

"US ARMY AIRBORNE ENGINEERS BUILD AN AIRFIELD"

Those of us at MEXE who are concerned with the plant and surfacing materials required for rapid airfield construction have studied Lieut-Colonel Wilson's most illuminating article on Exercise Swift Strike III with great interest.

The article shows very clearly that a large number of aircraft are needed to carry the plant and equipment for the construction and surfacing of M.R.T. airfields, even accepting the author's conclusion that there was considerable over-insurance in this particular exercise.

It follows that, with our more limited resources and since time is so important, it is essential that we ensure that everything is known well in advance about terrain conditions on any likely future sites, so that only the really vital requirements are flown in. I agree that the "friendly guerilla bands" used in this exercise introduced a somewhat artificial note and will not always be available; but I trust that the wrong conclusion will not be drawn from the author's comment that "the planning for a task of this nature must not be too detailed, and a well-rounded equipment family is required to deal with the unexpected".

By all means plan for the unexpected, and remember, as proved by this exercise, that a large proportion of air drop loads might not arrive on site in a serviceable condition. BUT at the same time arrange in advance for the best possible terrain information. In this connexion Terrain Evaluation—a system for collecting and storing *all* the terrain information we require on accessible sites, and also for inferring the conditions on inaccessible sites by matching them with known sites—may prove of the greatest value. In passing, I must emphasize that the CBR value of 6 per cent quoted by the author is virtually meaningless for want of information on the soil types.

The author doubts the value of the M9 aluminium mat for an aircraft runway, and suggests that "it should only be used after other alternative solutions, soil stabilization or dust palliatives, such as oil, have been tried and found infeasible". Better and lighter mats than the PAP used on the exercise are being developed by the USA and ourselves, and it does not seem likely that soil stabilization as such will provide an alternative to the mat in the foreseeable future. I agree, however, that there may be an urgent requirement for a dust palliative in places where membranes cannot be used, and it may be possible in some circumstances to employ a surface of bitumen and stone chippings.

It is certain, however, that there is at the moment no real alternative to the mat for soft ground conditions such as are found, world wide, on peat and sedimentary or alluvial clay. It follows that:—

(*a*) mats should be designed to be as light and as quick to emplace as possible. Also, to reduce the occasions on which they have to be used,

(*b*) the aircraft industry should be encouraged to produce STOL aircraft—as "S" as possible—with tyre pressures, wheel loadings, and undercarriages designed to permit the use of as rough, soft and undulating airfields as possible.

We at MEXE are doing our best with both these problems. We are in close touch with the Ministry of Aviation and the aircraft industry over the second, and are working on a research project aimed at giving aircraft designers some firm facts and figures from which they can design their landing gear to cope with relatively "unprepared" airfields.

The crunch, of course, comes in trying to put a meaning to the words "as possible" which are scattered about in (*a*) and (*b*) above, when the conflicting requirements of cost, aircraft aerodynamics, etc., are taken into account. Perhaps one of your readers can suggest a "break through" in this very intractable problem.

Yours faithfully,

(Sgd) R. A. Blakeway.

Major-General GH Addison CB CMG DSO

Memoirs

MAJOR-GENERAL G. H. ADDISON, CB, CMG, DSO, MA (CANTAB), MIMECHE, HON MISTRUCTE

COLONAL COMMANDANT RE (RETD)

PAST PRESIDENT—INSTITUTION OF ROYAL ENGINEERS

GEORGE HENRY ADDISON was born on 13 May 1876 the eldest son of Lieut-Colonel George William Addison, Royal Engineers, who was Inspector of Railways from 1894–99. He was educated at Wellington College and at the Royal Military Academy, Woolwich. For some time during his school days he studied at Dusseldorf where he learned to speak German fluently. Whilst at Woolwich he shared the Wellesley Exhibition and passed out with a prize for Drawing.

He was commissioned into the Corps on 1 October 1895 and during his Young Officers' Course at Chatham he represented the Corps at cricket and also at both Rugby and Association football.

In 1897 he was posted to the Bridging Battalion at Aldershot and he later served throughout the South African War with the battalion which took part in the main advance on Bloemfontein and Pretoria and operations in the Eastern Transvaal. In 1902 he returned with the unit to Chatham which later went to Aldershot.

From 1904 until 1909 he served at the Royal Military Academy, Woolwich, first as an Instructor and, during the latter part of that period, as a Company Commander, the first Sapper officer to hold such an appointment under the reorganization system.

A three-year tour of duty in Hong Kong followed in which Addison was both Officer Commanding the 25th Fortress Company RE and Divisional Officer. This his first introduction to "Works" aroused in him a profound interest in reinforced concrete construction. He was able to get away twice to Japan during his time in Hong Kong and, being a natural linguist, he quickly picked up a working knowledge of Japanese.

In 1912 he returned home to become Divisional Officer, Marlborough Lines, Aldershot where he was engaged on the construction of reinforced concrete buildings to the value of £100,000 a year. His mobilization appointment was as a Captain in the 23rd Field Company RE, then forming part of the 1st Division. He accompanied the 23rd Field Company to France in August 1914 as part of the British Expeditionary Force. He saw the War through to the finish on the Western Front, being in succession a Captain in the 23rd Field Company, Adjutant RE 1st Division, Staff Officer RE I Corps, Staff Officer RE Fifth Army, CRE 21st Division and Assistant Engineer-in-Chief at GHQ. He was the British Representative on the Armaments Sub-Committee of the Inter-Allied Armistice Commission which met at Spa on 12 November 1918 to arrange details for carrying out the Armistice conditions. In February 1919, on conclusion of the work of the Sub-Committee, he returned to GHQ until April when the Headquarters was finally closed. For his services in the war he was awarded the DSO in 1915 and the CMG in 1918. He was also made a Chevalier of the French Legion of Honour and was awarded the Belgian Order of Leopold and the Croix de Guerre, and the Russian Order of St Anne.

On his return home in May 1919 he was appointed as an attached officer to the Directorate of Fortifications and Works at the War Office to assist in the production of Volumes 5, 6 and 7 of the *History of the Corps of Royal Engineers* and to compile a series of nine volumes of the *Work of the Royal Engineers in the European War 1914–1918,* later published by the Institution of Royal Engineers, covering Works Services, Bridging, Military Mining, the RE Signal Services, Water Supply, Geological Work, Supply of Engineer Stores and Equipment, the work of the RE Experimental Sections, Camouflage, Searchlights, etc. The typescript of this vast work was just completed when in September 1920 Addison was sent to Cambridge where he became a Fellow Commoner of King's College to take charge of the first batch of Sapper officers sent to the University on their Supplementary Course and to act as a liaison officer between the War Office and the University authorities. He was also asked to submit a report on the course with a view to making it a permanent part of future Royal Engineer Young Officer training. Consequently he adopted the most simple but strenuous solution. He took the whole course himself and, although he had spent twenty-five years as a Sapper Officer with service in two major wars and the normal home and overseas postings in peace time, and when at school he had been a linguist and a classical scholar, he obtained a Second Class Honours Degree in the Mechanical Science Tripos after two years at the University. A Lieut-Colonel RE, aged 46, taking the Tripos in two years made a profound impression at Cambridge. In addition, as officer in charge of the YO classes, their successes at work and play drew congratulations from both Professor Inglis of Cambridge and Lord Cavan, then CIGS. Due to the excellent showing of those early Supplementary classes under Addison's inspiring direction and personal example, the University authorities became as enthusiastic as the War Office that the courses be continued for all young RE officers in future. They were so continued up to the outbreak of the Second World War.

After taking his degree Addison applied for full membership of the Institution of Civil Engineers, he had been an Associate Member since 1919. This was refused at the time after much discussion as it was ruled that the Charter of that Institution did not permit of a serving Regular Army Officer becoming a full member. This decision was changed later, but Addison resigned his Associate Membership. He was accepted as a full member of the Institution of Mechanical Engineers, and during the 1939–45 War he was made an Honorary Member of the Institution of Structural Engineers.

On leaving Cambridge he became in June 1923 CRE 1st Division and South Aldershot and he also acted as OC RE Troops Aldershot. After three years' hard work in that coveted appointment he became, in July 1926, a member of the RE Board where he re-wrote Military Engineering Part III Bridging.

On promotion to full Colonel he served as AAG RE from 1927 until 1930, an appointment which, in his own words, was the most interesting of his whole career although a most exacting one. Nevertheless he found time to write the classic article "Engineers Military" in the then new edition of the *Encyclopaedia Britannica* and a short history of the German Pioneer Corps.

In the summer of 1930 he was promoted Brigadier and made Chief Engineer, Aldershot Command; after a happy eighteen months he was promoted Major-General and, in December 1931, he received the appointment of Engineer-in-Chief India although he had never previously soldiered there. With customary thoroughness he learned Urdu on the sea voyage out to India where he landed in May 1932 at the height of the financial crisis. He found the Military Engineer Services a target for all both Military and Civil;

however, with the backing of Sir Phillip Chetwode, whom Addison had known well in his Aldershot days, everything was straightened out. He introduced Bills of Quantity with the necessary establishment of Surveyors of Works for the Military Engineer Services and had the Regulations for the MES completely re-written. The final result was that in 1936 the Government of India entrusted the Military Engineer Services with the complete rebuilding of Quetta, destroyed by the earthquake of 1931, a project estimated to cost over eight *Crores*, a very large item of the total Indian budget.

In the New Year's Honours List of 1933 he was created CB.

In March 1936, as he was preparing to retire at the age of 60, General Addison was pressed to stay on in India as an additional Financial Adviser (Military Finance) specially for the rebuilding of Quetta by the Military Engineer Services and for military works expenditure as a whole. Shortly after Addison had handed over his duties as Engineer-in-Chief the Financial Adviser fell sick and for eighteen months he shouldered alone the full responsibility for administering his Finance Branch of the Government of India. Such, however, was his resilience and ability to get through an amount of work that would have swamped others he found the time to be a most active President of the Simla Amateur Dramatic Club.

He returned home in 1938 to settle near Guildford; his period of restful retirement was, however, to be a short one for on 3 September 1939 he was recalled for duty as Inspector of Royal Engineers. He held that post for two difficult years when all types of engineer equipments were in very short supply.

On 30 March 1940 he was appointed Colonel Commandant RE in succession to Major-General Sir Henry Thuillier, KCB, CMG, and he completed his tenure on 13 May 1946. In 1941 he was elected President of the Institution of Royal Engineers in which capacity his great knowledge of the Corps was of the utmost value. Also during that year he finally retired from active Army employment and returned to his activities on the Board of Management of the Royal Surrey County Hospital, becoming Chairman in 1946. He was also on the Surrey Area Committee of the British Hospitals Association and Hon Secretary for Surrey of the Soldiers, Sailors and Airmans' Help Society.

In 1944 his Guildford house was destroyed by a flying bomb and General Addison had temporarily to leave Guildford and give up some of his local work and also that of President of the Institution of Royal Engineers. He returned, however, some seven months later and continued his duties with the Royal Surrey County Hospital.

General Addison married twice. On 7 January 1905 he married Margaret, second daughter of Robert Henderson, Esq, of Liss, Hants, who died on 21 October 1946. They had a son and a daughter who are now both dead. On 3 June 1947 he married Winifred, widow of Colonel A. D. Legard, 60th Rifles and daughter of Colonel Sir William Morriss, KCMG, CB, and Lady Morriss. She died in 1962. Since her death General Addison was looked after by his sister. He died suddenly at his Guildford home on 5 February 1964, aged 88 years, a truly venerable and outstanding Sapper officer.

General Addison's father was also an octogenarian when he died in 1937. He had been commissioned into the Corps in 1869 and he was still serving when his eldest son George Henry became a 2nd Lieutenant Royal Engineers. For seventy-two years (from 1869 until 1941) almost without a break an Addison, father and son, have served in the Corps—a most remarkable record.

Brigadier HTS King OBE

BRIGADIER H. T. S. KING, OBE

Horace Townsend Stuart King was born on 9 October 1896, the eldest son of Robert Stuart King of Rohika, Dharbhanga, India. He was educated at Clifton College and the Royal Military Academy, Woolwich and commissioned into the Royal Engineers on 27 October 1915.

After completing a war-time course at Chatham and at the Signal Services Training Centre he was posted to the Western Front where he joined 49 Signal Company RE in August 1916. In 1918 he served with XXII Corps Signal Company and in 1919 he returned home and spent a year at the Signal Training Centre at Maresfield.

The following year be began his Supplementary Courses at the School of Military Engineering, Chatham, and at Cambridge University, where he became an Undergraduate of Corpus Christi College and was awarded a Blue for tennis. At the conclusion of his Supplementary Courses he served at the School of Electric Lighting, Gosport, both as a pupil and later as an instructor, and at the Experimental Bridging Establishment, Christchurch. During the years 1922, 1923, 1925 and 1926 he played hockey for the Army side. As a tennis player, besides gaining a Cambridge Blue, he won the Army Singles Championship in 1924 and with L. C. Owen, the Army Doubles Championship also. He was a member of the Army team which won the Inter-Service Tennis Championship that year.

In 1926 he was posted to India as a captain and joined the Military Works Service first as Garrison Engineer Rawalpindi and later at Nowshera and at Peshawar. He took part in the 1930–31 North West Frontier Campaign.

On returning from India he became DCRE Belfast and in 1933 he was given command of 23rd Field Company then forming part of the 1st Division at Aldershot. In 1937 he was posted to Malta as DCRE Roads and Buildings.

On the outbreak of war he was recalled to the United Kingdom and went to France in command of a field company in the ill-fated 51st Highland Division. He managed to extricate his company from the German trap at St Valery and brought them safely back to England in June 1940. In September 1940 he was appinted CRE Bomb Disposal in the London Area, and he held that highly responsible and arduous post throughout the "Blitz" on the Capital.

In 1941 he was made CRE 45th Division and in March 1942 Chief Engineer XI and later of II Corps. From 23 September 1943 until 2 October 1945 he was Commandant the School of Military Engineering, then located at Ripon except for the Trades Training Wing which remained at Chatham.

In 1946 he was posted to Egypt where he became Deputy Engineer-in-Chief Middle East Land Forces. In 1948 he was made ADC to the King. His last appointment was Chief Engineer Scottish Command. He retired on 24 May 1951.

He married twice, firstly in 1926 to Kathleen Mary Darley, daughter of John Percy Stott of Cullybackey, Northern Ireland, who died in 1944. They had two daughters and a son. His second marriage in 1951 was to Rosemary Jennifer, daughter of Major F. R. Hedges of Wallingford Castle, Berks, and widow of Captain A. F. Wells, at that time she was a Lieut-Colonel WRAC, OBE, and a JP.

In company with seven other previous Commandants of the School of Military Engineering, he visited Chatham on 20 July 1962 on the occasion of the 150th Anniversary of the SME when the Royal title was bestowed upon the School.

Brigadier King died in the British Military Hospital in Hong Kong on 18 January 1964 after a stroke. He and his wife were visiting one of his daughters married to a Gunner Officer serving on the staff in Hong Kong. The funeral took place on 21 January in the Garrison Church, Victoria Barracks. A pall-bearer party of nine Royal Engineer Warrant Officers and Sergeants carried the coffin into and out of the Church and the service was attended by many officers and men and their wives of the Corps and by the Staff, headed by the Chief of Staff and the CRE Hong Kong. A cremation took place at Little Sai Wan Crematorium where his ashes were scattered. A Memorial Service was held at St Mary's Church, Wallingford, on 5 February 1964.

Brigadier King had an unusually analytical mind and applied this particularly to the games in which he excelled. He was, in consequence, an outstanding instructor, and it is not at all surprising that one of his daughters became a WRAC tennis champion.

He was a loyal friend and won the affection and admiration of all who served with him and accepted his high standards of conduct and intellectual honesty.

BRIGADIER E. H. KELLY, DSO, MC

EDWARD HENRY KELLY who died on 27 December 1963, aged 80 years, was the son of Major-General F. H. Kelly, CB, CMG. He won the Sword of Honour at the Shop and he was commissioned into the Corps in July 1902.

After completing the usual junior officer courses at Chatham he was posted to the Bridging Battalion RE at Aldershot where he spent a year. In 1904 he qualified at the School of Musketry, Hythe and the following year he completed an Advance Course at Chatham.

On posting to India in 1906 he joined the Depot Company of the Bengal Sappers and Miners at Roorkee. He served in both 1 Company and 3 Company, and with the former unit he saw active service during the Chitral campaign, and again during the Mohmand operations on the NW Frontier. In 1909 he became Adjutant of the Corps of Sappers and Miners at Roorkee. Shortly after taking up his duties, together with his Commandant Lieut-Colonel G. M. Heath, he tried to carry out a reconnaissance by night in a balloon during manoeuvres. Unhappily the balloon landed in "enemy" territory and both its occupants were "captured". Although he still had a year to go before promotion to Captain he was given command of 1 Company in November 1912.

On the outbreak of war in August 1914 Kelly was both in command of 1 Company and the officiating commander of 4 Company. He was not, however, to take either of these units overseas; he was instead transferred to the Headquarters of the Meerut Division as Assistant Field Engineer and he proceeded in that capacity to France with the Indian Expeditionary Force. On arriving in France his Division was soon in action and on 13 November 1914 he was transferred to 3 Company taking part in the battles of Neuve Chapelle and Festubert in the spring of 1915. For a most daring trench raid by night in which he was wounded Kelly was awarded the MC. He was also mentioned in despatches. In July 1915 he was given command of 2nd Field Squadron Bengal Sappers and Miners with the Indian Cavalry Corps and in January 1916, after the departure of the Indian Expeditionary Force from France, he became GSO3 in Headquarters V Corps. Later he became a Brigade Major to an infantry brigade and in September 1916 he was awarded the DSO for conspicuous gallantry in organizing the concentration of his brigade by night and for his personal direction of bombing attacks from a flank when the attack had been held up by uncut wire, as a result 1,000 yds of trenches were taken and 300 prisoners captured. Shortly after this exploit he was made GSO2 VII Corps, and in May 1918 he became GSO1 5th Army with the rank of Lieut-Colonel. Besides his award of the DSO and MC he was between 1915 and 1919 mentioned in despatches seven times.

After the war he was sent to the Staff College, Camberley, and on graduating from there he was posted to Chatham where he became Chief Instructor in Fortifications in 1922. In 1926 he was given a brevet colonelcy and posted to Headquarters London District. Two years later he was selected for the Imperial Defence College and on graduating from there he was posted to Army Headquarters India as Deputy Director of Military Intelligence. His last appointment was Brigadier General Staff, Headquarters British Troops in Egypt. He retired in July 1936.

In 1918 he married Helen Beatrice, widow of Major R. Carson, RA; they had no children. His wife died in 1953.

BRIGADIER D. CAMPION, CBE

DONALD CAMPION was born on 18 November 1898, the elder son of Bernard Campion, QC. He was educated at Marlborough College and the Royal Military Academy, Woolwich, and commissioned into the Corps in January 1918.

After a short war-course at Chatham he was posted to the Western Front in October where he joined the 84th Field Company, a company in the 20th Division then forming part of VII Corps. He saw service with the company during the "Advance to Victory" and with the Army of Occupation on the Rhine until the end of 1919.

On returning home he was sent on a course to the School of Electric Lighting, Gosport, and in the second half of 1921 trooping season he sailed for India where he joined the Bengal Sappers and Miners at Roorkee. From there he was posted as a company officer to the 5th Field Company at Rawalpindi. After a year in that unit he was sent to command the Chitral Platoon of the Bengal Sappers and Miners at Drosh where he spent another year to complete his overseas tour.

On returning home he completed his Supplementary Courses at the School of Military Engineering, Chatham and at Cambridge University. In January 1926 he became Adjutant of the 26th Anti-Aircraft Battalion (London Electrical Engineers) RE (TA), which appointment he held for four years before entering the Senior Wing of the Staff College, Camberley as a student. On graduating from Camberley he spent a year at Blackdown in the 1st Anti-Aircraft Searchlight Battalion RE before obtaining his first staff appointment as a GSO3 in the Military Intelligence Branch of the War Office in January 1933. A two-year tour of duty in that appointment was followed by another of two years as GSO3 at Headquarters Aldershot Command. In 1936 he returned to the War Office as a Deputy Assistant Master General of the Ordnance, a post he held until April 1940. He had been made a brevet major in 1936 and a brevet lieut-colonel in 1939, and with the war came rapid promotion. In 1941 he became a Brigadier and went to Washington as Deputy Director of the British Army Staff there and Senior Staff Officer of the Engineer Section of the British Military Mission charged with the procurement of engineer equipments and stores required by British Forces in all theatres of operations, a task for which his previous experience in the MGO Branch of the War Office well fitted him. At the end of the war he returned to the War Office as Director of Army Requirements, an appointment he held until his retirement in September 1946.

He was made an Officer of Merit USA in 1943 and created CBE in 1946.

During the late '20s and early '30s he frequently represented the Army at tennis. After his retirement he was a great supporter of the Royal Engineers Association and he was the Founder Member of the Northampton Branch. Recent ill-health, however, curtailed his REA activities.

In December 1923 he married Anne Joyce, younger daughter of John Martin, Esq, and Mrs Martin of Great Houghton Hall, Northampton. They had one son.

He died on 17 January 1964 at Stampton Lodge, Towcester, Northants in his sixty-sixth year.

BRIGADIER E. R. L. PEAKE, CBE, MC

Edward Robert Luxmore Peake was born on 9 October 1894, the elder son of T. P. Peake Esq, Indian Forest Service. He was educated at Cheltenham and the RMA Woolwich and commissioned into the Corps on 12 August 1914.

After a short course at Chatham he was posted within a year of being commissioned to the Western Front where he served throughout the war with RE Signal units. He was awarded the MC in 1915 and he was twice mentioned in despatches. At the end of hostilities he was an acting major commanding B Corps Signal Company RE.

In August 1920, after completing his Chatham courses, he was sent on Survey duty to the Gold Coast where he spent the next five years. This overseas tour was followed by a staff appointment with MI4 at the War Office where he became in 1928 a GSO2.

In 1930, with the temporary rank of Lieut-Colonel, he became the Senior British Representative on the Northern Rhodesian–Belgian Congo Boundary Commission. The work of the commission extended over three years and at its conclusion Peake was specially employed under the Ministry of Agriculture and Fisheries at the Ordnance Survey, Southampton.

From October 1940 to November 1941 he was Assistant Director of Survey, Home Forces. That appointment was followed by another tour of duty with the Ministry of Agriculture and Fisheries in the Ordnance Survey. In 1943, with the rank of Brigadier, he became Deputy Director-General Ordnance Survey a post he held until his retirement in October 1946. He was created CBE in the 1947 New Year's Honours List.

After retiring he was employed from 1947 to 1952 as Chief of Aeronautical Charts and Information Branch, International Civil Aviation Organization, Montreal, Canada.

He married Audrey Danvers Rutherford Hyde the daughter of Sydney Hyde Turner on 28 April 1928 at St Mark's Church, North Audley Street. They had a son and a daughter.

He died at Guildford on 27 April 1964, aged 69.

COLONEL A. D. CARDEN, DSO

ALAN DOUGLAS CARDEN died in Chippenham Hospital on 12 April 1964 in his ninetieth year. He was the fifth son of Major-General George Carden of the 5th (Northumberland) Fusiliers.

He was commissioned into the Corps on 12 December 1894. After completing his junior officer courses at Chatham he spent several years in submarine mining and electric light duties, serving with 34 Submarine and Mining Company RE at Gravesend (1897–1900), then at the School of Military Engineering, Chatham as an Assistant Instructor in Electricity (1900–1905) and finally in command of the West India Submarine Mining Company RE at Jamaica. In 1906 when submarine mining duties were handed over to the Royal Navy Carden joined the 44th Fortress Company RE, also stationed at Jamaica, as officer-in-charge of defence electric lights.

On returning from the West Indies in 1907 Carden became associated with military flying. His first appointment was Assistant Superintendent at the Balloon Factory, South Farnborough (now the Royal Aircraft Establishment). He was one of the "crew" of the *Nulli Secundus*, the first military airship, when it flew in its remodelled form in 1908. He was from 1910–13 also closely connected with the development of powered aircraft becoming one of a private syndicate of three, including Colonel J. E. Capper and the Marquis of Tullibardine, which endeavoured to develop for military purposes a monoplane designed initially by Lieutenant J. W. Dunne of the Wiltshire Regiment who had been invalided from the Army after the South African War. This officer had also developed gliders which showed a remarkable degree of inherent stability in flight. Lack of funds available to the syndicate prevented their final development of the Dunne aircraft. Carden, however, gained his pilot's certificate by flying this type of machine. The French manufacturing rights of the aircraft were eventually acquired by the Astra Company and the British rights were bought by Armstrong Whitworth and, although neither firm actually pursued the development of the Dunne aircraft at the time, some of the ideas incorporated in its original design have been re-used in the tail-less type of aircraft with swept-back wings being developed today. When the Air Battalion RE was formed in 1911 Carden was given the appointment of Experimental Officer. With the formation of the Royal Flying Corps on 13 May 1912, the Air Battalion RE was disbanded, many of its personnel being absorbed into the newly-formed Corps. Carden, while still remaining a Sapper officer, stayed on at Farnborough and in August of that year he was made a Squadron-Leader RFC with the temporary Army rank of Major. He remained with the Royal Flying Corps (renamed Royal Air Force in 1918) throughout the First World War, rising to the rank of Wing Commander/Lieut-Colonel, and for his services he was awarded the DSO.

In July 1919 he returned to Royal Engineer duties as E and M officer to the Chief Engineer Western Command at Chester. In January 1921 he was posted to the Central Engineering Board at the War Office and he became a Member of the RE Board. On promotion to substantive Lieut-Colonel in 1921 he was given command of the 1st AA Searchlight Battalion RE, then stationed at Blackdown. He held that appointment for three years after which he returned as a Colonel to the RE Board at the War Office. He retired in August 1930.

He married, on 2 January 1913, Nie Constance Mary, widow of Captain

J. D. Dauncey the Dorsetshire Regiment, only daughter of Dr Lithgow of Farnborough and grand-daughter of Colonel the Honorable Ernest Curzon, 52nd Oxfordshire Light Infantry, son of the 1st Earl Howe. His wife died in May 1949.

A younger brother, Lieut-Colonel E. D. Carden, OBE, the famous Sapper athlete, who was one of the pioneers in the introduction of wireless into the Army, died two years ago, aged 79 years.

CAPTAIN W. H. LIVENS, DSO, MC

Captain William Howard Livens who died in a London hospital on 1 February was well known as a gas expert in the First World War. He was educated at Oundle and Christs College, Cambridge. He was an expert shot, being Captain of the University Rifle Team and a member of the English Eight Rifle Team.

He was among the first temporary commissioned officers to enter the Corps in 1914. After serving in France as a divisional signal officer, he transferred to Brigadier C. H. Foulkes' Special Brigade RE in 1915 where his expert knowledge of both engineering and chemistry and his inventive genius, powers of improvisation and drive were invaluable in the development *ab initio* of gas warfare—the task allotted to the Special Brigade. His chief invention was the "Livens Projector" which he developed with his father, a one-time Vice-President of the Institution of Mechanical Engineers and chief engineer of Messrs Ruston and Hornsby.

The weapon consisted basically of a welded steel tube from which gas canisters could be projected, the projectors could be fired electrically in large numbers simultaneously. The bursting canister produced a highly lethal concentration of gas. At the Battle of St Quentin in March 1918, 3,000 Livens Projectors, each projecting 30 lb of phosgene, were fired simultaneously into the German trenches. He also developed flame-throwers used during the Battle of the Somme. Many of the stories about how he boldly cut through red tape and adroitly obtained top priority for his projects have become almost legendary.

LIEUT-COLONEL L. V. S. BLACKER, OBE, TD, AFRÆS

Lieut-Colonel Latham Valentine Stewart Blacker who died at the age of 76 years on 29 March, was the inventor of four "Spigot" weapons that helped to win the Second World War, namely the spigot mortar (Blacker Bombard), the PIAT anti-tank gun, the AVRE Petard and the Hedgehog anti-submarine weapon. More recently he developed a jet for the Bloodhound missile and an "anti-bandit" weapon used by the police.

Colonel Blacker on leaving the RMC Sandhurst was commissioned into the QO Guides, Indian Army in 1909. He qualified as an aeroplane pilot in 1911. He served in the First World War in France with his Regiment and with the Royal Flying Corps. He was twice wounded. After the war he served in the Trans-Caspian Campaign and in the Afghan War of 1919 and in other operations on the NW Frontier. In 1933 he was chief observer of the Houston Everest Flight Expedition which made two successful pioneer flights over the mountain, in 1935 he was promoted Lieut-Colonel in the 58th Sussex Field Brigade RA.

Blacker's inventive genius was described by Norman Kemp in his book *The Devices of War* published in 1956 and reviewed in the December 1956 issue of the *RE Journal* by Major-General B. T. Wilson. In a letter to the Editor, published in the March 1957 issue of the *Journal*, Colonel Blacker wrote:—

"Your reviewer, in his recent notice of *Devices of War*, was good enough to make some kind remarks about myself. He quite correctly referred to me as a Guide.

All the same, I feel it a duty to the Corps of Royal Engineers to tell your readers that the four 'Spigot' weapons of the 1939/45 War, the 'Bombard', the anti-submarine 'Hedgehog', the 'PIAT' and the 'Mortar, recoiling Spigot', alias the 'Petard', were the culminating fructifications of a germ implanted in 1904/05 by four attested Sappers of the East Anglian Royal Engineers. Their leading spirit was, afterwards, Lieut-Colonel G. L. Ritchie, Royal Scots Fusiliers; another was, rather later, the Right Reverend the Bishop of Blackburn and another myself.

The mortar then developed was inspired by the wooden, or bamboo weapons used by the Japanese in Manchuria. Closely resembling it were those mortars for jam-tin projectiles extemporized in Flanders, notably by the Royal Bombay Sappers and Miners. The 'hollow-charge' of the PIAT owed something to the instruction imparted to us of the Cavalry and Infantry, in Peshawar in 1909 by the Subaltern of No 3 Field Coy, Bengal Sappers and Miners, P. C. S. Hobart, who told his hearers about the 'Monroe' effect and plastic HE.

The wheel came full circle in 1944, when that subaltern became the Commander of the 79th Armoured Division, whose Royal Engineer Assault Regiments in Normandy used, and expressed their gratification with, the 'Petard', and its 'Flying Dustbin', the fourth of this series of low velocity but very high-powered weapons. The 'Petard' of the AVRE was, indeed, almost a much enlarged PIAT. The Army owed, as so often, a debt to the support of the unconventional, by the Royal Engineers."

Book Reviews

NEITHER FEAR NOR HOPE

By General F. von Senger und Etterlin
(Defender of Cassino)
(Published by Macdonald & Co Ltd (Publishers). Price 40*s*)

The author of the book under review is General von Senger und Etterlin, who is best known to British soldiers as the German Commander at Cassino in the Italian Campaign 1943–44. He was born into a Roman Catholic family in South West Germany; and, after a liberal education that included a Rhodes Scholarship at Oxford, he was commissioned into the German Army as an infantryman in 1914. Between the wars he served in a horsed cavalry regiment and in 1939 was given command of the only existing cavalry brigade in the *Wehrmacht*. He had never been to the Staff College, which was the normal stepping stone to high command in the German Army; but he was made of the stuff that shines in battle and promotion came to him steadily. He fought in the French campaign; then in Russia in 1942–43; in the Mediterranean theatre after that; and at the end of hostilities in Europe was commanding a Corps in Italy.

The theme throughout the book is the dilemma of a man with a cultivated mind and a wide international outlook serving a régime of which he did not approve, but caught in a war which patriotism compelled him to wage. He tells us how, when France fell, his wife wept. The victory over France gave Hitler's ambitions an impetus that could only end in ruin. If Hitler won the war, European civilization would vanish from the face of the earth: if Hitler lost, Germany was doomed. It was a proposition which could not inspire hope; nor in a stout heart must it give rise to fear. Hence, presumably, the title *Neither Fear nor Hope*. (The German title is different.)

This dilemma in the mind of the author is the dominant but not the only interest: the reader is certain to be interested in the man himself. He was not of the professional military caste; and even in the British Army he would be regarded as a man of wide interests outside his profession—architecture, beauty, scenery, history and music all attracted him. But none of these things diverted him from a proper understanding of the profession of arms. He writes with understanding on many military problems both great and small.

There are fascinating pen portraits of many German personalities, including Hitler. We get telling glimpses of Kesselring and other well-known military figures, as well as lesser men such as the author's batman, or his friend General Baade, who must have been an original character. (Baade habitually wore a captured kilt over his riding breeches, and was thought at one time—incorrectly as it happens—to have accepted an invitation on Christmas Eve to dine with the enemy.) Thus human interest is imparted throughout.

The military reader will also be interested in the strategical and tactical musings of the author. He shows how circumstances have altered the role of the commander; how better communications have reduced his freedom of action; and how, in the German Army, a "faith in the Führer" was sometimes regarded as a better passport to high command than professional skill. He reflects upon leadership at lower levels; and pays tribute to the courage that was shown by so many on both sides in the bitter struggles for Cassino.

He gives his views on armoured warfare, organization, staff work and on "Infantry, the Queen of the Battlefield". It is not possible in a review to present the author's conclusions; the reader must seek them for himself. He will never be bored, though he may not be in complete agreement.

There is one phrase that requires more explanation than it gets: the author frequently refers to a "Council of War", particularly in the section on the "Cassino Battles in Retrospect". This phrase is anathema to the British soldier and one would like to cross-question the author on some aspects of the subject. For instance (on p. 221) comes the following passage: "Neither the corps commander nor even the army commander play any more significant part in such a council than the local expert who puts his proposals to the vote and must act according to the council's decision". Your reviewer never beheld anything like this in our army either in defeat or victory; and one would like to hear more.

The tale the author tells is linked throughout by the thread of his own doing. Naturally there is much military detail such as the moves of corps, divisions and regiments, and accounts of actions great and small that came within the author's view. These are for soldiers only; but many passages will interest the civilian reader too.

The end of the books tells of the author's experience in defeat and as a prisoner of war in South Wales. He does not recriminate; and one hopes that we were not too corrupted by victory to be devoid of all chivalry.

The translator, George Malcolm, is to be congratulated. Liddell Hart contributes a typically lively foreword. The maps are adequate and the photographs good. Altogether, a good book though rather a costly one; easy to read and interesting throughout.

M.C.A.H.

THE MARCH ON DELHI

By A. J. Barker

(Published by Faber & Faber. Price 42*s*)

As if to make up for the "Forgotten" years, the five months, February to July 1944, which saw the siege and relief of Imphal, the epic of Kohima, and the turn of the tide of Japanese success on the mainland of Asia, have in recent times received their fair share of publicity. In *The March on Delhi*, Colonel Barker takes us once again over the now familiar terrain, but this time with a welcome difference. Gone are the chummy, "I was there", blood-and-mud clichés of which we have long since tired; and in their place this author presents a workmanlike picture of the operations viewed as a whole, and not only from our side of those hills, but from that of the Japanese also. His approach includes a foreword from the pen of Lieut-General Mutaguchi, at that time Commander of the 15th Japanese Imperial Army, which attempted the invasion of India, and so nearly succeeded; as well as a short course of instruction in the "Bushido" code of military honour which motivated our enemy and sustained his efforts beyond rational limits.

Beginning with a review of the situation in the Far East generally at the start of that year, Colonel Barker traces the development of the Japanese plan for the capture of Imphal, which so alarmingly disrupted our own preparations for the re-conquest of Burma; and describes the counter-measures hastily improvized to meet the threat to India and to the vital allied link with China. That *The March on Delhi* was not then intended to advance beyond Imphal, and that the all-highest Japanese Command refused permission to follow-through their initial gains at Kohima and to drive on to a "pretty defenceless" Dinapur, is perhaps the most exciting of the revelations from the other side of the hill. As in Malaya two years earlier, the Japanese seem to have been surprised at their own achievement, but fortunately less ready here to adapt their plan to changed circumstances, and to exploit unexpected success to the limit.

The ensuing actions and reactions in and around Imphal, Ukhrul and Kohima, as well as those farther afield in the Arakan, Lushai Hills, Northern Burma and on the Ledo Road, fall into place in a consecutive and related narrative which other pens have often made less clear and sometimes wholly confusing. The author is to be congratulated on the composition of this tapestry and on the balance of background and detail with which he fills it—a task complicated by the wide dispersion of effort in this war of detachments, made doubly successful by the skilful interweaving of the authentic Japanese thread. What a pity that he supports it by somewhat inadequately planned mapping, and by such a meagre selection of not too well reproduced photographs.

Of the players in this vast scene and of their exploits, from the top-brass on each side to the humblest *Jawan*, Colonel Barker reports convincingly. The reader can have nothing but respect for the individual courage, skill and discipline of our enemy; nothing but renewed admiration for the resilience, determination and endurance of British, Indian and Gurkha alike in conditions probably unequalled in any other theatre of the Second World War. Alone of the participants the much vaunted INA do not come well out of this analysis and there is little sympathy to be found for them—rather for the Japanese Commanders, to whom their presence must at times have proved more of a hindrance than a help.

The part played by the Air, and obviously by air transport in particular, receives its due; but one is led again to wonder at the optimism of an enemy committed, at that period in the history of warfare, to such a formidable task with wholly inadequate air support. Had the Japanese air force been present in effective strength, the story might indeed have been different.

For the Sapper there is little here of technical interest and Engineers are hardly mentioned, though their contributions on both sides was clearly both continuous and gruelling. It is probable that nowhere in the history of the Corps, of the Indian Engineers and of the three Corps of Sappers and Miners, have their units been more consistently and unremittingly engaged in what is so frequently mis-termed "the infantry role". In the engineer context the reader may from time to time be misled by the author's loose employment of the word "road" to describe what were at best fair-weather bridle-tracks, at worst shelves of sliding mud in the flanks of the hills.

There is a comprehensive index, a well set-out Order of Battle, and an Appendix of biographies of the principal characters in the play. *The March on Delhi* offers a most readable and professionally reliable account of a struggle which was, in fact, rather more than the "glorified boy-scouting" as which it was seen by at least one senior commander distinguished in the European Theatre.

L.E.C.M.P.

ELEMENTARY PHOTOGRAMMETRY

By D. R. CRONE, CIE, OBE, MSC

(Published by Edward Arnold (Publishers) Ltd, 41 Maddox St, London W1. Price 28*s*)

This book is intended for use by students studying for a degree in Civil Engineering as a background text to the practical part of the photogrammetry course. In particular the book relates to the course given to third-year students of Civil Engineering at the Queen's University of Belfast.

In his introduction the author tells us that the scope of a civil engineer's knowledge of photogrammetry should include at least three aspects. Firstly, he must know what to specify as his requirement for photogrammetric survey. Secondly, he must be able to assess the merits of offers by firms tendering for a particular task, and this involves a knowledge of different techniques as well as accuracies and tolerances. And thirdly, he must be able to derive other information from the photographs besides that which the contractor will extract for him.

To cover adequately this ground alone would require far more space than the author has allowed himself and he has, therefore, confined himself to basic principles aimed at a general understanding of the subject in accordance with his own definition of a civil engineer's requirements. The general approach is to devote the first few chapters to theoretical considerations, in particular the fundamental geometrical propositions forming the basis of the subject. The rest of the text deals with practice, including drawing office equipment and methods and concluding with a short historical summary. The absence of complicated mathematics will no doubt be to the liking of many readers although the statement that the text has been written assuming a knowledge of mathematics not beyond the General Certificate of Education at Ordinary Level is somewhat apocryphal.

The average student should not find this book difficult to follow. It is presented in a clear, logical manner and is illustrated with well-drawn diagrams. The notation is based on British Standard 1991 Pt I 1954, and is clear and consistent throughout, which is indeed a blessing when trying to follow diagrams and formulae. The printing is excellent and the bibliography, though limited to related works in English is adequate, up to date and clearly referenced.

A striking characteristic of the three chapters dealing with perspective theory, theory applied to surveying and drawing office methods is the author's propensity for careful analysis. He examines the changes in the inner and outer perspective due to the change in attitude of the aircraft at each exposure station and then analyses the effects of these changes on scale relationships, angular relationships at the various perspective centres and heights of points in the focal plane. He derives expressions for these relationships which can be readily evaluated using any combination of assumed values. This is all sound, basic material and essential to a proper understanding of photogrammetry at a more advanced level.

The main criticism of the book concerns the inclusion of certain theoretical aspects and practical methods which are not likely to be encountered in practice nowadays and might, therefore, have been omitted. Examples of this are those paragraphs in chapter 2 (perspective theory) on the graphical construction of a perspective grid and the construction for common convergence.

Again, in chapter 8 which deals with drawing office methods, it is most doubtful whether the descriptions given of the spatial resection of a single photograph, mapping from single photographs and from high oblique photographs are worth including nowadays.

On the other hand certain items have been omitted which many will consider are the concern of the civil engineer, for example, there is nothing on photographic interpretation or photo mosaics. Chapter 5, on the subject of the photographic task, seems incomplete without the addition of a typical set of calculations such as need to be prepared when planning a photographic task, including the choice of lens and B/H ratio.

Finally, a special word on chapter 9 which deals with stereo plotting machinery. Students may well find the somewhat abbreviated descriptions of precise stereo plotters insufficient for a clear understanding of the principles of operation. The diagrams cannot be faulted but after reading the descriptions of the C8, A7, A8 and the Thompson-Watts plotter one is left with only the most vague conceptions. Since photogrammetric plotting machinery is of the greatest value to engineers either when contours are required or for making precise measurements it seems a pity that more space could not have been devoted to a fuller description of them and to the factors governing the choice of instruments for particular projects.

Summarizing, this book will be a worthy acquisition for the libraries of those universities and teaching institutions which are concerned with teaching the fundamental principles of photogrammetry, and although intended primarily for civil engineers it will be valuable alike to air surveyors and cartographers whose concern is the making of topographic maps and plans from air photographs.

P.C.S.

NONCONSERVATIVE PROBLEMS OF THE THEORY OF ELASTIC STABILITY

By V. V. Bolotin

Corrected and Authorized Edition

Translated from the Russian by T. K. Lusher and English Translation edited by G. Herrmann of Northwestern University, Evanston, Illinois

(Published by Pergamon Press, Headington Hill Hall, Oxford. Price 60*s*)

Due to technological advances made in the past ten years a number of previously unknown phenomena have made themselves apparent with the growth of knowledge in respect of elastic instability under aerodynamic forces, "follower" forces, and the associated forces of inertia and friction.

Most of these phenomena have been discovered in an international field of research and the dissemination of information concerning them has, hitherto, been just as wide in the manner of its publication.

This book is an attempt by Professor Bolotin of Moscow to present in a unified form the nonconservative problems of the theory of elastic stability which have developed since the original subject works of Euler, which in themselves are limited in their range of application.

Aerodynamic and hydrodynamic loads, the forces acting on parts of turbines and electric machines, and the loads induced in parts and linkages of automatic control systems are in most cases nonconservative forces, and the problems they pose lie mainly in the development of present-day mechanical, aeronautical and rocket engineering.

The book contains an introduction and four chapters. The first chapter covers general problems, their formulation and methods of solution. The remaining chapters are given over to applications and the study in detail: the stability of elastic systems which, during the process of loss of stability under the action of nonconservative forces, behave according to some predetermined law (so-called "follower" forces); the stability of high-speed rotating elastic rotors under hydrodynamic and electric forces and internal friction etc; stability of elastic systems in high-speed gas flow; supersonic flutter of elastic plates and shells. Some of the problems are considered in non-lineal form after the loss of stability.

A short chapter at the end of the book outlines a number of suggested directions for future research.

This well-produced book, comprising some 300 pages, is highly suitable for reference by graduate students, scientific workers, and design engineers dealing with structural stability, aeroelasticity, high-speed rotating machinery, vibration analysis, and the theory of oscillators.

F.T.S.

FATIGUE RESISTANCE

By P. Ye Kravchenko

Translated from the Russian by O. M. Blunn

Translation edited by N. L. Day, BSc (Eng), PhD, AMIMechE

(Published by Pergamon Press Ltd, Headington Hill Hall, Oxford. Price 30*s*)

This textbook was first published in the USSR in 1960 and a revised edition was issued in 1962. American and British scientists recommended the Pergamon Institute to publish the book in the English language because of its practical value to engineers and technicians employed in engineering design and development.

In spite of the fact that fatigue failure has been studied since 1919, and the literature printed on the subject is extensive, only scant references to the subject are made in English text books on Strength of Materials. Graduate students will, therefore, find this book extremely useful, particularly the preface that outlines the growth of experience, experiment and knowledge of the subject in Western countries.

Commencing with the definitions "that metal fatigue is defined as the gradual failure of a metal under the action of cyclical stresses; and that metals which are able to withstand a large number of cyclical stresses without failure are said to have a high fatigue or cyclical strength", chapter 1 details the main types of cycles and their criteria, test equipment, the method of testing, the production of fatigue curves and maximum safe stress diagrams.

Chapter 2 deals with the theory of metal fractures and their external appearance; whilst chapter 3 studies the factors that effect the endurance limit under symmetric cyclical stresses. The ways of improving the fatigue strength of engineering components are discussed in chapter 4, and these cover the principles of production design and technology. Chapter 5 is devoted to the fundamentals of endurance limit analysis for the determination of the reserves of strength under symmetric and non-symmetric stress cycles or a combination of bending and torsion.

Two appendices present tables of the mechanical properties of grey iron and certain steels, and the values of various coefficients used in fatigue calculations.

As the book was originally intended for students taking the USSR training course "Strength of Materials" references are included which refer to Soviet Standards and testing machines.

This 110-page book is well produced and the type is easy to read. Most of the text is descriptive in nature.

F.T.S.

TELEMECHANICS

By V. S. Malov

Translation from the Russian by F. Immirzi

Translation Editors: B. Meltzer and G. E. Walker

(Published by Pergamon Press Ltd, Headington Hill Hall, Oxford. Price 35*s*)

Telemechanics may be defined as the branch of engineering science that deals with the theory and practice of transforming and transmitting over a distance the information required remotely to operate and control the apparatus and equipment employed in production processes, utility services, transport, flight and other specialized applications.

This book, Volume I of the Pergamon International Series of Monographs on Automation and Automatic Control, presents the basic concepts and definitions of telemechanical systems, and the theory of telemechanical signals, telemetering systems, and remote-control and remote-signalling systems. It does not contain descriptive references to any specific telemechanical apparatus, Russian or otherwise.

The text on telemechanical systems is largely devoted to an explanation of the comparatively new theoretical branch of science *information theory*, its probability and mathematical statistics. The section dealing with telemechanical signals covers the nature of signals used in the transmission of messages and differentiates between continuous and discrete signals, modulation forms, codes with enhanced noise-immunity and the methods used in the separation of signal elements. Telemetering, that is the long-distance transmission of monitored meter readings, is discussed in some detail for systems using continuous or discrete signals, or multi-channels. The operational principles of remote control and remote-signalling systems are given, together with descriptions of the more important units used in the functional stages.

The text is mainly descriptive and well illustrated with generic block diagrams and circuits. Although condensed into 100 pages it is sufficient to enable the non-specialist engineer to obtain a fair knowledge of this particular branch of engineering.

A number of appendices provide: A table of Binary Numbers; a table of Logarithms Base 2 for numbers 1–50; and Frequency Spectra of Certain Signals.

F.T.S.

SOME PROBLEMS IN THE THEORY AND ASSESSMENT OF TURBO-JET ENGINES

By K. V. Kholshchevnikov

Translated from the Russian by Wm E. Jones, UK, Atomic Energy Authority

Translated edition by Dr B. P. Mullins, Deputy Chief, Scientific Officer, Ministry of Aviation, Farnborough

(Published by Pergamon Press, Headington Hill Hall, Oxford. Price 35*s*)

This text-book is Volume 4 of Division III in the Pergamon International Series of Monographs in Aeronautics and Astronautics which deals with propulsion systems including fuels.

The text, which develops from first principles the basic general theory of the design and performance of turbo-jet engines, is presented mathematically and consists entirely of algebra that is suitable for first and second year technical college students of aeronautical engineering.

The book has two chapters. The first expounds the general problems of the theory of turbo-jet engines in relation to initial equations and conditions of thrust, specific thrust, and specific fuel consumption; also the optimum thermodynamic parameters for determining minimum fuel consumption, optima of gas temperature and expansion ratio, and special features evolved by the use of reheat chambers. The second chapter covers the selection of engine parameters for rated flight conditions taking into account aerodynamic and design data for the compressor and turbine.

The text is illustrated by a number of graphs and the book is excellently produced.

This volume will be of particular interest to performance engineers employed in the turbine industry and students of aeronautics and astronautics. It is also suitable for reference use in technical libraries.

F.T.S.

PROBLEMS OF THE DESIGN AND ACCURACY OF COMPLEX CONTINUOUS ACTION DEVICES AND COMPUTER MECHANISMS

Edited by N. G. Bruyevich

Translated from the Russian by Gerald Segal

English Translation Editor: A. M. Andrews, PhD

(Published by Pergamon Press Ltd, Headington Hill Hall, Oxford. Price 70*s*)

This is Volume 8 of the International Tracts in Computer Science and Technology and their Application, as published by Pergamon Press. It contains a collection of monographs dealing with aspects of the design of mechanical and electro-mechanical analogue computing devices. All the papers are by leading Russian scientists and are written on the basis of research carried out by the authors in 1955–56.

The term "devices" used in the title refers to the mechanisms and electrical networks within a computing instrument or machine. Such devices may be either primary or complex. The primary devices are those which carry out the elementary mathematical operations of addition, subtraction, multiplication, and division, raising to a power, integration, differentiation etc. The choice of primary devices determines the complex devices that can be obtained by combination to solve any prescribed mathematical or logical function.

Each of the papers is quite separate, but the book is divided into two parts.

Part I, comprising three papers, deals with:—

The problem of the Inputs and Outputs of Complex-action (ie "analogue") computer devices. (The inputs of a device are those elements of the mechanism or circuit to which the energy from an external source is fed. The outputs are the elements of the mechanism, or the electrical circuit, from which the energy is transmitted to other devices or circuits.) The design of computers for the calculation of Implicit Functions by the Method of Approximations.

Random processes in the problem of the accuracy of mechanisms.

Part II consists of seven papers each dealing with an investigation of the accuracy of the following Standard computer mechanisms:—

The effect of Servo Systems upon the accuracy of performance of an Automated-Differentiating Friction Mechanism; a non-Automated Friction Mechanism; the Cardan Transmission; a Conoid Mechanism; Mechanisms with a Variable Transfer Ratio, and Transmission by Cylindrical Toothed Wheels and its improvement by means of adjustment.

These papers are perhaps of little use to graduate engineers wishing to learn the basic operating theory and mechanisms of computers and their practical application; but designers and manufacturers of instruments and other intricate mechanisms will find a wealth of information in the experimental data given in the individual papers and their associated graphs, tables and diagrams.

F.T.S.

BEAMS AND FRAMED STRUCTURES

By JACQUES HEYMAN, MA, PhD, AMICE

(Published by Pergammon Press. Price *17s 6d*)

This is a textbook on the analysis of relatively simple indeterminate structures. In addition to all the common elastic methods of analysis, there is a section on plastic methods; the solution of the moments in beams, portals and simple multi-storey frameworks is considered with each method.

Much space is devoted to the development of equations and relationships and the book appears to be written for the student rather than for the practical engineer. There are several worked examples, most of which are treated algebraically and yield formidable solutions.

The print is well spaced and easy to read; the page size, however, is only octavo, with wide margins, so that it is too often necessary to turn back a page to refer to previous equations in any section.

J.C.P.

CONCRETE FINISHES AND DECORATION

By H. L. CHILDE

(Published by Concrete Publications Ltd, 1963. Price *18s*)

This is a completely revised edition of an earlier book in the well-known Concrete Publications series. Whilst the subject is not one to have much application for the military engineer under field conditions, it does give sound information for use when more importance can be given to the appearance and standard of finish of a concrete surface.

The first chapter in particular is of general value and gives much good advice on ways of ensuring a good clean surface, free of blemishes, when a plain finish is required. This could well be studied by everyone responsible for the design and construction of formwork, whether in timber or other materials.

Other chapters cover, with numerous examples, such aspects as exposed aggregate finishes; the use of precast slabs as shutters; reconstructed stone; terazzo; ways for laying special facing layers to walls; precast slab and block walls, etc. The use of shaped plastic and rubber forms, which are becoming so popular for giving relief to concrete surfaces, is also described.

The book is well illustrated with numerous photographs showing examples of different finishes. It should be of value to architects and engineers, especially those responsible for work in both precast and *in situ* concrete work.

J.C.P.

RECENT TRENDS IN THE DEVELOPMENT OF THE THEORY OF PLASTICITY

By Professor W. Olszak, Dr Z. Mroz and Dr P. Perzyna

(Published by Pergamon Press Ltd, Headington Hill Hall, Oxford. Price 50*s*)

This book, originally published in Poland during 1963, is an incomplete survey of the contemporary trends in the development of the theory of plasticity based on a number of lectures given by authoritative scientists on various aspects of the subject in Budapest, Grenoble, Hanover, Moscow and Vienna. The survey contains those matters which, in the author's opinion, are typical and decisive for the future development of the theory.

The subject matter is presented in three main parts: In the first a review is made of the research work done on the laws relating to the kinematical elements of the strain-rate tensor, and strain accelerations of higher orders, to the dynamic elements of stress rate and stress accelerations. Treated separately are the small and finite strain problems, and the uniqueness problem and the extremum theorems are also reviewed. Numerous experimental investigations are discussed to try and establish the basic physical foundations of the theoretical structure of the modern plasticity theory to secure as close an approach to reality as possible

Part two is concerned with the applications of the theorems to the problems of limit analysis and limit design; the adaptability of structures and the shake-down problem; three dimensional and axially-symmetrical problems, the boundary layer, effects of non-homogenity, and the theory of granular media. The third part describes some recent work on dynamical problems of the theory of plasticity, and concludes with some critical remarks and discussions on future developments.

An outstanding feature of this book is the large bibliography given at each chapter end which cover an international range of further reading.

The subject matter is very advanced and only suitable for reference by qualified engineers specially employed on structural design work.

F.T.S.

EFFECT OF MANUFACTURING TECHNOLOGY AND BASIC THREAD PARAMETERS ON THE STRENGTH OF THREADED CONNEXIONS

By A. I. Yakushev

Translated from the Russian by S. H. Taylor

Translation edited by the Staff of the National Engineering Laboratory

(Published by Pergamon Press Ltd, Headington Hill Hall, Oxford, in association with the Department of Scientific and Industrial Research. Price 50*s*)

This book, a translation of the original volume published in Moscow during 1956, sets out the results of the author's investigations to determine the effect of the parameters and manufacturing technology of a metric fastening thread on the strength of threaded connexions.

In his foreword the author states that the investigations made by "foreign" engineers on the design and manufacture of threaded connexions have been incomplete and the findings erroneous; and claims that his experiments prove that it is not the production of a high-class "fit" (normally regarded as essential in highly-stressed machine parts) which ensures satisfactory fatigue strength of threaded connexions, but the guaranteed clearances. A number of design and manufacturing recommendations are given in support of his findings. He also states that a quantitative relationship exists between surface quality and the technological conditions of manufacture and the effects of this quality on the fatigue strength is stated.

The text, some 250 pages long, covers with typical Russian thoroughness most of the aspects of the design and manufacture of threaded connexions and, as a large percentage of the parts of modern machines are threaded, it is worthy of study by designers and production engineers.

F.T.S.

ELEMENTARY THEORY OF ELASTIC PLATES

By L. G. JAEGER

(Published by the Pergammon Press Ltd. Price 17*s* 6*d*)

This is Volume 2 of the Structures and Solid Body Mechanics Division of the Commonwealth and International Library of Science, Technology, Engineering and Liberal Studies, and is published as a paper back booklet.

The simplest method of design for a plate or thin slab is to consider it as a series of beams of unit width placed side by side. This is inaccurate and does not approximate to the actual behaviour of a plate, which is far stronger than such an analysis shows it to be. If the slab is curved or cranked it is even stronger, and spans of 80 ft are built with hyperbolic parabaloid reinforced concrete slabs only three or four inches thick. If a more rigorous analysis is attempted, the elastic theory designer finds that he must master complicated, tedious, mathematical relationships. These give the elastic or lower bound solutions, which are so complex, that the engineer prefers to use the upper bound solutions based on yield line theory. However, the two methods are inter-related and the design engineer should understand both.

The book gives a good introduction to the elastic methods, and the author has selected subject matter which is most likely to interest the engineer. To follow the working the reader must be familiar with elementary calculus and differential equations though a valuable appendix of relevant mathematics is included. The first three chapters evolve the basic theory and apply it to rectangular plates with various boundary conditions. The circular plate is dealt with in a similar manner. A chapter on potential energy methods and another on the membrane analogy make up the remainder of the book. There is a summary at the end of each chapter which is an excellent innovation. There is a set of examples for the reader to solve. Despite the clear lay-out and well worked examples few engineers would read this book to get an insight into the subject because the treatment is too mathematical. If one has to study the subject then one might read it, but 'Theory of Plates and Slabs' by Timoshenko deals with the subject better and in greater detail.

R.D.P.B.

DIMENSIONING FOR INTERCHANGEABILITY

By L. P. WAKEFIELD, MIED

(Published by Pergamon Press Ltd, Headington Hill Hall, Oxford. Price 10*s*)

Only a few production engineering firms, other than small concerns producing simple apparatus, manufacture their machines or other products in their entirety. Most place sub-contract orders on other firms for the supply of sub-units of a specialist nature, and electrical components, high pressure fuel pumps, bearings and oil seals are typical examples of these. In addition, occasions often arise when the volume of orders received exceed the production capacity of a firm, and then sub-contracts are placed for the manufacture of non-specialist parts, and even the assembly of sub-units.

In the latter cases, in particular, it is essential that the workshop drawings issued to sub-contractors should leave no doubt in anyone's mind as to what is required and the dimensional tolerances that are permissible. Failure to ensure this only results in assembly headaches and a great deal of financial controversy.

These matters have always been apparent to production engineers, although it was not until 1948 that a real attempt was made, by an Inter-Services Committee, to iron out the deficiencies of drawing office dimensioning practice. The Committee's Report, called The Dimensional Analysis of Engineering Designs, was followed by British Standard No 308 for setting out prescribed methods for tolerancing dimensions for size, position and form.

Mr Wakefield's book is based on these sources, his own practical experience in drawing offices, and the publications of the General Electric Company and the

Ministry of Supply. In a concise but clear manner it gives in fair detail the: Methods of Expression; Production Design Analysis; Datum Selection; Tolerances-Limit Systems; Drawing Office Standards; and a Summary of Drawing Approval Analysis.

This well illustrated, paper-backed book will be of considerable value to apprentice draughtsmen, students of electrical and mechanical engineering, and junior production executives.

It is good value for its modest price of ten shillings. F.T.S.

DESIGN AND PERFORMANCE OF CENTRIFUGAL AND AXIAL FLOW PUMPS AND COMPRESSORS

By A. KOVATS

(Foster Wheeler Corporation, New York)

(Published by Pergamon Press Ltd, Headington Hill Hall, Oxford. Price 5 guineas)

This book presents a unified and up-to-date recapitulation of the fundamentals of fluid mechanics, thermo-dynamics and the theories of design and performance for the subject machines. It does not deal with the associated equipment of pipes, valves, controls, measuring instruments, or the design of systems for normal or specialized applications.

As the book has been prepared for publication throughout the Western Hemisphere the author has taken the precaution of reconciling the symbols and units used in Europe to those adopted in America, and in certain cases the derivations of alternative formulae are given.

Except for Chapters 1 and 4, which deal respectively with Fundamentals, and Pumps for Special Duties, the text is more suited to the designer than the student, unless the latter intends to specialize in this particular branch of engineering practice.

The book with its easy to read print is excellently produced, well bound, and its 450 pages are illustrated by a large number of design drawings and diagrams. A summary of further reading is given at each chapter end.

In spite of the wealth of literature already published on the subject matter, this book would be, in my opinion, a worthwhile acquisition to the reference libraries of design offices and colleges of technology.

F.T.S.

APPLICATION OF COMPUTERS IN VALVE GEAR DESIGN

PREPARED UNDER THE AUSPICES OF THE DIESEL ENGINE SUB-COMMITTEE OF THE SAE POWER-PLANT ACTIVITY COMMITTEE

(Published by Society of Automobile Engineers, Inc, 485 Lexington Ave, New York 17. Distributed in the UK by Pergamon Press Ltd, Oxford. Price 40*s*)

This publication, Volume 5 of the SAE Technical Progress Series, contains a collection of papers relating to the design problems of the valve gear systems of internal combustion engines and the application of computer techniques to their solution.

Each paper was recently read to the Diesel Engine Sub-Committee USA; whose membership consists of representatives of the Armed Forces, research institutes, universities and leading automobile manufacturers of the USA.

The papers, which are supplemented by discussion observations, are titled:—

Aid of Digital Computer in the Analysis of Rigid Spring-Loaded Valve Mechanisms.
By M. S. Hundal, University of Wisconsin.

Studying Valve Dynamics with Electronic Computers.
By G. I. Johnson, Detroit Engine Div, General Motors Corp.

Recent Developments in Cam Design.
By J. H. Nourse, Engineering Consultant; R. C. Dennis, Atomic Power Development Associates; W. M. Wood, Associated Spring Corps.

Problems in Valve Gear Design and Instrumentation.
By C. A. Beard and J. G. G. Hempson, Ricardo & Co Engrs (1927) Ltd.

These reference works provide a foundation on which specific programmes for the research, design and development of valve gear systems could be built to suit individual requirements. They are too advanced to be of use to mechanical engineering students, although the papers would serve to illustrate the degree of development now reached in the field of automobile engineering.

Those engineers who are concerned with the application of electronic, digital and analog computers in general engineering design will applaud this extension to the ever-growing range of computer use.

F.T.S.

Technical Notes

CIVIL ENGINEERING

Notes from the *Civil Engineering and Public Works Review*, December 1963

THE CONSTRUCTION OF THE DARTFORD–PURFLEET TUNNEL: This article describes the construction of and main features of the tunnel. Driving was carried out in compressed air using conventional shields. A variety of grouts including clay, cement and sodium silicate were used to cement the surrounding soil and cement grout curtains were used to form "bulkheads" round the tunnel to reduce the flow of water without using a high air pressure.

THE DESIGN AND CONSTRUCTION OF HARBOUR WORKS AT FIJI: Describes the construction of a new deep water quay, two new slipways and a repair quay at Fiji. The designs had to take into consideration hurricane winds up to 150 mph and earthquakes. The main quay consists of 23-in external diameter 14-in internal diameter prestressed concrete piles with a deck of precast concrete units.

DIMENSIONLESS SPECIFIC ENERGY AND FORCE EQUATIONS FOR TRAPEZOIDAL CHANNEL FLOW: The solution of the hydraulic equations for flow in channels is often dependent on successive approximations or trial and error. An article in the November issue dealt in general terms with the solution of hydraulic equations by the use of non-dimensionless parameters. This article deals with the specific case of trapezoidal channels and shows that the solution of such problems as the formation of hydraulic jump can be solved by the use of tables.

THE LANGTON-CANADA IMPROVEMENT SCHEME: Describes the construction of a new locked entrance to Liverpool Docks. The new lock is 825 ft long and 130 ft wide with three sliding caisson gates. The intermediate gate is not central so that there is the choice of three different locking lengths. All the caissons for the main lock have footways fitted to the top which fold down when the caisson is withdrawn in to its chamber. The caisson between the Brocklebank Dock and Canada Dock carries a roadway and railtrack which also fall as the caisson is withdrawn into its chamber.

THE HALLGATES SERVICE RESERVOIR: The Hallgates Service Reservoir will hold 10 million gallons of water and is part of the supply to Leicester. The walls are 20 ft high and were designed as mass concrete gravity sections using fly ash concrete to reduce temperature effects. The superstructure of the reservoir consists of pre-cast beams and slabs supported on pre-cast columns.

APPLICATIONS OF DIMENSIONAL ANALYSIS METHODS TO CIVIL ENGINEERING PROBLEMS (PART 4): This is the final part in a series of articles and deals with Foundation Problems. Although there are indications that the dimensional analysis approach could be very useful, the example given in this article is based on material in a book that is available only in Russian and Polish.

D.F.M.

Notes from the *Civil Engineering and Public Works Review*, January 1964.

Air Bubble Curtain for Water-borne Blasting Shock: In Canada, for the Sir Adam Beck-Niagara Generation Station, there was a requirement for the removal of the last plug of rock between a canal and the forebay to an existing power station. If this plug had been removed by normal blasting methods, damage would certainly have been caused to the existing power station. It was decided to blast the plug but to screen the power station by producing a curtain of tiny air bubbles in the water. This was highly successful. 11,200 lb of explosive were used and the peak hydraulic pressure was only 15 lb/sq in compared with 55 lb/sq in for a 100-lb shot without the air curtain.

The Clyde Dock Project: Describes some aspects of the construction of the Clyde Dock and adjacent Repair Quay. The dock will be one of the largest in the world and will be capable of handling oil tankers in the 100,000-ton dead weight range. There was an interesting case of the use of radioactive isotopes in the construction of the sheet pile wall for the excavation. Each tie rod was fitted with a cap containing a radioactive pellet and the rod thrust bored to the anchor pile line. The position of the rod was then found with a geiger counter and the necessary hole formed in the anchor pile. This saved the large amount of excavation and back fill which would have been necessary if the orthodox method of placing the tie rods had been used.

An Appreciation of the Hydrobot: The Hydrobot is a probe which measures the resistivity of a concrete mix and a control circuit. Having set the control to give the required water-cement ratio, the apparatus effectively controls the water-cement ratio of further batches to an accuracy of ± 0.02.

The Use of Stabilized Fly Ash in Road Construction: Pulverized Fuel Ash or Fly Ash is available in very large quantities (about 7 million tons a year), as a waste product from generating stations burning pulverized coal. Fly Ash has been used for some time to replace a proportion of the cement in concrete in very large masses, for an example, concrete dams to reduce the heat of hydration. This is the first part of a series of articles describing tests and trials on the use of fly ash in road and embankment construction. This part introduces the subject and deals with ways of reducing the frost susceptibility of the material.

The Escravos Bar Training Moles, Nigeria: This article describes the construction of two training moles, one 29,650 ft long and the other 3,000 ft long in Nigeria. The River Escravos is part of the Niger Delta system and there had been severe deterioration of the navigation conditions due to siltation and the formation of a bar. Even before dredging was started and before the moles were complete, the channel across the bar had increased from 12 ft to 16 ft.

The Analysis of Ground Supported Open Circular Concrete Tanks (Part 2): This article and Part 1 which appeared in the previous issue analyses the bending moments of circular tanks constructed directly on the ground for cases where the contact pressure can be assumed uniform. The articles cover tanks with walls monolithic with the base, with or without a peripheral toe and also tanks with a flexible joint between the base and the walls so that the base acts as an independent circular slab.

D.F.M.

Notes from the *Civil Engineering and Public Works Review*, February 1964.

Modern Trends in Soft Ground Tunnelling: A good article describing the development of present techniques, and why this branch of civil engineering has lately received increased attention. It is being used for the new Victoria Line, and for the Dartford and Clyde tunnels. The methods have also been developed for large size sewers and water conduits.

The Guayaquil Port Facilities: Guayaquil is the main port of Ecuador, but it is situated above the reaches of the Rio Guayas which are navigable by ocean-going ships. In order to eliminate the need for unloading into lighters and ferrying ashore, it was essential to construct a deep-water port for large vessels. The only suitable sites for a port near the city were mangrove swamps, where a depth of 45–55 ft of muck overlay a 10–20 ft thick layer of sand. The proposed wharf area was cofferdammed, the muck removed and the estuary in front of the wharf dredged to navigable depth. The underlying sand was pumped hydraulically into the cofferdam. The sand was placed 6–9 ft high to consolidate the fill, and the surcharge was removed when the structures were started.

DIRECT APPROXIMATIONS TO THE CRITICAL LOADS OF RIGIDLY JOINTED PLANE STRUCTURES. The majority of plane structures are either triangulated frames or portals. The safe load of the former is calculated by the method of sections or graphically, on the assumption that all joints are pinned. As the joints are fixed such a solution is inaccurate, but it is simple and sufficiently accurate to give a working design. It is also desirable to check the frame for buckling, which can only be done by considering the joints as fixed. The resulting analysis is slow and tedious. In this article and in the March number the author shows a method of fixed joint analysis suitable for both triangulated and portal frames. It is simple and short. Unfortunately the articles cannot be followed without reading all the references quoted, so that the method is not readily understood. The working of the examples is condensed and difficult. If the whole explanation and detail was given by the author these articles would provide a useful engineer's tool.

ROAD AND MOTORWAY CONSTRUCTION: A series of generally descriptive articles. The main ones of interest are on new paving techniques and motorway structures. In the former details of the concrete slip-form paver are given, and the design system now used for flexible surfaces. The latter show how one of the main costs in motorway construction, namely over and under bridges, can be reduced by standardizing their design. The authors do not seem to have realized the full potential of such repetitive construction.

USE OF STABILIZED FLY ASH IN ROAD CONSTRUCTION: The second and third articles in this series continue the description of the experiments carried out in the use of stabilized fly ash for road bases. The results show that they are easy to lay, and 7–10 per cent cement or 7–10 per cent lime content give 28-day strengths of at least 350 lb/in^2. They are frost stable. The cost of a 5-in layer is about 3*s* 6*d* per sq yd.

R.D.P.B.

Notes from the *Civil and Engineering and Public Works Review*, March 1964.

THE DRIVING OF THE 10-MILE LONG CANYON POWER TUNNEL IN THE USA: This is an interesting sequel to the article in the February number of this magazine which described the development of soft tunnelling in the UK. This tunnel is being driven through granite, and it requires little lining or rock bolting. The contractor is a former tunnel boss, and he is using standard methods in a most efficient and economical manner. One innovation is the use of an explosive made of a mixture of fertilizer-grade ammonium nitrate and fuel oil. About 80 per cent of the total charge in each round is AN-FO, and the remainder is dynamite. AN-FO gives much better fragmentation, 50 per cent less cost, less toxic fumes and simpler and faster handling.

NEW METHOD FOR THE VERTICAL AND HORIZONTAL HYDRAULIC TRANSPORTATION OF SOLIDS AND LIQUIDS: The staff at the University of New South Wales have developed the "Hydro-Lift" as a means for moving ore, particularly from deep mines. The ore is fed into a hopper with a conical bottom, in the middle of which is a water jet. A little above the jet, and in the same line as it, is a pipe which leads to the surface, the jet starts the ore rising to the surface, where a sieve separates the ore from the water. The water is filtered and pumped down to the jet at the bottom of the hopper. Naturally the difference in head between the surface and the bottom of the mine helps to provide additional head. In a wet mine the water being removed can be used for transport. This is the first article and shows the principles and development of the system.

LAUNCHING A STEEL GIRDER OVER THE WHITE NILE. A bridge consisting of a concrete deck and two welded, parallel flanged steel girders was recently completed near the Owen Falls Dam. The bridge is continuous over three spans of 65 ft, 160 ft, and 50 ft. The launching of the girders at this site provided the main problem as the Nile is very deep and fast-flowing. Access was only easy from one bank. The girders were joined and put in place on rollers with the help of a derrick pole, and then pushed out as fabrication continued. Finally a heavy kentledge was placed at the rear of the bridge for the final part of the pushing-out. The tackles and winches were all hand powered.

THE BEHAVIOUR UNDER LOAD OF SIX CASTELLATED COMPOSITE T-BEAMS: The results of tests on six different castellated composite T-beams under heavy shear loading are reported. Failure occurred at the webs, and the shear connection with the concrete was satisfactory. The authors give no theory or calculations derived from this work.

AN ANALOGUE COMPUTER FOR GRIDWORKS: The analogy between the flow of current in a network of resistors and the moments in a framed structure has been used to construct an analogue computer for solving problems in gridworks. This is the first of two articles, and it gives the theory of the calculations, the setting up and operating of the computer. It is well written and it is the first time the reviewer has been able to understand any article on the use of analogue computers.

A MERCURY-FILLED GAUGE FOR MEASUREMENT OF THE SETTLEMENT OF FOUNDATIONS: A mercury gauge has been developed to measure the settlement of foundations particularly road embankments constructed over compressible soils. It is more accurate than a water-filled gauge, and is not as easily damaged as a rod-gauge. It costs about £20–£25, and a further £15 for the mercury which is recoverable.

R.D.P.B.

CIVIL ENGINEERING

Notes from *Civil Engineering and Public Works Review*, April 1964

MODELS FOR STRUCTURAL CONCRETE (PART I). After a short introduction on the requirements for structural models, the author describes in some detail the various scale factors relating the behavior of models to that of a prototype; density, bond, creep and the stress-strain patterns must be considered in addition to the linear dimensions. Various suitable materials for models are mentioned, and a short description of micro-concrete is included.

WEBSTER STREET TUNNEL. The tunnel was recently completed below a river in California; for most of its length it is constructed from precast concrete tubes, 200 ft long, which were sunk into a previously dredged trench across the river bed. The tube units, including an integral carriageway slab, were cast in a graving dock upstream of the tunnel site; they were thoroughly waterproofed and the ends were then temporarily sealed; ballast was added to get the correct buoyancy, and the angle of flotation was adjusted by regulating the amount of water in sections of the void below the deck slab. Before lowering the sections by cranes, additional water was pumped into these spaces to give negative buoyancy. Couplings on the tubes engaged with each other at the joints, and tremie concrete was then poured around them. Sand fill was placed and vibrated below and around the pipes, with additional heavy ore cover in the deep water channel. Exact positioning of the tubes was ensured by sighting on to masts fitted to each end and tall enough to be visible above the water.

SHEAR STRENGTH OF PRESTRESSED CONCRETE BEAMS. This article describes a series of tests to destruction, made by applying uniformly distributed loads to pre-stressed concrete beams without web reinforcement. Details are given of the occurrence of diagonal tensile cracks and of the method of ultimate collapse which in all cases developed within the web. Except for one case, in which the duct was not grouted, the results confirmed the design procedure in CP 115 as being satisfactory.

CEMENT STABILIZED BASES. This is a review of recent practice in cement stabilized bases for roads and airfields. The three main types are lean concrete, cement bound granular bases, and soil-cement. In each case specifications (normally those specified by the Ministry of Transport), mixing and placing methods, and the performance of such bases with respect to experience and failures are described at reasonable length. The conclusions summarize the advantages of the different types of cement stabilized base.

OFF-SHORE DRILLING PLATFORMS. These platforms have been constructed off Trinidad; each has ten 3 ft cylindrical steel piles to support a total load of around 3,000 tons. The earlier piles were filled with concrete, but more recently they have been surrounded by concrete sleeves with in situ concrete placed in the resulting annular space. Increasing use has been made of precast concrete units in place of steel which suffers severe corrosion in these waters.

CHEMICAL GROUTING IN THE BLACKWALL TUNNEL. A short summary of the grouting procedures in the new Blackwall Tunnel was given in the February 1962 issue of this Review. This article covers the same subject in greater detail. The tunnel was driven through variable alluvial deposits some of which had high permeability and gave little cover between the tunnel and the river bed. Grouting was carried out from the two pilot tunnels to form a hollow cylinder some 11 to 15 ft thick around the position for the main drive; the majority of the grout was a clay/chemical mixture, but the crown position was reinforced by a 4 ft thick band of a pure fluid chemical grout called TDM. The grouts were pumped down the tunnel and injected into the ground through proportioning pumps, thus ensuring accurate control of the gelling time and preventing the start of gelling before injection.

TIMBER FEATURE. A series of articles in another "Timber Feature" cover preflexed timber beams, structural laminated frameworks, and an unusual type of timber roof structure at Canterbury entailing some concrete members; this last subject also includes valuable comments on the complications involved with timber folded plate roofs.

ANALOGUE COMPUTER FOR GRIDWORKS. The article started in last month's issue is concluded with a worked problem, showing how the circuits are arranged, and comparing calculated and measured moments and torques.

HYDRAULIC TRANSPORTATION OF SOLIDS. This concludes the article on the Hydro-Lift system for lifting solids in a fluid medium. Several examples are given with sketches of possible arrangements for using the system to raise coal and ore from deep mines.

J.C.P.

THE MILITARY ENGINEER

JANUARY–FEBRUARY 1964

SWIFT STRIKE III. AIRBORNE SUPPORT, by Colonel H. F. Cameron, Corps of Engineers, United States Army. Swift Strike III was a big exercise involving large forces which took place during July and August 1963 in South Carolina. The article under review is an account of the construction of two airstrips by airborne engineers. The problem is clearly stated in terms of equipment, etc required and there is a useful summary of lessons learnt. The strips were required to enable two divisions to be maintained by air after having been flown in. (See *RE Journal* of March 1964.)

DISTILLING SEA WATER WITH WASTE HEAT, by J. S. Williams and W. R. Nehlson. Military bases in remote locations are frequently faced with the problems of providing a fresh water supply where nothing but sea water is available. The practicability of using the waste heat from the cooling and exhaust systems of diesel-driven electric generators, usually installed at such places, has been examined in a series of tests at the Naval Civil Engineering laboratory (NECL) at Port Hueneme, California. This article is a well illustrated account of the tests carried out. The conclusion come to is that an electric-generator diesel engine with a boiling-condensing cooling system can furnish heat and power for sea water distillation without adverse effect on the engine. A rough idea of the output of distilled water to be expected from a suitably adapted 120 kW generating set is about 300 gph. This should perhaps be reduced to 200 gph making allowance for field conditions.

CONSTRUCTION IN THE FAR EAST DISTRICT, by Colonel Wilmot R. McCutchen and Lieut-Colonel Thomas T. Jones, Corps of Engineers, US Army. This article describes the organization of the engineer works services in Korea paying particular attention to the progress made with training Korean engineers and contractors. Very good progress has been made and the standard in many cases is satisfactorily high. There are illustrations of works carried out or in progress but there are no details of design.

COUGAR DAM, by Colonel Sterling K. Eisiminger, Corps of Engineers, US Army. This is a description of the design and construction problems connected with the construction of a 519-ft high earth and rock fill dam across the Columbia River. There is also a description of the water conservancy problems and plans for the Willamette river basin. There are many good illustrations.

MILITARY ENGINEER FIELD NOTES

DEFENCE OF ENGINEER COMPANY BIVOUACS IN VIETNAM, by Captain Dai-uy Nong Van Thang, Commander 2nd Engineer Battalion, Army of Vietnam. This is an account of a system of bivouac defence consisting of an open random pattern of three-or-four man foxholes used by Vietnam engineers when employed on tasks without any protection from other arms. Successful actions against Viet Cong troops are quoted.

RUBBER-TIRED TRACTOR FOR THE DIVISION ENGINEER BATTALION, by Captain Walter M. Jastrzemski, United States Marine Corps. The Engineer Research and Development Laboratory is working on a replacement for the crawler tractor, called the Universal Engineer Tractor (UET). This item of equipment has among other features a high-speed track which can operate on and off the road. It is not expected to be ready for service until 1966. In the meantime the author of this article recommends that rubber-tyred tractors should be provided. He gives many sound arguments in favour of this recommendation.

ATOM SMASHER FOR NUCLEAR PHYSICS RESEARCH, by Colonel B. F. Rose, Jr, United States Army Reserve (retd). The most powerful accelerator in the world is under construction at Stanford University and is known as the Stanford Linear Accelerator. This article gives an explanation of the function of accelerators and the theory of how they work and the objects to be achieved and then goes on to describe in some detail the design of the Stanford Linear Accelerator and the construction problems involved in its installation. The main part of the installation is a copper tube 2 miles long 4-in in diameter with a bore of $\frac{7}{8}$ in which has to be in perfect alignment for its entire length despite uneven terrain, the curvature of the earth and potential earth movement. The other parts of this great undertaking are also described. There are interesting illustrations.

HOLLAND AGAINST THE SEA, by J. de Jong. This is a short summary of the history of land reclamation in the Netherlands with an account of work in progress and plans for the future. There is a description of the work done to repair the breaches in the sea walls of Walcheren Island made by allied bombing in 1944. The steps being taken to shorten the overall length of sea walls to be maintained and the reclamation of the Zuyder Zee are also described. There are good maps and photographs.

PICKING UP THE PIECES. ENGINEER AID IN OKINAWA, by Arthur D. Hands. A short account of how the Society of American Military Engineers helped in the reconstruction and modernization of Okinawa after the damage caused by battle and typhoons, mainly by giving practical assistance and encouragement to the education of Okinawans in engineering and by giving technical advice.

Dry Docks Through Five Centuries, by Captain J. E. Rehler and Lieutenant G. C. Bottager, Civil Engineer Corps US Navy. A brief history of the development of dry docks. There are good illustrations.

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California State Water Project, by Alfred R. Golze. A very interesting and well-illustrated account of the work that is being done on an overall plan to provide adequate water supplies for the State of California both domestic and for irrigation for the foreseeable future. The scale of the project is impressive.

M2 Panel Bridge at Restricted Sites, by Major Anthony M. Pine, RE. A description of tests carried out at Fort Bevoir of a method of building and launching the M2 Panel Bridge (Bailey Type) believed to have been developed by British Army Engineers in Italy. The method consists of constructing the bridge launching nose round the tank (which is to serve as a counter weight) and then driving the tank on to the deck of the bridge up an internal ramp. A steel cable anchored to the far bank is fastened to the tank and when the tanks tracks are rotated away from the gap their action on the bridge causes the bridge to be launched over the rollers.

Navy "Man on the Moon" Construction, by Commander R. E. Dunnells, Civil Engineer Corps, US Navy. The Navy Bureau of Yards and Docks is acting as construction agent for facilities at Seal Beach, California, for the manufacture and test of the second or SII stage of the Saturn V launch vehicle. This article gives a description of SII and of the various buildings and plant under construction. There are many photographs.

The Nicaragua Canal Story, by Lieut-Colonel H. R. Haar, Jr, Corps of Engineers, US Army. In view of the recent events in Panama and the questions that have arisen as to the future of the Panama Canal the article "The Nicaragua Canal Story", by Lieut-Colonel H. R. Haar, Jr, which was first published in *The Military Engineer* May–June 1956 is reprinted. The article provides background information and pertinent comments on Central American Canal sites. It will be news to many readers that there was keen competition between the supporters of the Panama route and the Nicaragua route which was only settled in favour of Panama after some very interesting political manoeuvring. It is likely that more will be heard of the Nicaragua route in the near future as, apart from the political issues, the Panama Canal is hardly able to compete with the present level of traffic.

Military Engineer Field Notes

More About Assault River Crossings, by Captain Graham Wood, Corps of Engineers, US Army. This is a brief account of a suggested method of carrying out a rapid river crossing by providing floatation gear as part of every vehicle. There would be attached to each vehicle a bearing plate on each side that folds into the space between the wheels. Attached to each bearing plate is a polyethylene bag folded tight against the plate. When a water gap is to be crossed the plates are folded out on either side of the vehicle, the bags are inflated with styrofoam.

Engineer Troop Construction in France, by 1st Lieutenant Jerry A. Hubbar, Corps of Engineers, US Army. The interest of this article is mainly that it shows how much is involved in the US support to NATO. The activities of one Engineer Construction Battalion (Construction) at Toul-Rosieres and Laon Air Bases and at the Nancy General Depot are described.

Ice Bridge in Korea, by Captain Julian H. Carnes Jr, Corps of Engineers, US Army. This is a description of the construction of an ice bridge over the Imjin river at a time when the temperature ranges were from 5 to 10° high to −5 to −10° low. The method in broad terms was to build up a reinforced surface to the track by strewing it with rice straw approximately to a depth of 4 in and then flooding it and letting it freeze. Subsequent reinforcement was made of brush and twigs branches from ½ to 2 in in diameter. The final thickness of ice including the river ice was 20 in which successfully carried a M-41 tank.

Mobility Doctrine for the Future, by Lieut-General Dwight E. Beach, US Army. The author is the commander of the Army Combat Developments Command at Fort Belvoir. In this article he emphasizes the necessity for developing to the fullest extent all the weapons and equipments which technical advance make available for the use of the army. He makes a special point of the value of aircraft in providing mobility. Much of the article consists of a description of the various types of what he calls air vehicles in service with the US Army or under development. The various types are illustrated. The scale on which air mobility is being provided in the US is striking.

CPM in the Minuteman Program, by Frederick J. Rose. This article describes how the Critical Path Method has been used in the successive construction projects undertaken by the Army Corps of Engineers Ballistic Missile Construction Office. Lessons in its use which have been learnt are given as basic guides and the advantages of the system are summarized.

Log Bridges in Remote Areas, by Captain H. R. Hansen, Corps of Engineers, US Army. This is a detailed description of how to build a timber bridge using the minimum amount of equipment. A valuable piece of knowledge for engineers operating in well-wooded country at the end of a tenuous L-of-C along which heavy loads cannot be transported. Reading it takes one back to the days before the first war when stick and string was more popular than it probably is now. There are good drawings and the article is clearly written.

Missile Range Facilities in the Pacific, by Willard H. W. Nip. This article provides another item in the immense space travel programme. The general layout of three stations in the Hawaiian Area is given but there are few engineering details. There are good photographs which give some idea of the size of the project.

J.S.W.S.

REINFORCED CONCRETE ASSOCIATION

One-Day Symposium on Piles and Foundations

This symposium, organized by the Reinforced Concrete Association and the Prestressed Concrete Development Group, was held at the Institution of Civil Engineers on 27 April 1964. During the morning session the subject was pre-tensioned prestressed piles, and in the afternoon long bored piles were discussed. The aim of the symposium was to establish a basis on which codes of practice for these two types of piles could be started.

The first paper "Some notes on the draft PCDG Standard Specification for pre-tensioned prestressed piles" was presented by Dr F. W. Gifford. As the title implies it explained the reasons for selecting the various requirements in the specification. The author stressed the importance of obtaining a high release cube strength to use the pre-tensioning beds on a 1-day cycle. He explained that the design criteria were the handling, transporting, pitching and driving, and he suggested that 400 lb/sq-in was the average prestress required. At the end of the paper four graphs were given showing the relationship between prestress and length of pile to satisfy the conditions of handling, minimum prestress and slenderness ratio.

Mr N. S. Williams presented the next paper, "The Transporting, handling, pitching and driving of prestressed concrete piles". The practical aspects of prestressed piling were well described. Particularly valuable were the points dealing with dollies, helmet packing, hammers, and lengthening of prestressed piles. The author stressed the advantages of prestressed over ordinary reinforced concrete piles in marine work, where they are far more durable.

Both papers were then discussed. It was obvious that prestressed piles are being used more and more widely. No new method of design was put forward, but it seemed to be generally agreed that the sequence of design is, first investigate the driving conditions and stresses, then check for handling, and finally ensure that it can carry the working load. Dr Gifford hoped that information about the first point might have been given, but none was mentioned, though three speakers said that usually the limiting factor is the tensile stress set up by the driving shock wave. There was considerable disagreement about the minimum prestress of 400 lb/sq-in recommended by Dr Gifford. Several speakers preferred a minimum of 750 lb/sq-in, and this is the minimum quoted by a recent American Code of Practice. It was agreed that soft driving requires a higher prestress than hard driving. Another speaker said that he had used post-tensioned piles with great success at sites remote from precast factories. It was agreed that prestressed piles are more economical than reinforced concrete piles for $\frac{L}{r}$ ratios exceeding 30, so they require a smaller area of concrete and less reinforcement for handling.

The afternoon session began with a paper introduced by its author Mr T. N. W. Akroyd. The title was "Specification and practice for concrete in foundations". When writing a specification one must consider the working conditions facing a contractor when he comes to place and compact the concrete in foundations. In simple foundations, ground beams and slabs it is comparatively simple to obtain the desired strength and density. In cast *in situ* piles the prevention of segregation is most important and it can be achieved by using a bottom opening skip or a tremie pipe. As compaction is well-nigh impossible, a self-compacting concrete should be used with a high slump, 5–7 in, which is obtained by slight over-sanding and a high cement content, 500–600 lb per cu yd. Each pile must be concreted in one continuous operation.

The second paper, "Some aspects of the use of concrete for foundations" was prepared by Dr P. E. Halstead of the Cement and Concrete Association. He has been carrying out research into the causes of failure of cast *in situ* piles. The most common form of attack is by ground water, in which solutions of sulphates are the most aggressive. However, the author's research has shown that the most frequent cause of damage to bored piles is by flow of water into the hole as the concrete is placed. If the flow is low the bore must be pumped dry before placing the concrete, which should have a high slump value. If the hole has a high flow into it, then a tremie must be used for placing and consideration should be given to the use of a waterproof lining to the hole. The damage most often found is caused by elutriation where the rising water separates the concrete into bands of material, with the largest particle size at the bottom and the smallest at the top. The smallest particles are the cement, which is the only zone which sets.

In the general discussion following these papers the speakers agreed with most of the points made by the authors. There was a sharp division of opinion as to which part of the pile carried the load; is it the sides of the pile in skin friction or the bottom of the pile in bearing? In the latter case it would be essential to achieve the best possible concrete at the bottom of the hole, particularly if the pile is under-reamed. In the former theory it appears essential to avoid lining the excavation with material such as polythene sheeting to prevent water ingress, as one author suggested, since this will prevent skin friction developing. One speaker suggested that half the coarse aggregate should be omitted from the first batch, so that the tremie pipe, trunking and reinforcement received a grout coating without spoiling the concrete at the bottom of the bore-hole.

Copies of the symposium papers are held in the RE Corps Library, and the proceedings are to be published in the September/October and November/December issues of *Structural Concrete*, the Journal of the Reinforced Concrete Association.

R.D.P.B.