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CONTENTS

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VOL. LXXVIII

CONTENTS

DECEMBER, 1964

Army Railways in the United Kingdom Today

By Colonel R. C. Gabriel

One of the least known but surprisingly interesting units which the Corps will shortly be losing as a result of the implementation of the recommendations of the McLeod Committee on the reorganization of the Army's logistic services is 1 Transportation Group, RE, a unique unit with many unusual features. Even after commanding it for the last fifteen months, I find it incredibly difficult to describe its complex organization and far flung responsibilities, briefly, clearly and with accuracy.

Many people believe it to be a group of AER units under a regular group headquarters, and more still imagine that it somehow comes under the Transportation Centre at Longmoor. When one reminds them that it used to be known as No 1 Railway Group until early 1963, when a small port element was added to the organization to operate the wee Scottish port of Rhu (in no way comparable to the former military port of Cairnryan which was the Group's responsibility for several years), they immediately crow in a knowledgeable way "Ah, yes! you mean the Railway *Home* Group—we know *that* well". Some have even been known to imagine that this was a Home Guard formation concerned with keeping an eye on British Railways!

No 1 Railway (Home) Group of course was the unit's title during the latter part of the Second World War, but it had earlier been known by other and more lengthy names since its formation in May 1942.

In it at the end of the war were some 2,400 military personnel deployed in thirty-nine depots throughout the UK where railway systems required 200 locomotives and 600 miles of track. Amongst them was the Shropshire and Montgomeryshire Light Railway (complete with its military extensions) on which civilian freight and military passenger services were provided for many years. Visitors to Longmoor will remember the historic little "Gazelle" that ran on this railway and which now stands outside the Headquarters of the Transportation Centre but few will connect it with my Group.

I often wonder how many in the Corps realize that today I am the only military member of this extraordinary unit, comprising some 760 or so civilians, although I do have eight NCOs attached as an increment, mainly to supervise Royal Pioneer Corps and other labour on track lifting and relaying projects that are beyond the capability of my somewhat elderly civilian platelayers. I regard myself as a sort of General Manager of the Army's Railways in the United Kingdom, providing railway services within a number of depots and installations throughout the country, from Stirling in the north to West Moors in Dorset and from Antrim to Shoeburyness, and coming under the direct control of the Ministry of Defence (Army Department). There is probably scope for some extension of responsibilities, but after all the RSME was not built in a day and that in any case one major reorganization is quite enough at the moment. Other changes may follow and already there are indications that they will.

Photo 1. In Memoriam?

Army Railways in the UK today 1

PERT also uses the terms "late free float" and "independent float". They are not normally applicable to CPM. The RSME publication defines the term "independent float" and also another term "interference float" which is the total float less the free float. Personally I cannot see any reason for introducing either "independent float" or "interference float" into CPM. Let us keep the theory as simple as possible. The table above suggests that the theory is already in danger of becoming unnecessarily complicated for the beginner due to the variety of terms used, so why add further complications?

The End Object

A Senior executive of an American Construction Company speaking of Critical Path Scheduling, is quoted as saying that it represents "one of the greatest advances in construction scheduling since the Pharaohs". So be it, but an advance does not mean that what was good in the past must necessarily be scrapped. If I may make one general criticism of Major Johnson's article and also the RSME publication, I think that both show an undesirable tendency to sweep away the old with the introduction of the new. It is essential to keep in mind the end object. The first point which I wish to stress is that the end object of CPM is to make a plan and to present it in the simplest possible form which can be understood by all who require to use or to refer to it, and which can be easily adjusted as and when the necessity arises. To make a plan requires an appreciation, and nobody will claim that this is a new doctrine. The second point I wish to emphasize is that CPM is nothing more, and nothing less, than a simple and logical method of making that appreciation and arriving at a plan in programme form. It follows the sequence of any good appreciation; it sets down the factors; it examines these factors in logical sequence; it considers various possible solutions and finally it ends up with the best plan to suit the relevant factors affecting the attainment of that plan.

The RSME pamphlet criticizes the old bar chart (sometimes known as the "Gantt" chart). These criticisms are valid but, in my opinion, they are wrongly directed. It is not the bar chart which is at fault at all. It is the limitations of the older methods used to compile the bar chart. The bar chart has one particular merit which must not be lightly set aside. It is a very simple and practical method of presenting a construction plan or programme which is readily understood by both the lowest Foreman and the highest Executive, and, I trust, their military counterparts.

Can the same be said about the final programme shown in Figure 6 of Major Johnson's article? Indeed would this method of presentation be practical for a more complex project? I fear the answer is "No". What then is to be done? Quite simply, produce the plan on a bar chart suitably modified to show the additional information which CPM gives. When using CPM first produce the arrow diagram, then do the calculations (or get a computer to do them for you) and then produce an initial bar chart—some computers will even do this for you. The initial bar chart corresponds with Figure 4 of Major Johnson's article and all the subsequent adjustments should normally be done from this bar chart. I say normally because there are times when it is quicker to start afresh, but this is the exception and not the rule. You will arrive at the final bar chart by the same considerations as set

To return to the description of the Group, my difficulties will perhaps be appreciated when it is realized that lately a lot of depots have been closed down, while some have been kept open longer than envisaged and others have even been expanded. The pattern is forever changing, yet 1 Transportation Group's establishment must fit it, continue to provide the best service possible to all the depots and installations and also be worthwhile economically to the Ministry of Defence and the country as a whole.

Freight Traffic

The economic aspect is a most important one, highlighted probably by Dr Beeching's proposals for British Railways. Increased demurrage charges (for unwarranted detention of BR wagons in "private" sidings) for instance coming soon after we had launched a scheme for a number of Army owned railway wagons to be constructed and registered for main line running, have now made these wagons terrifically popular, for of course they do not incur these charges in military sidings, and we are quite unable to meet the ever-rising demand for them. The demurrage bill for one of the smaller Ordnance depots using BR wagons rose as a result of the stricter application of the rules concerning unloading time and the increased rates from a figure of less than £300 to one of almost £900 in one month! For the next two months when Army wagons were used as much as possible, depending on availability, BR demurrage charges fell to £44 and £33! A case can clearly be made for increasing the annual quota proposed a few years back as reasonable replacement for our fast ageing internal user wagons! It is obvious that one must hold a proportion capable of travelling over the main line so that switches in rolling stock strengths can be made without too much inconvenience. There are about 1,700 goods wagons on the books and all these of course have to be maintained in running order. Only 400 of them, however, are in the so-called main line fleet of which all but 130 are the well-known Warflats and Warwells, which have always been "main liners". Many of the Warflats have been used lately for transporting the new Armoured Personnel Carriers (APC) from factory to depot and from depot to various destinations for issue to Units. In view of their slightly asymmetric cross section they have to be very accurately placed on the Warflat deck which was, therefore, modified by the addition of a pair of positioning rails, bolted down on their side to guide the carriers' tracks. The design for this was worked out in my HQ, immediately accepted by British Railways, and the modification work carried out by Group personnel.

The nerve centre for all Army-owned wagon movements is an office in Group HQ called "Wagon Control". Here all movements are recorded and individual wagons can be quickly traced. By keeping a close watch on wagons detained in Army sidings, "demurrage shirkers" can be hustled and wagons kept on the move. Demands are received either direct or via "Q" Movements in Command HQs, and there is close liaison with the British Railway Central Wagon Authority.

With only three-quarters of the 130 "opens" and "covered vans" (known also as "Pallet Vans") registered for main line use (the remaining quarter were not "passed" for registration until July 1964), traffic figures jumped following their introduction in the autumn of 1963 from an average of ninety loads monthly to one of 260. For the first eight months of 1964 that have included APC and other movements the monthly average of main line journeys carrying loads has been 336, compared with ninety-eight for the equivalent months in 1963. September's figure was 524.

Overall wagon movements including empties and internal ones which are extensive in some places, particularly ammunition depots where roads are sparse, remain fairly constant at about 42,000 per month despite the reduction in the number of depots served in the last few years.

Extent of the Organization

Not counting our own Central Workshops at Bicester and Port Terminal at Rhu, (so many people have asked what the initials RHU stand for!) there are thirty-seven "active" depots and installations where railway systems are actually operated by the Group. Some thirty-four depots are operated on an agency basis, ie, by a daily shunt by BR, and there are several Royal Ordnance factories, where we have certain responsibilities for the main line connexions and signalling. A further forty-four can be classified as "defunct" but, until they are finally disposed of, we still have some responsibility for them. This is usually in connexion with the preservation and sometimes ultimate removal of the track of which there is the equivalent of 110 miles in closed depots and other similar establishments. Track mileage in the "active" places as in June last added up to 490 miles, of which 29 miles were narrow gauge (2 ft) instead of the usual standard gauge, but it is interesting to note that the total track miles are about the same as when the Group numbered 2,400 military personnel!

Few people realize what sort of railway layouts some of these depots have. Many think in terms of a few dead-end sidings and possibly a run-round for the locomotive served by a daily shunt from a British Railways "pick-up" goods train. Those, however, who know 1 ESD Long Marston will be conversant with the fairly straight-forward layout of the depot railway there. Fig. 1 shows one example of a more complicated layout service. All these depot railways are run by tailor-made detachments of the Group, some large, some small, and controlled by a Divisional Railway Officer who has a small technical and administrative staff. For some years there have been three divisions but, following a recent reshuffle, it is likely that in the future there will only be two as shown in Fig. 2. Divisional areas are in the main determined by British Railways regional boundaries which have themselves been altered to some extent lately.

Prime Movers and Cranage

Recently an officer in the Corps expressed surprise that my group should hold more locomotives than Longmoor and even then he guessed a figure of twenty or thirty. The total is actually over 140 but that includes several "steamers" about to be replaced, and diesels including narrow gauge ones in Central Workshops or awaiting disposal instructions. An effective figure therefore is between 110 and 120.

Mention must be made of the dieselization programme and how steam power was recently replaced at Bramley, Chilwell and Long Marston and will be largely replaced at the COD Bicester; mid-1965 four new 500 hp "double ended" Barclay-Cummins diesel locomotives should be in service there. Steam, however, is likely to be retained for some time to come at Shoeburyness, where the railway, once known as the Military Tramway, serves the ranges of the Proving and Experimental Establishment. Hugh railway cranes, some capable of lifts up to 60 tons, have to be inched into position and heavy gun sleighs have to be "anchored down" by using relatively heavy locomotives with a strong initial drawbar pull. The 0-6-0 steam (Austerity) saddle tank is, therefore, generally preferable to diesels of 275 hp or less, such as we now hold (though not to the 500 hp model which, however, is too costly to provide in sufficient quantity all at once). Nevertheless there are already some diesels there and steam will eventually be superseded. Comparative trials between a 275 hp diesel and a steam Austerity for the particular range requirement are currently being held. On a busy test day several locomotives may be required simultaneously at different points so the working of such an installation cannot but be terribly uneconomic, from our point of view, especially when the shed backing and other labour figures are taken into account. Nevertheless the railway is a vital part of the establishment and some expansion is now under consideration. This involves the crossing of Havengore Creek where the present road and rail bridge is not considered strong enough for the loads envisaged. This problem is certainly not a new one but many readers will be amused to learn that it is once again to the fore and owing to the many shifts of responsibility, not only for "Works" but for "Railway Construction", this project is a pretty "hot baby"!

Those people not conversant with depot railway working problems often make the mistake of assuming that all locomotives are much the same and can, therefore, be switched round at will. Few understand that the size, weight and horsepower must suit the task, that the locomotive selected for a depot must be capable of negotiating the curves there which may be too sharp for some particular design. In explosive storage depots, in petrol and in certain ammunition depots, locomotives may have to be flame-proofed or spark-arrested and only those equipped with the appropriate additional features may be used; it is not just a question of fitting on some contraption as it enters the danger area, but of having a locomotive designed and constructed to meet the particular local requirements. Many RE officers will remember the locomotives that used to work underground at Corsham.

It can be seen, therefore, that the phasing of overhauls must be carefully planned to fit in with operating requirements, thus the allocation of motive power, its deployment and subsequent maintenance, exchange and overhaul are all management problems best dealt with at Group HQ. Divided responsibility is just not workable.

In recent years the practice of naming locomotives of the Group seems to have been dropped, probably with the advent of the diesel shunter, but a few still proudly carry name plates such as *Sapper* and *Craftsman* at Bicester. Nor are they alone in so declaring themselves for, amongst the cranes, we have, in addition to one or two famous generals, like *Gort* and *Montgomery*, a number of naval heroes such as *Frobisher* and *Drake*, besides *Sturdee* and *Blake* and other "Admirals of the Range".

Locomotive sheds for diesels are highly sophisticated these days and provide three working levels for, apart from the normal rail level, there are side-recessed repair pits, complete with built-in lighting and also maintenance platforms at footplate level with fitters' bench etc. Heating and the comfort of the shed staff both play a big part in the design of modern sheds. The Kineton shed was the first of the new type and one now under construction at Moreton-on-Lugg will be followed shortly by another at Bramley and later by one for Long Marston.

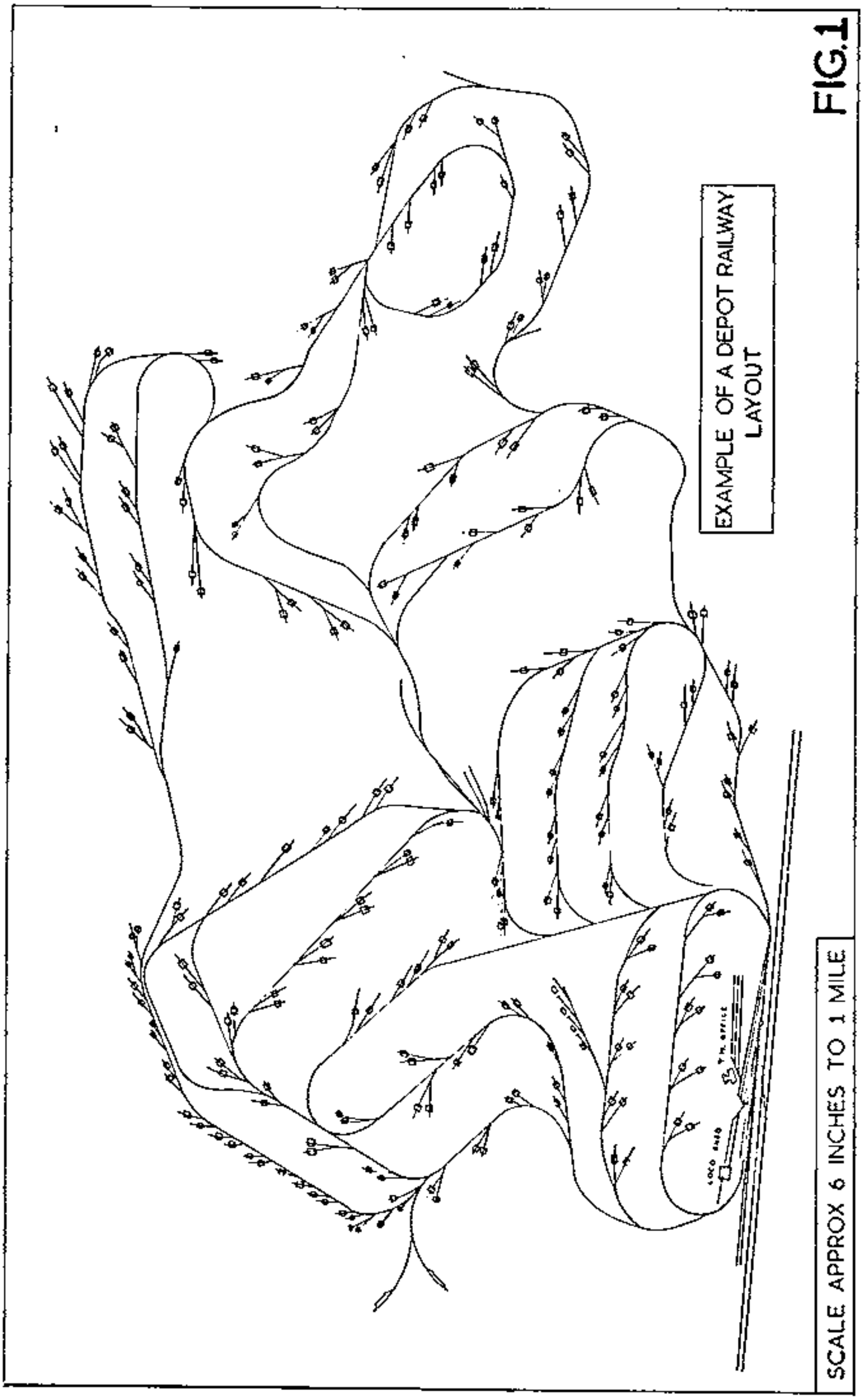
EXAMPLE OF A DEPOT RAILWAY
LAYOUT
SCALE APPROX 6 INCHES TO 1 MILE

FIG.1

There cannot be many lady engine-drivers about, but this group has one on its strength, with the defiant name of Mrs Notman! Admittedly she only drives narrow gauge locomotives but this baby can sure haul a load of dynamite! I suppose that strictly speaking she could remain "sapper cap-badged" in the reorganization, being the driver of a piece of RE Construction Plant!

Other primemovers held by the Group are railcars of several different types and sizes. There are thirty-seven in all, including some used by the Army Fire Service; these are virtually rail-mounted fire engines that carry pumps and lengths of canvas hose in special boxed-in compartments from which they can be quickly "flaked out" and connected up to the hydrants or static water tanks at the storage sheds. They certainly look most impressive in their scarlet livery and gold lettering. All of them are converted railcars and not specially purpose-built; the modifications are designed in Group HQ to meet the Army Fire Service and Depot requirements and the actual conversion carried out in the Group's Central Workshops at Bicester.

It is to these workshops that Army locomotives are sent from all over the country for complete overhaul, every few years according to their age, hours run and condition generally. Central Workshops also overhaul and carry out major repairs to the main line wagon fleet referred to above, in conformity with BR practice and requirements, every three and half years when brake gear in particular is checked. This is an intermediate overhaul and every seven years a very thorough or general overhaul is undertaken. Over distances up to about 80 or 100 track miles, locomotives are best moved over British Railways under their own power or, failing that "dead" with "motion" disconnected and as part of a British Railways freight train, but being shunting locomotives they cannot usually be moved at more than 20 mph because of the nature of their axle bearings. Thus locomotives from as far as West Moors in Dorset, Donnington in Shropshire and Old Dalby in Nottinghamshire may be able to be moved in this manner. From further away a road move has usually to be resorted to though the smaller locomotives up to about 100 hp can be sent on an Army rail wagon (Warwell). Bigger ones, even if carried on the lowest trolley wagon that British Railways possess, would be "out of gauge" loads because of their height and so probably not acceptable for main line passage within the required time limits. Investigations in this field are still being made and it is a pity that all our diesels have not got detachable cab roofs as fitted on the new Rolls-Royce Sentinel locomotive *Lord Robertson* at Longmoor.

To return to the railcars, which are so useful for inspection of the line and even of the depot itself and also for the carriage of small quantities of stores such as test samples of explosives, it should be mentioned that they carry quite a lot of passengers including depot commanders on regular journeys and visiting VIPs. Not many people know that the Group carries over 200,000 passengers by rail in a year! Coaching stock is held for this purpose and regular services run within certain depots. Shoeburyness and Bramley each has a set of three former London Transport coaches, ie Underground tube stock, and it looks a bit strange to see such vehicles being hauled by a locomotive. Also at Shoeburyness is a very old coach that once ran in the Sudan, so it is believed, and is always referred to as the "Kitchener Coach". Though undoubtedly of historic interest there is no positive evidence that it was used by the great man himself (See *RE Journal*, December 1959).

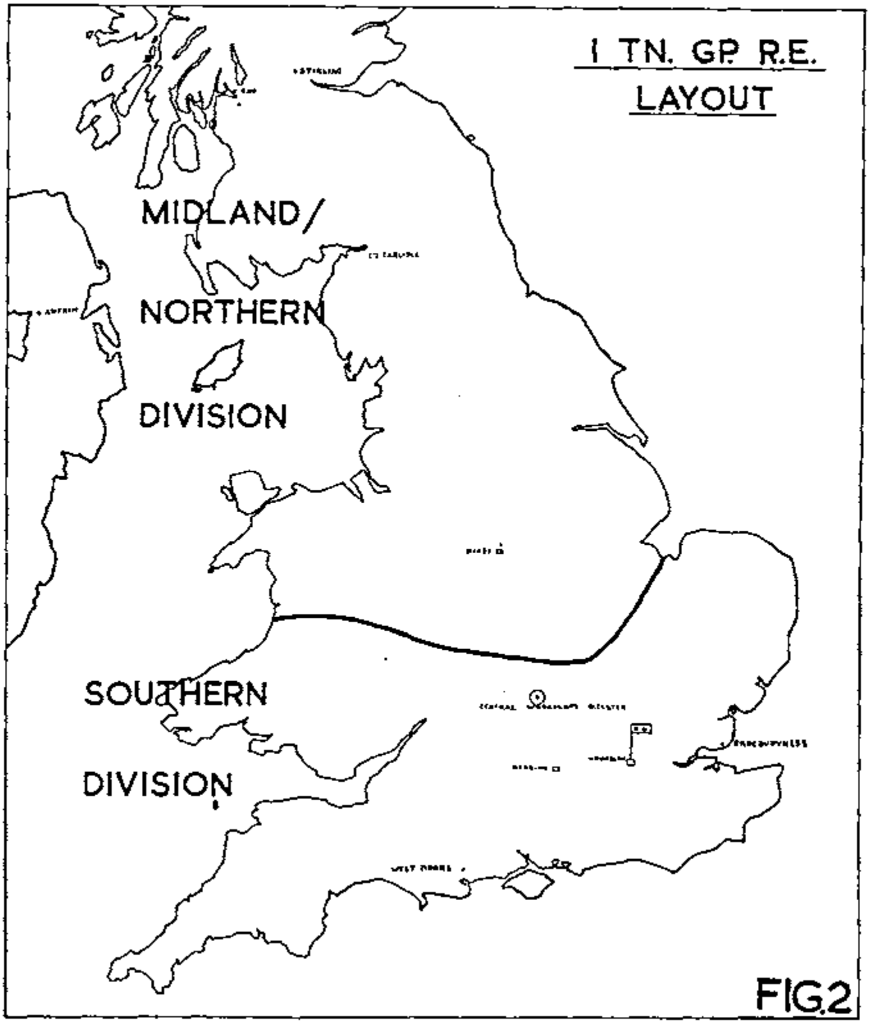
1 TN. GP. R.E.
LAYOUT
MIDLAND/
NORTHERN
DIVISION
SOUTHERN
DIVISION

FIG.2

Special Rolling Stock

Apart from the normal coaches and freight wagons, there are some very unusual ones on the Group books including special heating and refrigerating vans used in connexion with the proving of various ammunition and explosives at experimental establishments, flats equipped for carrying long and heavy gun barrels and some fitted with a special type of side-elevating platform that enable small depot-pattern fork-lift tractors to be moved by rail between sheds where platforms are at varying heights. There are also various kinds of cistern wagon used as emergency reservoirs of water for fire fighting and others for weedkilling sprays. The control and annihilation of weeds is quite a task for the civil engineering side and all sorts of tests with reputed long term effect granular substances have been carried out lately. These are more persistent than the chlorate and non-chlorate solutions and attack the roots of weeds. Though generally more expensive, nevertheless their use in some of the smaller depots, where application is by hand or hand-operated spreading machine, achieves a considerable saving in maintenance costs. Something like a fifth of all track mileage maintained by the Group was treated with granular weedkiller during the past year.

Army Railway Users

It is interesting to consider who are the Group's customers and how they compare in importance from our point of view. This comparison can only be made by studying the number of wagons handled at each and every installation. On this basis approximately 78 per cent of all wagons handled are for Ordnance, half of these being for general stores and well over a quarter for ammunition and bulk explosives. Engineer Stores account for 9 per cent and Proving and Experimental Establishments for slightly less. Figures for food supplies and petrol, both to become an Ordnance responsibility, are relatively small. A parade of our principal customers would include one major-general, (the Commander Stores Organization RAOC), six brigadiers, five colonels besides a number of more junior officers, all of them being in appointments outside the Ministry of Defence. Their existence and the need to see them from time to time to discuss the railway service provided for them, training and housing of reservists and arrangements in the event of a national emergency provide good reasons for the Group Commander continuing as a serving colonel.

Military Aspects

The Group suffered a severe blow when all military posts save that of the Commander were abolished some two years ago, causing a considerable loss in military railway knowledge and experience quite apart from flexibility. Civilians are virtually immobile and with every grade the nature and extent of duties is subject to continual regard to Civil Service and relevant trade union rules and practices.

The Group offers wonderful military railway training, the like of which cannot nowadays be equalled at Longmoor or elsewhere. Traffic is real and of immense variety; it is considerable and must be dealt with. Time is important not only for the shunts but as regards repairs of wagons and motive power; in fact the task is a substantive and dynamic one every day and always. What better training therefore can one have? Such training of course is of the advanced practical type for the qualified man. Basic tuition and practice on

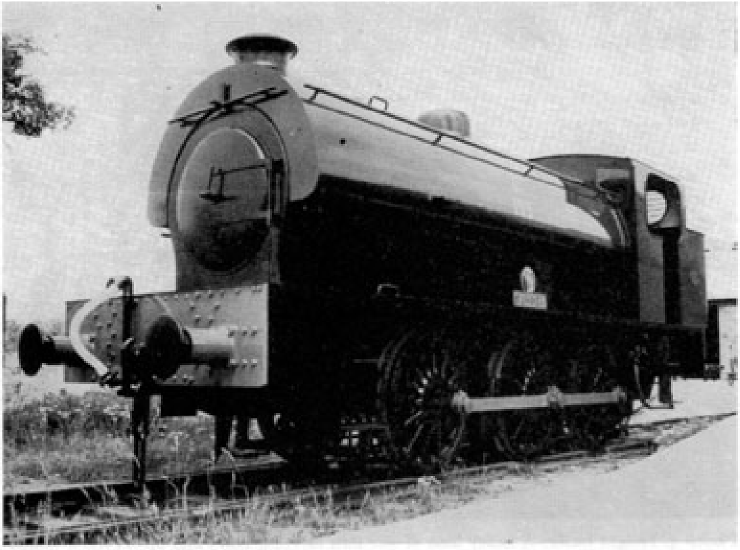

Photo 2. The Old:—The 0-6-0 Austerity type steam locomotive "Sapper" at Bicester Depot

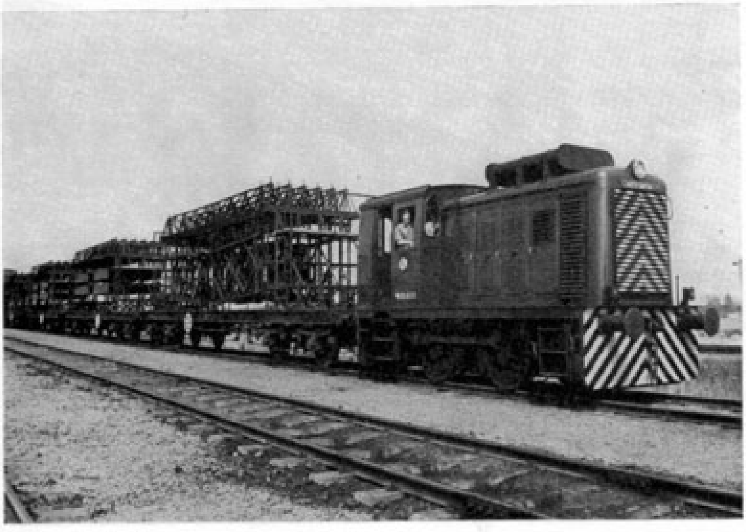

Photo 3. The new:—A 275 hp North British diesel-hydraulic locomotive, with an AER driver under training, hauling a train load of bridging equipment at Long Marston

Army Railways in the UK today 2 & 3

Photo 4. Freight traffic. A heavy load of war flats carrying tanks and an AVRE is double headed by two 275 hp diesel locomotives at Ludgershall

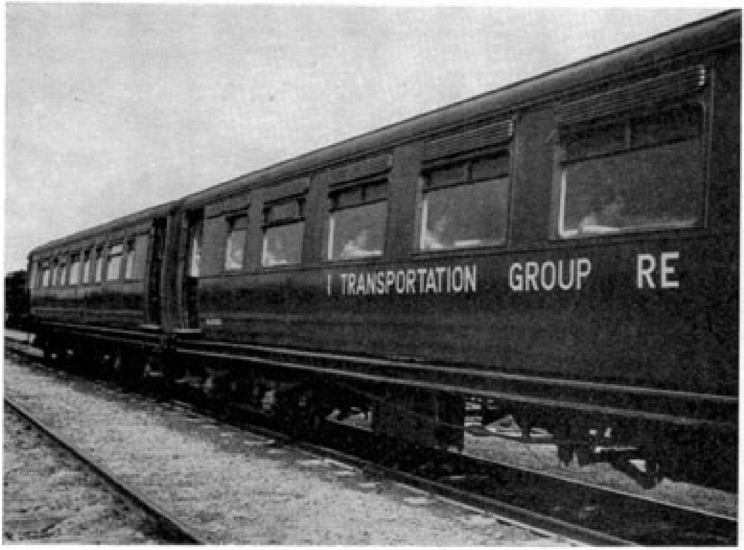

Photo 5. Passenger services. On internal depot services something like 200,000 passengers are carried annually

Army Railways in the UK today 4 & 5

Photo 6. Lady engine driver. The Group's only lady engine driver on the footplate of a 2-ft gauge diesel locomotive at a depot north of the border

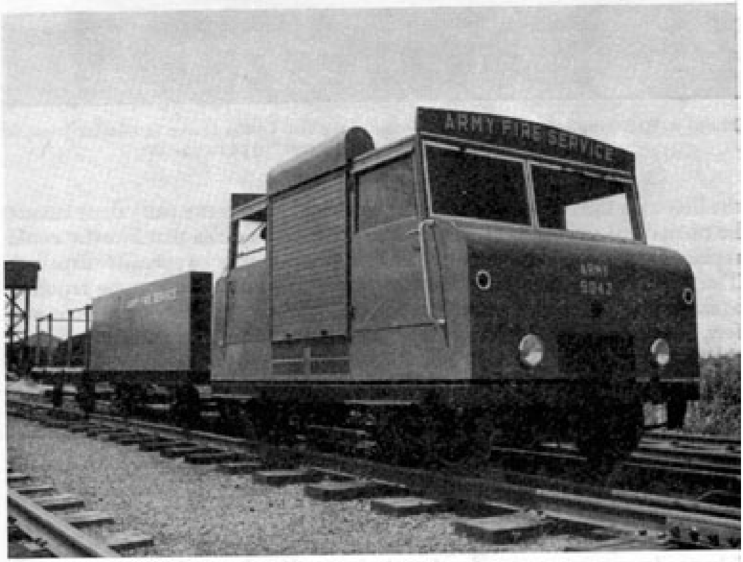

Photo 7. Fire tender rail car. A 30 hp Wickham rail car converted for carrying fire fighting pumps and equipment. The two trailers are for canvas hose and AFS personnel respectively

Army Railways in the UK today 6 & 7

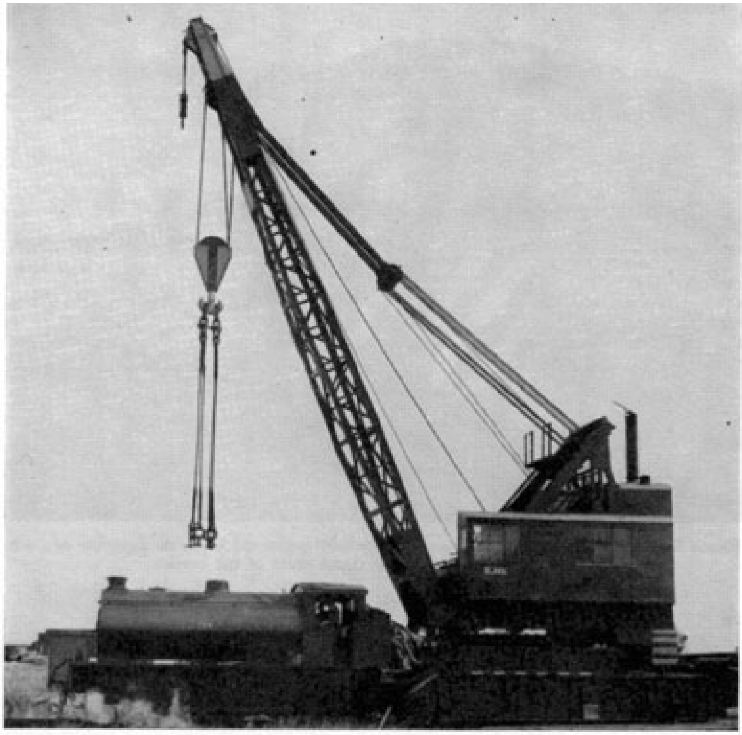

Photo 8. Rail-mounted crane. "Blake"—one of the two 60-ton cranes at Shoeburyness, is seen being moved by an 0-6-0 "Austerity" type locomotive

the line with the necessary theoretical instruction to accompany them cannot be carried out satisfactorily at the same place, so any idea that Bicester could replace Longmoor as the Railway Training Centre may be speedily dispelled. The strange idea current in the Army that railways will never be required again in war will pass, but by then the damage may well have been done and few, if any, will be trained in their operation. Even that does not disturb many misguided people who think that any RE unit can operate a railway, and that apart from training a handful of specialists no other preparation is really necessary. All this is due to a misconception of the whole problem and probably stems from several instances when field units have in the past repaired and operated a train on a rehabilitated length of line for a limited period of time.

The Future

The Group is far from being moribund and looks into the future with confidence. Its service must not only suit, but really please, the customers and, as already stressed, it must be a worthwhile concern economically. Should its

Photo 9. Central Workshops, Bicester. A general view of the workshops area showing a re-built "Fowler" 150 hp diesel locomotive in the foreground

vast assets in rolling stock, power, track and buildings ever be allowed to deteriorate to a low level of efficiency, thereby necessitating sudden expensive replacement, then its prospects might well indeed be gloomy. It must certainly be a difficult problem to find money for this in our nuclear age and it is all the more imperative, therefore, that technical development be right up with the times. Preliminary trials have shown for instance that there is obviously scope for the use of radio telephony on certain depot railways and shortly it is hoped that more extensive trials will reveal how savings in telephone circuits, time, and even in the numbers of railcars and locomotives can be achieved. With the Channel Tunnel Project looming up to extend very considerably the scope of cross-channel rail movement, surely we must have military wagons capable of travelling straight through to our depots on the Continent? Locomotives used there should be readily and easily interchangeable with ours in Great Britain; admittedly they can be transferred with appropriate modifications, but these are not easy in peacetime. Nevertheless the day must come when an easy flow of rail traffic will be possible in spite of the present differences in loading and structure gauges, etc (those on British Railways are more restrictive than on continental railways).

Railway assistance to Proving and Experimental Establishments must be geared to their progress and even though there may not be a requirement today for humping around 15-in naval gun barrels yet some very awkward equipments have still to be moved and lifted.

Very shortly the Group will become part of the new Royal Corps of Transport but happily will continue in close association with the Royal

Engineers who will remain responsible for all track maintenance and civil engineering advice and liaison for works projects with the Ministry of Public Buildings and Works. Similarly, repairs to all motive power, railway cranes and rolling stock will come under the aegis of the Royal Electrical and Mechanical Engineers. Operating, however, is the primary function of the Group, so management, control and organization are likely to remain essentially as they are, but under the flag of the RCT.

"Sic Transportation Gloria Mundi"

The Critical Path Method—Some Simple Practical Considerations

By Lieut-Colonel K. R. Hasildon, RE (Retd), MA, MICE

Introduction

The theoretical aspects of the application of Critical Path Analysis to engineer planning have been the subject of two articles in *The Royal Engineers Journal*. The first "Critical Path Planning and Scheduling" by Major H. P. Munro appeared in the December 1963 issue, and the second "The Critical Path Method" by Major J. R. Johnson in the March, 1964 *Journal*. (Note this article was written before the publication of Colonel P. S. Baines' article "Critical Path Techniques" that was printed in the June 1964 *Journal*.)"

With two exceptions which I shall mention later, one a very important one, I have no reason to differ with the theory as presented in those two articles, but after reading them I did wonder whether some readers might not say "This is not for me, I must leave it to the experts". This is a pity because, however complex the problems to which Critical Path Analysis may be applied, both the basic theory and practice are simple, and any engineer should be able to apply the technique to planning problems whether complex or not, within his own particular sphere. This is not to say that an expert in the technique will not apply it more successfully and more quickly, for, as in all things, practice generally improves even if it does not always make perfect.

In writing this article I have avoided, as far as possible, any repetition of theory and I concentrated on practical application in its simplest form. Indeed many who know the subject well may feel that in writing at length on some extremely elementary points, I have underrated the intelligence of readers of the *Journal*. I have deliberately risked such an accusation so as to illustrate both how easy it is to apply "C.P.M." and how a few simple pitfalls can best be avoided. To illustrate my points I have made frequent reference to the two previous articles and I have also used Major Johnson's example rather than introducing a new one. This article must, therefore, be regarded as complimentary to the earlier articles and not as another introduction to the subject. Nevertheless if any reader has not studied the previous articles, or better still the RSME Publication "The Theory and Application of the Critical Path Method of Planning and Scheduling", or had some other previous experience of the subject, I hope he will not on this account be put off from proceeding further but that by reading on his interest may be stimulated.

It is unfortunate that a standard set of terms has not been adopted in connexion with Critical Path Scheduling. This is no doubt partly due to the many different problems to which Critical Path Analysis may be applied. To avoid confusion, as far as possible, I set out below in tabular form the principal terms of which I shall make use in this article and the corresponding terms used in the preceding two articles and by the RSME. Although this article concerns the Critical Path Method (CPM) it is desirable to include also some of the terms used in the Project Evaluation and Review Technique (PERT). CPM and PERT can generally be said to be at the opposite end of the range of the various different techniques which embody the principles of Critical Path Analysis. Why then are the terms used in PERT relevant? Simply because a PERT computer programme will give the same answers as a CPM computer programme (and a few more besides which may or may not be useful to the civil engineer). If a PERT computer programme is available, it may well be that a CPM programme is not since this would be an unnecessary addition to the range of programmes maintained at the computer centre. Anyone who wishes to make use of a computer to perform the lengthy calculations sometimes necessary when applying CPM to more complex problems than the simple ones which serve well to illustrate the theory and practice should, therefore, be familiar with the terms used for both CPM and PERT. The terms used in the two previous articles are not wholly one or the other. Which are the better? I do not know. Use whichever suits your requirements or fancy provided that, as when using abbreviations, your meaning is quite clear. The terms I personally prefer are those which the Americans use for the Critical Path Method of Analysis.

Both Major Johnson and Major Munro in their respective articles, suggest that Mauchly Associates Ltd, are the source of the terms which they use, yet the two articles do not consistently use the same terms. For this reason also a comparative table of the principal terms used is desirable.

CPM	PERT	RSME	Major Johnson's Article	Major Munro's Article
Activity	Activity	Job or activity	Job or activity	Job
Node	Event	Event	Event	Node
Time	Time	Job duration	Duration	Elapsed time
Earliest start	Earliest start	Earliest activity start time = earliest start event time	Earliest event time	Earliest start
Earliest finish	Earliest finish	Earliest activity finish time	—	Earliest completion
Latest start	Latest start	Latest activity start time	—	Latest start
Latest finish	Latest finish	Latest activity finish time = Latest Finish event time	Latest event time	Latest completion
Total float	Total float	Total float	Float	Total float
Free float	Early free float	Free float	Float	Free float

out by Major Johnson and more comprehensively covered in the RSME notes. What is in fact going on during these stages is that the various possible solutions are being considered in a logical sequence until the best plan is achieved. Before I am taken up on my statement "the best plan is achieved", let me say at once that it is the best in the opinion of the man, or men, who produced it. There may be others equally good but, if the logical steps of CPM have been followed, then the chances of an inferior final plan are much reduced.

Jumping to the end of Major Johnson's example, I have drawn at Figure 1 the final bar chart for the same works programme as is illustrated in Figure 6 of his article by an arrow diagram to a time base. Activity numbers have been used instead of letters for a reason which I will explain later, and an error has been corrected, but with these two exceptions, the only change is in the method of presentation.

Figure 1 fulfills the following functions:—

(1) It presents the works programme in bar chart form intelligible to anyone who can read a bar chart, even though that person may not be conversant with CPM, nor understand the purpose of some of the additions on this chart formerly absent from bar charts.

(2) It lists all the activities and their reference numbers.

(3) It shows at a glance, by means of solid bars, the critical activities.

(4) It shows also at a glance, by means of hatched bars, the activities which, although not on the critical path, have for certain reasons been made critical by postponing their start and completion to the latest possible time.

(5) It shows by full arrows how much, in either direction, each non-critical activity can be moved in time without affecting activities on the critical path and, therefore, the shortest time for completion of the project. In other words the full arrows show the total float for each non-critical activity.

(6) It shows by broken arrows how much, in either direction, each non-critical activity can be moved in time, if at all, without affecting some other activity, ie the broken arrows show the free float of any non-critical activities which have free float.

(7) It shows at the beginning of the bar representing an activity the node (= event) number at which that activity starts and at the end of the bar the node (= event) number or numbers at which that activity ends. By this means the chart enables the preceding and succeeding activities to be picked out with comparative ease, however numerous.

(8) It shows the planned labour and plant content for each activity.

(9) It shows the planned total labour and plant content for each unit of time to which the chart is plotted, in this case the unit being one day.

I submit that the above represents a great deal of information to crowd into one chart. Examine Major Johnson's Figure 6 and see to what extent it fulfills the same nine functions.

It does not fulfill (1) because it is not a bar chart. It does not fulfill (2) as it includes only the activity letter reference (perfectly acceptable in lieu of numbers, though not recommended). It would not, however, be impossible to insert abbreviated descriptions against the arrows representing activities although the shorter ones, such as job A (= activity No 1 in Figure 1) would present some difficulty if crowding and, therefore, confusion are to be wholly avoided.

It fulfills (3) and it also fulfills (4) though not, I submit, quite so readily.

It fulfills (5) but a certain amount of careful study is necessary to extract this information.

It fulfills (6).

It fulfills (7) very well indeed; in fact in my opinion it fulfills this function more readily than the bar chart, and this is the principal advantage of arrow diagram presentation.

It does not fulfill (8) at all, but it fulfills (9) in exactly the same manner as the bar chart presentation.

It is I think fair to say that the presentation of the works programme by means of an arrow diagram to a time base, is much inferior to such presentation by means of a modern bar chart in four out of the nine functions listed, equal in four out of nine and superior in only one. To everyone his choice, but for me a bar chart every time.

Before I leave the comparison between arrow diagrams and bar charts, I must point out two advantages of being able to include function (8) in the bar chart presentation. Major Johnson has given this information separately in his Table 1. Apart from the nuisance of having to refer to a separate table, Table 1 unfortunately sets out only the labour and plant contents for each job as originally planned. I presume that Major Johnson did not include a revised table because in his example there is only one revision—job "D" (activity 4 in Figure 1 of this article) but the only way of discovering this alteration is to work backwards from the revised daily contents. I have no doubt Major Johnson worked it the other way, but it is important to put the full details of the final plan on record in a form which is convenient to the person who will be in charge of the execution of the project.

The second advantage of including (8) is that it enables the daily totals to be ascertained quickly and also to be readily checked as alterations are made during the various steps leading up to the final programme. It so happens that Major Johnson has made a mistake in the daily totals in his final programme, having omitted the "Compressor and Vibrators" for job D (Activity 4 in Figure 1) on the 8th and 9th day. This error was immediately apparent when the bar chart at Figure 1 was drawn. It is only a minor error in this instance, but had a similar error been made in the labour totals in Major Johnson's Figure 4, this would have affected his subsequent thoughts, and while the error would probably have been discovered before completion of the programme, planning time would have been wasted. It is human to err, and in the planning of more complex projects, errors all too easily creep in. Let us, therefore, adopt a planning procedure which minimizes the chances of errors in the first place and provides the maximum check for discovering, as soon as possible, any errors made.

To sum up, to the other advantages of using CPM for planning a project, there can be added that of enabling the engineer of today to present his works programme in the recognized and well established form of a bar chart with additions which give a great deal more information than the rather limited bar chart which the engineering profession has had to accept in the past. An arrow diagram is an essential step in the process and in certain

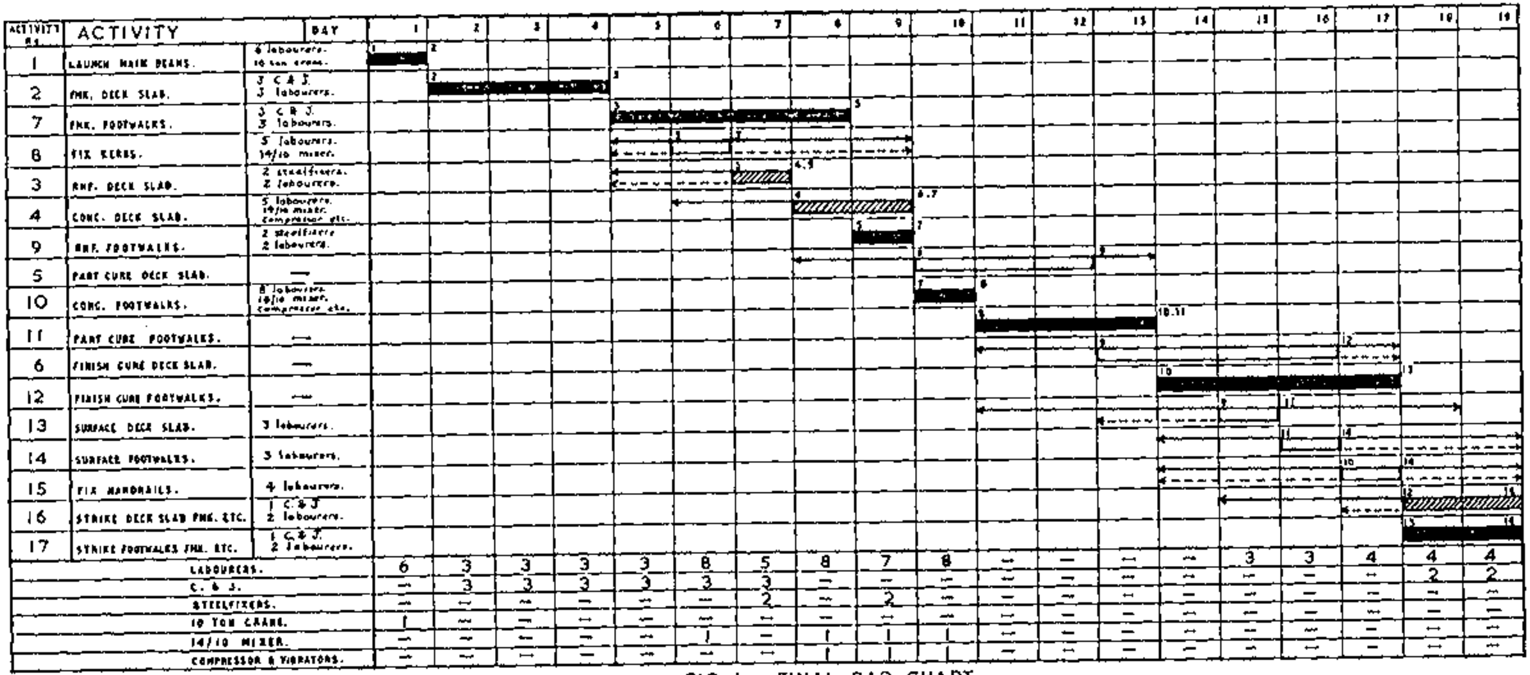

FIG. 1 - FINAL BAR CHART.

circumstances an arrow diagram to a time basis may be the most suitable conclusion of the process, but to exploit CPM to the full for a construction project it will normally be found more practical to consider the later stages of the planning process by means of bar charts and to present the final works programme in that form.

I make no apologies for beginning my article with what is in fact the end-object for unless this is understood the full advantage of CPM may be lost on the beginner. With this end-object in view, I trust that the beginner will see the point of some of the practical steps I shall later suggest, and also understand the reasons why some of the workings illustrated by Major Johnson can sometimes be omitted without danger. In my opinion each step in the planning process should be kept as simple as possible, but the final programme should contain as much useful information as can reasonably be included, for there is nothing more annoying to the man charged with the execution of a project than to have to wade through the planner's workings to discover certain information essential for the proper conduct of the operation.

Major Johnson's example is an extremely simple one, yet the arrow diagram in his Figure 3 is terribly cluttered up with detail which may well frighten the unitiated into thinking that CPM is more complex than it really is. In projects with a large number of activities there are complications enough without unnecessarily introducing more. Even in his example Major Johnson has omitted certain factors which would often have to be taken into account if a real project was being planned. I have no doubt that he did this deliberately to help to keep his example simple, and to criticize it because of these omissions would be unjust. However, for those who have not yet noticed any omissions, I will mention some queries which immediately came to my mind.

Before the concrete can be made, aggregates and cement have to be supplied. Why was this supply not included in his Table 1 and Figure 2?. Is it necessary to lay on a water supply? What about the supply of timber for formwork? These are all activities which may possibly have to be considered, but it is impossible to say until faced with the actual project. It must then be decided whether or not they are important activities which must be included in the analysis or whether they are unimportant and for simplicity can safely be left out of the analysis.

For the rest of this article I have assumed that anything which Major Johnson may seem to have omitted, was deliberately omitted after due consideration. However, before I leave this point I would stress that the supplies of certain materials can often be critical activities. This is one reason why I prefer the term "activity" to "job", even though the latter is a shorter word. If your Chief Engineer asks you for a plan to construct a bridge and you produce one without taking into account the time it takes to obtain materials and stores on site, and these later turn out to be critical, I fear your reputation as an engineer will suffer. If, however, the Chief Engineer has already told you not to worry about this aspect, and that he will see to it that you get the materials and stores at the time you want them, then you may rightly ignore such activities as factors of importance in the preparation of your programme, although it is still useful to record them as Major Johnson has done in Figure 3, but not regrettably in Figure 6. I have omitted them from Figure 1 of this article only because Major Johnson omitted them from his final programme and I have, therefore, assumed that they are not limiting factors. Each case must be considered on its merits, because it is only when a practical problem is before you that you can decide which activities must be included and what may safely be omitted. If you follow CPM, then, because it is a logical method of planning, the important activities should not escape you.

The Arrow Diagram

To go back now to the beginning.

The first step is to set down the main activities necessary for the execution of the project. At this stage the sequence does not really matter nor is it likely that your list will be complete. It is one of the advantages that arises from the logical process of thought which is CPM that such omissions will normally leap to your mind when you consider the sequence of activities. This is particularly true of the supply of materials and stores.

In listing activities you will immediately be faced with the problem of deciding how much detail is necessary. The greater the detail, the greater the number of activities and, therefore, the more complicated your actual planning. The general rule is to keep the individual activities as broad as possible. This is usually easier with a civil engineering project than with a building one because the latter normally embraces a greater variety of trades. When you first start you may find that the tendency is to break the project down into too many, rather than too few, activities. In my opinion, in spite of the general rule, to err on the side of too many activities is to err on the right side. With experience you will learn which tasks may safely be combined in one activity, whereas if initially you over-simplify the problem by combining too many tasks in one activity, you may lose some of the benefits to be obtained from CPM. I suggest, therefore, that in spite of the disadvantage of having too many activities you should be guided by the principle that when in doubt whether two or more tasks should be combined in one activity, do not combine them.

Number, or letter, the activities on your schedule if you want to. I prefer numbers because they are unlimited. Some persons prefer to number activities later when the sequence is known but with a large number of activities this makes checking more difficult. I personally prefer the compromise of numbering them as I draw the arrow diagram. This means that they will be numbered in something approaching their final sequence, provided of course that none are omitted initially, or the diagram does not have to be altered. In this event the last thing I am tempted to do is to go back and renumber, since this is purely a waste of time as the order of numbering the activities is not important.

You are now ready to start on your arrow diagram. At this stage I differ with Major Munro on two points. The first is one of theory. He states that before an arrow can be drawn six factors must be known about each activity. Only the first five he mentions should be considered. The sixth "What is the time for the activity?" he does correctly qualify by stating that it is required for scheduling only. But at this stage you are not scheduling but only sequencing, so do not bother about time. Is this a golden rule? The pundits say "Yes", but in practise it is a rule which may have to be broken. For example when a concrete slab, supported only at its edges, has been poured it has to be cured before the shuttering can be withdrawn, but you may be able to carry on with work above the slab after only a short period of curing. Again you may be able to withdraw the shuttering and reprop to enable you to get on with the next activity before curing is complete. You can hardly take cognizance of these factors without having some knowledge of the time after which curing will have advanced sufficiently far for a start to be made on the next activity. Make the system your servant not your master, and if time does affect your consideration of sequence then do not be tied by the rules. But equally do not break them unless you have to, for surely your sins will find you out!

The second point on which I differ with Major Munro is the purely practical one of drawing the arrow diagram. I like to illustrate a node by a node and that is why I prefer the term "node" to "event" although the latter is a perfectly correct description.

If you draw a line to represent a node as advocated by Major Munro, then with any project with a large number of activities, you will be off the drawing board and down the end of the corridor before you know where you are. Besides, except in the most simple projects, you are sure to have to come back and make alterations sooner or later and with straight lines for nodes you may find that this entails major alterations to your diagram. It is not easier, and on this issue I emphatically disagree with Major Munro, to draw your arrow diagram on a drawing board with straight lines. Forget straight lines for nodes and even at times for activities. Use a large piece of squared paper, or a piece of tracing paper with squared paper under it, and do not cut it off the roll if you can help it until you know how long your diagram is going to be. Draw circles for nodes with a suitable template (the hole in some set squares is often very suitable for this). Use a pencil and always have a rubber handy. These are the two most important tools you require for CPM planning. Draw free-hand if you want to and go all over the place without let or hindrance. The neater you draw the easier you will make things for yourself later on, but with a complicated project you will be lucky indeed if your first attempt at the arrow diagram does not have to be so modified that you do not have to draw a better edition. In any case a second edition often brings to light errors of thought when you composed the first. Major Munro makes the point that the type of arrow diagram which he prefers is more like a works table in appearance. It is indeed a form of bar chart although, at this stage, it lacks any scale, and it might be thought that if the final presentation of the works programme is to be on a bar chart, then there is some advantage in adhering to the same form right from the start. However, to draw a bar chart to a time-base after all the sequences have been properly worked out, the time for completion is known, and a suitable scale can be adopted to keep within the limits of the drawing board, is a very different proposition from drawing an initial arrow diagram similar in form. To attempt the latter, is, I submit, to retain one of the disadvantages of the older system of preparing a works programme.

I have another practical reason for using circles and not lines as nodes. You can put the node numbers in them and there is then no danger of mixing them up with activity numbers. But this comes later for you cannot number your nodes until you have otherwise completed the arrow diagram. Before leaving this point, however, I should mention that there are times when so many activities start from or finish at one node that a circle only is impracticable unless you draw a ridiculously large one. On such occasions by all means use a base line.

The following Figures 2, 3 and 4 mean exactly the same thing:—

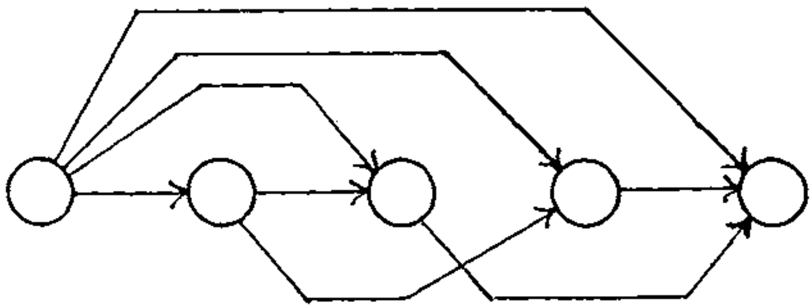

FIG. 2.

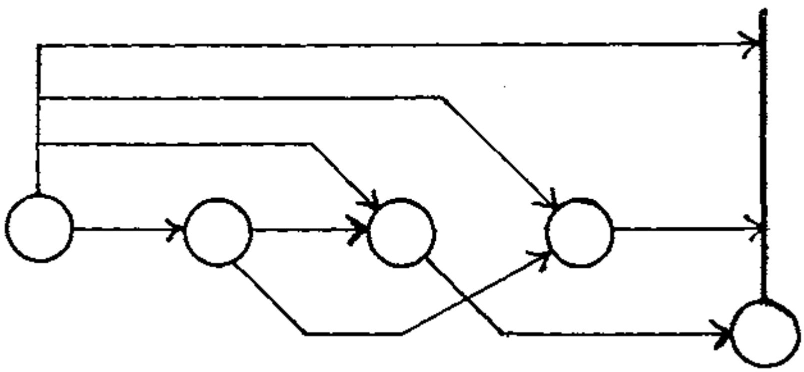

FIG. 3.

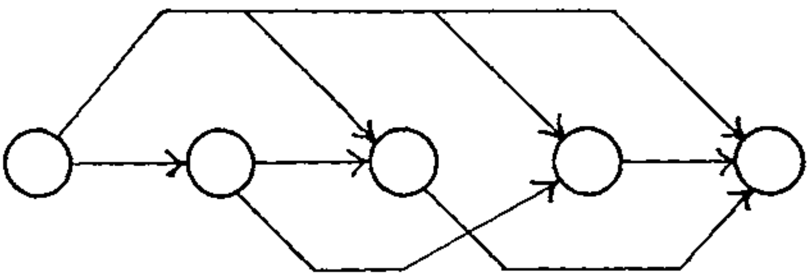

FIG. 4.

Adopt the simplest method to suit your purpose and do not be hide-bound, provided that you do not confuse yourself or others.

Figures 2, 3 and 4 also illustrate the answer to another question which is sometimes asked. Is it permissible to cross the arrows in an arrow diagram? It is not only permissible, but often unavoidable, and there is no need to follow the system of looping one over the other as used in some electrical diagrams when circuits cross one another. Provided that you do not allow the arrows to cross at too small an angle, no confusion can result.

Enter the briefest possible description against each activity, and unless you want to leave this step until the end when the overall sequence is known, enter the activity numbers as well. Why not, you may ask, identify the activities more simply by the activity number only? Because if you do, you will constantly have to refer back to your schedule of activities. Worse still, you can more easily miss an error, for you may be sure that you will initially make some errors when drawing the arrow diagram for any large project. I wrote earlier on that you should not unnecessarily complicate the diagram, but the writing in of activity descriptions as you draw the diagram, is, I find, an extra labour which saves much time and assists in the spotting of possible errors later on.

I must now jump to the completed arrow diagram. I illustrate at Figure 5 the arrow diagram for Major Johnson's example as I would have drawn it, save only that in practice my drawing would be in pencil and nothing like so neat.

Note that the node numbers are in the nodes. This is the very last step in the preparation of the arrow diagram. Start numbering the nodes at the starting node with 1 and follow the arrows along any path you select numbering the nodes in ascending order until you come to a node which has an arrow leading in to it which starts at a node not yet numbered. At this point you must stop and go back to pick up the unnumbered nodes, for it is a golden rule, which must never be broken in any circumstances, that an arrow cannot finish at a node number which is smaller than the node number at which it started. You will not necessarily finish up with all your nodes numbered in the same order as Major Johnson although some are bound to be the same, including the first and the last. However, for convenience I have followed Major Johnson's node numbering. I numbered through to 5 and then I had to go back to 4 because at that stage the node which is to be numbered 7 had an arrow leading into it from the then unnumbered node 6. I could not, therefore, number node 7 as node 6. However, note that although node 5 had two activities leading into it, one started at 3 and the other at 4. The numbering of this node as 5 was, therefore, perfectly in order. Perhaps I may seem to have laboured this rather simple point, but it is a vital one and it is very easy to make a mistake. If you find you have numbered a terminal node lower than one from which an arrow starts, there is nothing for it, but to rub out node numbers as far back as necessary and renumber.

There is, however, a different kind of mistake, which is also easily made in a large diagram. You may find that you have accidentally jumped some numbers. In this case there is an alternative solution which may save time. I quote an actual example. In a diagram which had 846 nodes and 836 activities plus 429 dummies (of which more anon), the planner accidentally jumped from node 544 to 555, and did not spot the error until completing the data sheets for the calculations to be performed on a computer. A stupid error you will say. Certainly, but he was not the first to have made such an error nor will he be the last. What was to be done? Rub out nearly 300 node numbers and rewrite a large number of activity data sheets? Certainly not.

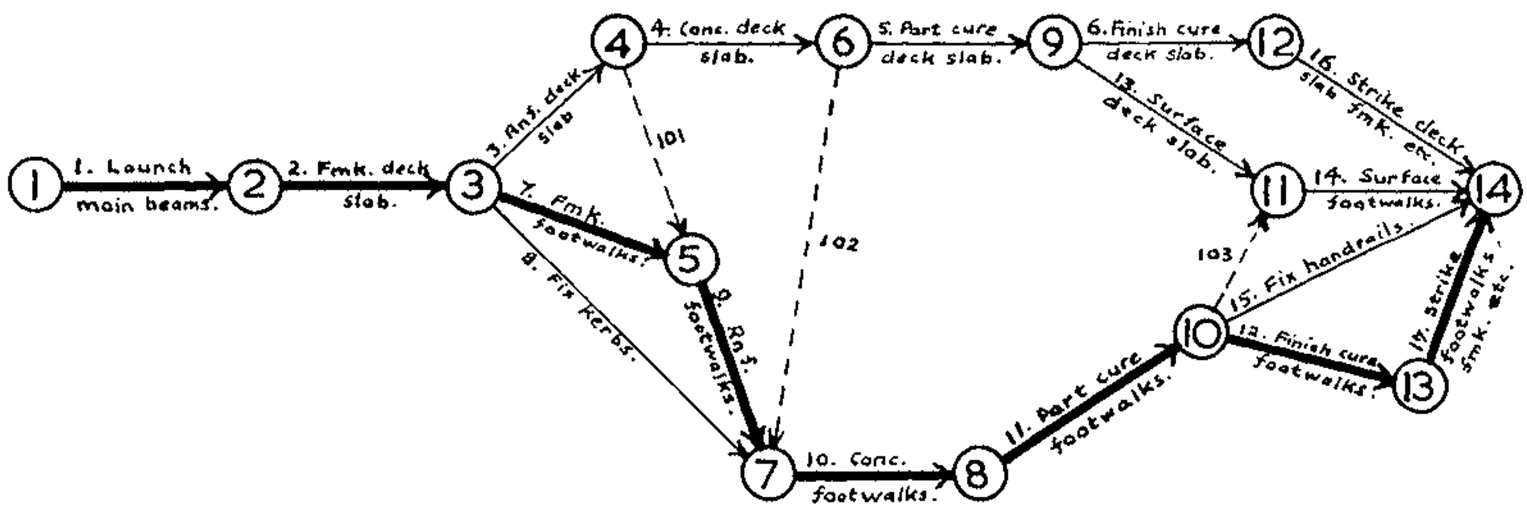

FIG. 5 - ARROW DIAGRAM.

Figure 6 illustrates the error.

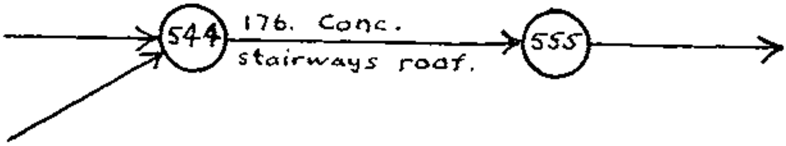

FIG. 6.

Figure 7 illustrates the quick alteration which provides the necessary correction.

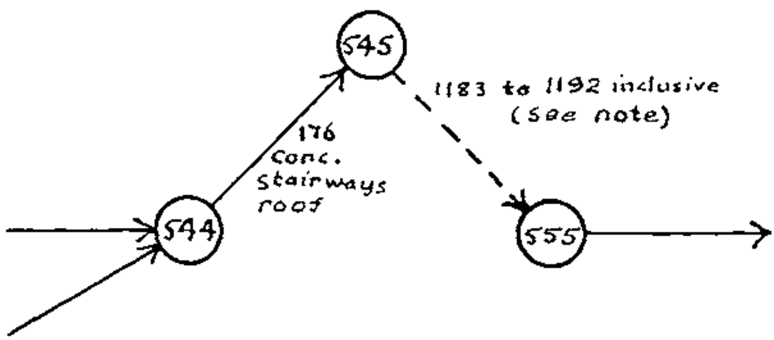

FIG. 7.

The missing nodes, except for 545, were not drawn in but they were duly entered with the inserted ten dummy activities in the computer data sheet and all was well. How this could have been done with Major Munro's system of drawing nodes, I do not know. It will be noted that this mistake did not break the golden rule of ascending node numbers. Had it done so, there would have been nothing for it but to go back and renumber. You may ask if it was really necessary to correct the error. With manual computation the answer is "No", but it is advisable to do so to avoid any confusion. Using a computer for the calculations, correction was essential for a computer will stop when it fails to find the next ascending node number unless it be last node of all. However a computer is quite helpful in such circumstances. It will print an error message saying "no node 545" or something to that effect.

Coming back to the simple arrow diagram in Figure 5, Major Johnson has explained the broken arrows which represent dummies. In every case in his example, the dummies represent a restraint in that they restrain the start of the activities commencing at the nodes where the arrow heads of the dummies terminate, to the completion of the activities which finish at the nodes where the dummies start. Major Johnson also correctly uses the word "restraint" in connexion with supplies of materials and similar considerations which may affect the starts of some activities.

Usually in an arrow diagram there are also many dummies which are pure dummies. They also have a restraining effect but their insertion is not essential to the theoretical compilation of the arrow diagram. The ten inserted as shown in Figure 7 (but only one drawn) are pure dummies in that theoretically the Arrow Diagram is complete without them. A much more common dummy, however, is that used to distinguish between two or more activities which begin at a common node and end at a common node.

Theoretically Figure 8 is perfectly correct, but in practice this situation must be drawn as Figure 9.

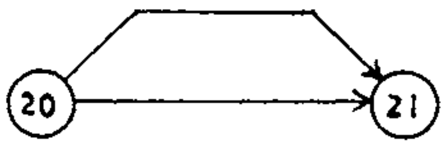

FIG. 8.

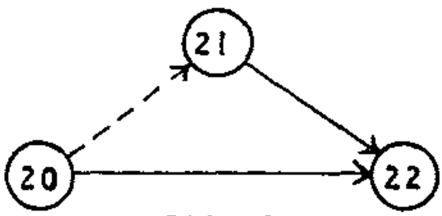

FIG. 9.

Figure 10 however is equally correct in theory and is probably what you will first draw.

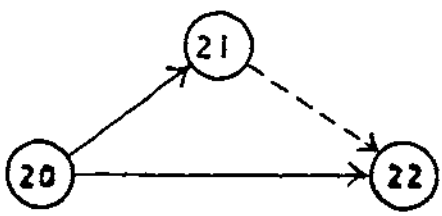

FIG. 10.

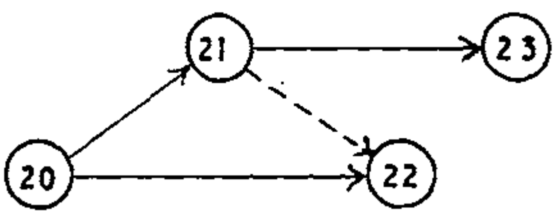

FIG. 11.

Figure 8 is wrong in practice simply because it does not distinguish between the two activities in terms of node numbers. In Figure 8 both activities are 20.21 while in Figure 9 one is 20.22 and the other is 21.22.

Figure 10 is not incorrect but as a practical tip always draw this situation as Figure 9. Whether you do your calculations manually, or they are done for you on a computer, the advantage of Figure 9 over Figure 10 is that the free float, if there is any, will be revealed against the activity instead of the dummy, and you will later save yourself the time of picking out this float when drawing the bar chart.

This tip only applies when no other activity starts at 21. Faced with the situation illustrated in Figure 11, there is nothing you can do about it for another factor, namely activity 21.23 starting at node 21 has entered into the picture. However in this case as you will discover, any free float available on the dummy is of no use for your initial bar chart, so it does not have to be picked out.

Major Munro suggests another use for a dummy. He quotes the example of a job "c" which cannot start until job "a" has progressed a certain amount. In the method of arrow diagramming which I prefer, his example could, I imagine, be as shown as in Figure 12 although I have certain qualifications on this score.

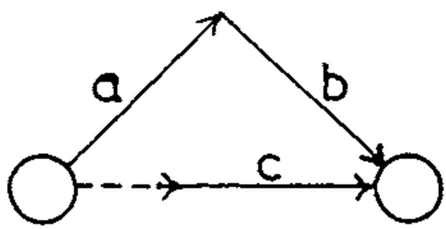

FIG. 12.

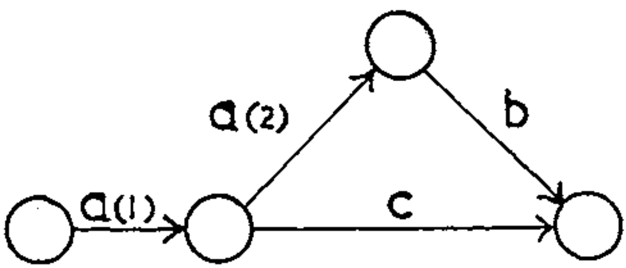

FIG. 13.

Major Munro states that this dummy would be given an elapsed time. This to me is a complete contradiction, and I agree wholeheartedly with the note by the Engineer Planning School that dummy arrows should not be given an "elapsed time". I will be even more emphatic and say that they must never be given "time". It is another golden rule which must not be broken, that a dummy has no time. It can have total and free float but never "time". Again I consider that it is wrong to have two activities "a" and "b" with no node between them. The correct diagram for the situation for which Major Munro is attempting to legislate is shown in Figure 13.

This simple illustration however broaches a real problem, namely that of overlapping activities. They can be quite a headache because, before you know where you are, you find that properly to illustrate the position in an arrow diagram it is necessary to split up so many activities that the number is multiplied exceedingly, thus increasing the volume of your calculations and possible chances of error. It is something which cannot always be avoided nor, if the number of activities is so large that the calculations will be performed on a computer, is it perhaps so important to keep the number of activities down. However avoid splitting up activities in this manner if you reasonably can. On a bar chart overlapping is a very simple situation with which to deal. Therefore, if possible, postpone consideration of any overlapping until you have completed the initial bar chart. It is not always possible to leave it as late as that, for, to ignore a known permissible overlap at the arrow diagram stage may introduce serious practical errors in timing and sequence which are better avoided right from the start. This is a matter in which experience is the best guide, but the necessity for considering overlaps is another good reason for finishing up with a bar chart proper, and not an arrow diagram to a time base as advocated by Major Johnson. It is by no means impossible to illustrate the situation on such a diagram, but in my opinion it is more logical to do so on a bar chart.

To take an extreme example, a programme was recently prepared under my auspices for the construction of a low cost housing scheme. This is a repetition job, the houses being, for the most part, similar. Any particular activity in one house has to be repeated 517 times with only a few exceptions. In any one house there are only 51 basic activities, but if each of these activities had to be divided up into 517 activities to indicate the starting point of the suceeding event in each house the number of activities would have been increased to 26,267. In fact it was not quite as bad as this as the number of activities could have been reduced to one eighth, ie 3,283, still a formidable total and to draw an arrow diagram even for all these repetitive activities, let alone one to a time base, would still have been an appalling waste of effort. I understand that there is a form of critical path analysis for manufacturing processes which might be applicable in such a case, but I am not familiar with it and the way in which this particular problem was solved was to make a critical path analysis by CPM for a typical house going as far as the initial bar chart stage. A bar chart was then produced for the whole 517 houses taking into account that each activity has to be completed for eight houses (the ultimate output being eight houses per day) before the succeeding activity can start in those same eight houses while the preceeding activity continues in the next eight houses. The total and free floats, where they existed, were, with certain exceptions on which I cannot digress in this article, the same as for one house but the Bar Chart for the whole shows overlaps even for critical activities over almost the entire duration of each activity except at the beginning and end of each. This is an extreme but actual case of overlapping on a grandiose scale being introduced at the bar chart stage rather than unnecessarily complicating the arrow diagram and subsequent calculations. How far construction will follow the programme has yet to be put to the test, but I think that it was the only practical method of applying CPM to the planning of this particular project. However, as I have said a Critical Path Analsysis applicable to a manufacturing process might well have been another way of approaching the problem.

I now turn back to Major Johnson's example. After completing the basic arrow diagram except for node numbering, it must be very carefully checked indeed. First, have any activities been omitted? If you numbered your activities in advance or as you drew the arrow diagram, this check will be the more simple. Another very important check indeed is to work backwards from the finish and ask yourself the question for each activity in turn "Does the start of this activity really depend on the completion of all activities terminating at the node at which this particular one starts?" You must be strictly truthful with yourself when making this check. The kind of situation illustrated in Figures 14, 15 and 16 can easily occur when compiling an arrow diagram.

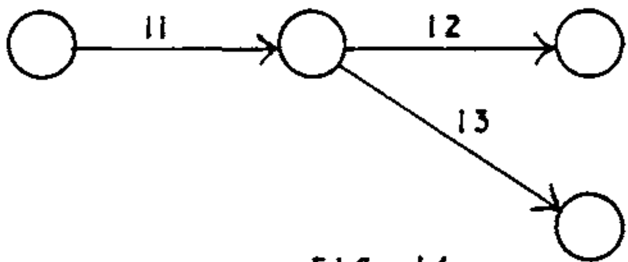

FIG. 14.

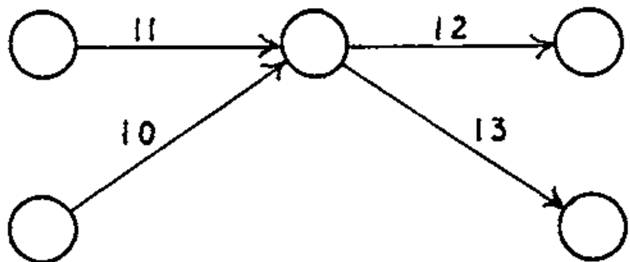

FIG. 15.

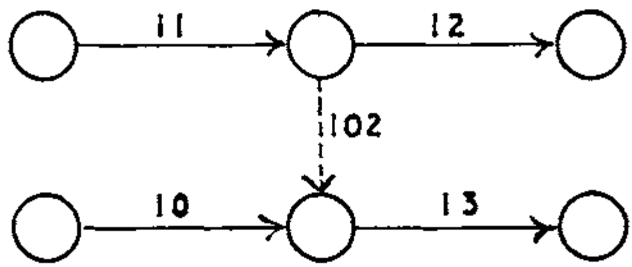

FIG. 16.

You get as far as Figure 14, or even further, and then find that you have omitted activity 10 which has to be completed before activity 13 can start. Without further ado you insert it and Figure 15 is the result.

When you start checking back you ask yourself whether the start of activity 13 depends on the completion of both activities 10 and 11. It does, well and good, and now you examine activity 12. Remember that when you first drew in activity 12, activity 10 was not there. When you ask yourself if the start of activity 12 depends on the finish of both activities 10 and 11, you may find to your horror that activity 12 depends only on the completion of activity 11 in which case your diagram is wrong. The correct answer is shown in Figure 16.

Note that this means not only the insertion of a dummy but also an additional node. If therefore you are wise, then you will check your arrow diagram working backwards from the finish before numbering the nodes.

What I have just illustrated is a very common error indeed. Disbelieve me if you will, but do not say that you were not warned.

Having thus checked your diagram and, better still, got someone else to check it as well and made you explain any sequences the reasons for which were not abundantly clear to him, then, and not before, number your nodes as I have already described and check your numbering carefully.

The activities on your arrow diagram are all briefly described and if you follow my advice, numbered. But until you started to draw the arrow diagram you had no dummies scheduled. You must also number these but no description is necessary. Whether you number them as you draw them in, or wait until you have completed the diagram, does not matter but it is probably less easy to miss giving one a number if you adopt the first course. Use a different series of numbers. If, for example, you have less than 100 activities, start the dummies at 101. This clearly distinguishes dummies from other activities.

The Calculations

The next stage is the calculations. Both the RSME's notes and Major Johnson's article advocates what virtually amounts to performing these on the arrow diagram. For a simple project this presents no great difficulty, but the greater the number of activities the more difficult it will become to tackle the calculations systematically by this method. I advocate setting down all the necessary information on special calculation sheets and once this has been done, thereafter working solely on the calculation sheets referring back to the arrow diagram only when necessary for the purpose of making checks.

Major Munro, in his article, sets out a systematic method, not dissimilar to what I am about to describe, but he does not indicate how easy it is for this to be done on one set of calculation sheets, and he seems to me to have unnecessarily complicated the matter with his instructions "(b) (i) Initially set all A's to zero" and "(c) (i) Initially set all Z's to the highest A obtained from (b) above". It is unnecessary to apply these instructions except for the activities beginning at node 1 and the activities ending at the last node respectively. Again these instructions still require constant reference to the arrow diagram.

Before you start on the calculation sheets you must decide whether you are going to compute manually, or have the calculations done for you on an electronic digitial computer to give this machine its full title. If you are going to use the latter, then it is a waste of time preparing calculation sheets. Instead you must complete the computer data sheets which are normally provided by the computer centre. As a general guide, if a computer is available, it is worth while using one when the number of activities exceeds 200 and it may be worth while for as few as 50. Some of the advantages of a computer are—it does not make mistakes: it tells you if you have made any

CALCULATION SHEET N.o 1

Act No	Activity description	Orig node	Term node	Est. time	Earliest St				Earliest Fn	Latest St	Latest Fn				Float Tot	Float Free
1	Launch main beams	1	2	1	0				1	0				1	—	C
2	Fmk deck slab	2	3	3	1				4	1			4	~~8~~	—	C
3	Rfn deck slab	3	4	1	4				5	7				8	3	—
7	Fmk footwalks	3	5	4	4				8	4				8	—	C
8	Fix kerbs	3	7	1	4				5	8				9	4	4
101	Dummy	4	5	—	5				5	8				8	3	3
4	Conc deck slab	4	6	1	5				6	8			9	~~10~~	3	—
9	Rnf footwalks	5	7	1	8				9	8				9	—	C
102	Dummy	6	7	—	6				6	9				9	3	3
5	Part cure deck slab	6	9	3	6				9	10				13	4	—
10	Conc footwalks	7	8	1	~~8~~	9			10	9				10	—	C
11	Part cure footwalks	8	10	3	10				13	10			13	~~18~~	—	C
13	Surface deck slab	9	11	1	9				10	17				18	8	3
6	Finish cure deck slab	9	12	4	9				13	13				17	4	—
103	Dummy	10	11	—	13				13	18				18	5	—
12	Finish cure footwalks	10	13	4	13				17	13				17	—	C
15	Fix handrails	10	14	1	13				14	18				19	5	5
14	Surface footwalks	11	14	1	~~10~~	13			14	18				19	5	5
16	Strike deck slab fmk etc	12	14	2	13				15	17				19	4	4
17	Strike footwalks fmk etc	13	14	2	17				19	17				19	—	C

Fig 17

in your actual presentation of the data: it is quick and will print as many copies of the calculations as you require: it is able to give you the results of the calculations in several different groupings and this may well be of assistance to your final planning: some computers will also produce an initial bar chart in a form very simple to convert to a normal initial bar chart. Some of the disadvantages are—a computer can break down and you may be left at an inopportune moment with no answer at all: filling in the computer data sheets is a lengthy exercise, and it takes a fair amount of time for the specially trained experts to produce the necessary punched computer cards from the data sheets; if mistakes have been made you may be faced with the additional cost of putting the data through the machine again after correcting the error or errors. For projects with over 200 activities the chances of human error in manual computation are so great that the use of a computer is really advisable but calculations by the method I describe in this article are not impossible, and for the military engineer in a theatre of operations there may well be no alternative to manual computation. Again to understand properly the results which a computer can give it is advisable to know how to compute manually. The method which I shall now describe, has, in my opinion, the merit of simplicity and, therefore, lessens the ever present risk of making arithmetical errors when dealing with so many figures. Although the calculations require only simple addition and subtraction, it is amazing how easily mistakes can be made, and you will save much more time in the long run if you follow a definite system, do not try to rush, and apply such checks as are possible as you go along.

But first let us look at the suggested form of calculation sheet in Figure 17, and see how far it can be filled in. The places to start is the two node columns, "Orig. node" "Term. node" which I think need no explanation.

Working from the arrow diagram start at node 1 and enter the 1 under origin node and under terminal node, the number of the next higher node connected to node 1 by an arrow whether a full one or broken one indicating a dummy. Write in the corresponding activity or dummy No and the activity description. Although your description is not essential it does help when checking. You must enter under origin node 1 all the activities starting at node 1 before you pass on to node 2. In Major Johnson's example there is only one activity starting at node 1 but when you come to node 3 you will have three entries to make, 3.4, 3.5, and 3.7, before you pass on to node 4. This is illustrated in the calculation sheet at Figure 17, which has been completed for Major Johnson's example. Work right through the arrow diagram and when you have done so you will have listed all the activities and dummies in ascending order of origin nodes and within each origin node, but only within each, in ascending order of terminal nodes. This will make such things easier later on.

The next step is to enter the "time" for each activity under "Est. time". Quite deliberately, until now, except for referring to Major Munro's statement that "elasped time" is a factor which must be known before an arrow can be drawn, and to state that dummies have no "time", I have hardly mentioned "time". It played no part in the construction of the arrow diagram. Yet it is an all-important factor. The accuracy of your ultimate programme depends upon the accuracy with which you can estimate the time for each activity. This is largely a matter of experience, but there are also guides to outputs which can be very helpful.

Now planning is often regarded as the province of experts or back-room boys. To some extent it is, but the planning team which does not include at least one practical experienced man will probably not only get its sequences wrong, but is also likely to be very wide of the mark in its estimates of time.

The team required will vary according to the project. I have found generally that a team of three is desirable. The first must be someone sufficiently senior who is competent to give decisions and has some flare for planning. Some firms employ a projects manager for this purpose. The second should be an engineer or building manager as appropriate, who is used to looking after large projects at management or agent level, and the third an experienced general foreman, preferably the one who will run the job. I will call these three Smith, Brown and Jones respectively. What usually happens is that Brown and Jones first examine the drawings, draw up an initial list of activities, and think out the general method of construction. This done all three get into a huddle, and a very rough arrow diagram is sketched out. The result will be a rather more accurate list of activities and an embryo arrow diagram. Smith now goes into a quiet corner and himself or an intelligent draughtsman under his eagle eye draws out the arrow diagram proper. Meanwhile Brown and Jones work out the most economic labour and plant requirements for each activity and they estimate the time that each activity will take with this labour and plant. Smith may frequently have to refer back to Brown and Jones while preparing the arrow diagram proper. He will have second thoughts on some sequences previously agreed and with his second and more methodical approach to the arrow diagram may find that other sequences need reconsideration. But any alterations he may make must be agreed with Brown and Jones for they are practical men, and even if Smith is also practical he may lack the detailed experience of the other two in actual construction work.

When Smith has completed the arrow diagram and Brown and Jones have completed the "times", labour and plant schedule, the team get into a huddle again to enter the "times" in the calculation sheets or the computer data sheets as the case may be. Smith is not going to accept all the "times" without any queries, for if he knew so little about construction work he would not be in the position he is, so there will be discussions on these and possibly some adjustments, but in the end the "times" will be agreed and entered in the appropriate column.

One small tip here, which I am unable to show in Figure 18. For manual computation, enter the "times" in red or some other colour noticeably different from the other entries. There are going to be a lot of figures on your calculation sheets before you are finished and it will be very easy to take one from the wrong column and so introduce an error which will later have to be found and corrected.

The actual calculations now start.

In the form illustrated in Figure 17 there are four columns under earliest start and again under latest finish. You may have more or less than four columns if you wish, but I have found that four are usually sufficient for calculations involving up to 200 activities. One column only will suffice but in this case some rubbing out will be necessary, whereas with four columns, all the figures you enter can remain on record which makes it easier to find errors.

Starting with all activities beginning at node 1 enter zero in the left hand of the four columns under earliest start. Add the time for the first activity listed and enter the result under earliest finish. Carry the figure from the earliest finish column to the left hand column under earliest start for all activities starting with the same node number as that at which the last activity finished and then repeat the process.

Turning to the example in Figure 17:

Activity 1 starts at node 1 and finishes at node 2. There are no other activities starting at node 1. Enter 0 in the left column under earliest start. $0 + 1 = 1$. Enter 1 under earliest finish and carry this figure 1 across to the left hand column under earliest start against activity 2 which starts at node 2. $1 + 3 = 4$. Enter 4 in the earliest finish column for activity 2 and carry this figure 4 to the left hand column under earliest start for activities starting at node 3. In this case there are three entries to make, activities 3, 7, and 8. Repeat the process for each of these three activities in turn, and so on.

When you come to activity 8 you obtain the figure 5 for its earliest finish and you carry 5 into the left hand column under earliest start against activity 10 starting at node 7. But when you come to activity 9 you obtain an earliest finish of 9 for node 7. Against activity 10 you must now substitute 9 for 5 under earliest start. If you have used only one column for earliest start you will have to rub out the 5. If, however, you have used more than one column you can merely cross out the 5 and enter 9 in the next column, leaving the alteration on record, as in figure 17.

When you come to dummy 102 you will obtain yet another earliest finish for node 7. But this time the figure is 6 and as this is lower than the 9 you have already entered against activity 10, no further alteration is necessary. The rule is that if a later earliest finish comes up you substitute it under earliest start but if an earlier one comes up you make no change.

This all sounds very simple and indeed it is, but it is fundamental and you must get it right.

Eventually you come to the end, and the latest (if more than one) of the earliest finishes for the last node, which will nowhere appear under earliest start, will be the time for the whole project, provided you have made no mistakes. Not until you have attempted this simple exercise yourself will you realize how easy it is to make a mistake, and unfortunately at this stage there is no real check. You may think it unnecessary to have any form of check, but should you have made a mistake, you will save yourself a lot of time in the long run if you find it before proceeding further. There are only two ways of doing this, and neither is infallible. One is to "redo" the calculations yourself. It is best in this case to start on a duplicate sheet, for it is very easy to make the same mistake a second time if you merely check back what you have done. The other possible check is to have someone else calculating completely separately at the same time as you are, and to compare figures. This is the quicker and less fallible method. If your calculations cover more than one sheet, and they usually will, although the example in Figure 17 does not, it is best to check when you get to the end of each sheet rather than wait until you get to the end of the first stage of the calculations. The greater the number of calculation sheets, the wiser it is to take this precaution.

The second stage is to work backwards from the end completing the latest finish and latest start columns. This is not quite so simple because the terminal nodes are not in descending order. If you find you get really muddled during this stage, you can if you like, prepare new sheets listing the activities, starting at the last, in descending order of terminal nodes just as you prepared the original sheets in ascending order of original nodes starting at node 1, but while this may make your immediate task more simple, you will then have to copy the results in the correct order on to your original sheets and I suggest that you are just as likely to make a copying error in the process as you are to make an error in working on the original sheets.

To illustrate the normal method of performing this stage, I refer again to the example in Figure 17.

The last node is 14 and under earliest finish for this node you have four answers of 14, 14, 15, and 19 against activities 15, 14, 16 and 17 respectively. The latest of these in time is 19 against activity 17, and although in this example this happens also to be the last activity, this will not always be the case unless only one activity terminates at the last node. You take the figure of 19 and enter it under the right hand column under latest finish for all activities ending at node 14, ie activities 17, 16, 14, and 15 working upwards.

Start with activity 17. 19 − 2 = 17. Enter 17 under latest start. As activity 17 starts at node 13 you carry the figure of 17 to any other activities terminating at node 13. In this case there is only one, activity 12. I need not carry the illustration any further except to deal with the alteration against activity 11; those against activities 4 and 2 are also of a similar nature. When you come to activity 15, you find that the latest start for this activity is 18 and as this activity starts at node 10, you carry the figure of 18 to the right hand column under latest finish against activity 11. When you come to activity 12 you obtain a latest start for node 10 of 13. This being earlier it must be substituted for the 18 already entered against activity 11. Next you come to dummy 103 which gives a latest start of 18 for node 10. As 18 is higher than the figure you now have against activity 11, you do not make any further alteration. The rule is that when an earlier latest start comes up you substitute it under latest finish, but if a later one comes up you make no change, ie exactly the reverse of what you did when calculating forwards.

And so you carry on until you get back to the first activity, and if you do not arrive back at zero for one of the activities beginning at node 1, then you have made a mistake. Should you be so unfortunate, you will at least be thankful at this point if you can be reasonably certain that you have left no error undiscovered in the first stage of your calculations.

When calculating backwards checks are possible which may help you to discover any errors before reaching node 1. The activities on the critical path will be those which have no total float. There must be at least one such activity ending at the last node and also one starting at the first node. When calculating the latest start and latest finish for activities, you can, if you wish, isolate and follow through the critical path first, thus saving a possible waste of time in calculating other node times before you have established that you really do get back to zero at the beginning.

If an activity has no total float then its earliest start will be the same as its latest start and its earliest finish will be the same as its latest finish. Turning to the example in Figure 17, you are lucky because you find the last critical activity straight away, it being activity 17. If it had not been you would have had to examine activities 16, 14, and 15 to find out which of these was critical. However, having established that activity 17 is critical you can jump to activity 12 which ends at node 13. As this is the only activity ending at node 13 it too must be critical. It is, so there is no error so far and you can press on to activity 11 ending at node 10, then to activity 10 ending at node 8. After that you proceed to dummy 102, activity 9 and activity 8, all three of which end at node 7. You find that activity 9 is the critical one and proceed from there back to activity 7, thence to activity 2 and finally activity 1. You have reached zero and established the critical path. Now you can go back and complete the rest of the calculations.

Sometimes there is more than one critical path over portions of the arrow diagram. If a second path is picked up at this stage well and good, but if not, it does not matter. It will be picked up later on. If there is more than one critical path, then the two or more paths must meet up somewhere unless, as is most improbable, there are two or more separate critical paths through the entire arrow diagram.

If you lose the critical path entirely, then you have definitely made a mistake and it is no use proceeding until you have found the error.

When completing the rest of the calculations for latest finish and latest start you can either leave the calculations of the total float until the end or you can do them as you go along. The total float is the difference between the latest start and earliest start or the latest finish and the earliest finish, and it is as well to make use of this check, for if you get different answers you know at once that either your last subtracting exercise was wrong, or, less likely provided that you checked the first stage of your calculations, your adding exercise for this same activity was wrong.

When an activity has no total float it is a useful tip not merely to enter a dash or zero under total float but also put a "C" under free float. The activity being critical, can have no free float and if you make these entries, it makes it even more easy to pick out the critical activities and so avoid wasting any time inadvertently establishing that these activities have no free float when later calculating what free float, if any, the remaining activities have.

The final stage of the calculations is to determine the free float. This is simple enough but it requires care lest you pick out the wrong figures.

The steps for any one activity are:—

Read its terminal node. Find this same node as an origin node and read the earliest start. From this subtract the earliest finish of the activity which you started with and the answer is the free float for that activity.

Example from Figure 17.

Activity 8—terminal node 7.

Node 7 is the origin node for activity 10 and its earliest start is 9 (as altered). The earliest finish for activity 8 was 5. $9-5=4$ which is the free float for activity 8.

There are only two real checks when doing the final stage of the calculations. First, free float can never exceed total float. Second, at this stage of the planning, free float can only occur in the last activity of a sequence of non-critical activities, either where the sequence joins the critical path, or where it is otherwise restrained from the critical path. Referring back to Figure 5, it can be seen that the only activities which can have free float are 8, 13, 14, 15, and 16 and dummies 101 and 102. Of these activity 13 is perhaps not so obvious as the others. It can have free float because the earliest start for activity 14 ie node 11, is restrained by dummy 103 from node 10 on the critical path. The calculations at Figure 17 confirm that all these activities have free float and no others.

In spite of the checks possible during the later stages of the calculations, I still advise the checks suggested for the first stage of the calculations, ie do them twice, or get someone else to do them simultaneously. The later checks are not in every case fool-proof and if you have made any mistake in the calculations you may be wasting your time in proceeding.

I have laboured the subject of calculations for two reasons. Firstly because Major Johnson's example is a simple one and the calculations can be done as he has illustrated on the arrow diagram. However, you may well find that to perform calculations on the arrow diagram can be very complex when attempted for a project with more than about two dozen activities. The method illustrated in Major Munro's article is worked partly from, but not on, the arrow diagram, and it produces the answers in tabular form. My main criticsm is that it requires the production of two lists and an output data sheet, whereas the method I have described combines all three operations in one set of calculation sheets.

But secondly, and more important, I have laboured the subject because if you seek a full understanding of CPM, then you must know how to do the calculations. If you always rely on others or a computer to do the calculations for you, you will take much longer to obtain a grasp of the subject, and you may never fully grasp it.

RECAPITULATION

At this point, it is worth while recapitulating the steps so far taken and comparing them with those taken by Major Johnson.

(1) A schedule of activities was prepared with a suitable abbreviated description for each. This schedule corresponds with Major Johnson's job table (table 1) column (2) only.

(2) The basic arrow diagram was drawn. This step corresponds with Major Johnson's Figures 1 and 2 except that the durations were not included nor were any supply restraints inserted because, in the event, Major Johnson did not regard any of them as activities affecting his programme. Had he done so then they too would have been included in Figure 5 of this article but with the difference that they would have been treated as activities and shown as full arrows starting in every case from an appropriate node. In Figure 5 of this article, unlike Major Johnson's Figures 1 and 2, a brief description of each activity was entered and, as the diagram was produced, activity serial numbers were allotted (in lieu of letters). The final step was to number the nodes. The thickening of certain arrows in Figure 5 of this article to indicate critical activities had not, at this point, been accomplished as the critical activities were still unknown.

(3) Either simultaneously with the production of the arrow diagram, or immediately after, the schedule of activities was revised to take into account any alterations found necessary during the construction of the diagram. There are two such revisions in Major Johnson's examples. His jobs E and K have each been split into two activities. To the schedule of activities was added the activity numbers, (Column (1) of Major Johnson's Table 1), the labour and plant contents and the time for each activity (Columns (4), (5) and (7) respectively of Major Johnson's Table 1). Note that Column (3) of Major Johnson's table 1 is unnecessary for these factors were considered in their logical sequence as the arrow diagram was drawn, and having been shown on that diagram it was superfluous to record them elsewhere. Column (6) of Major Johnson's Table 1 was also omitted because these restraints were not, in this example, factors affecting the plan.

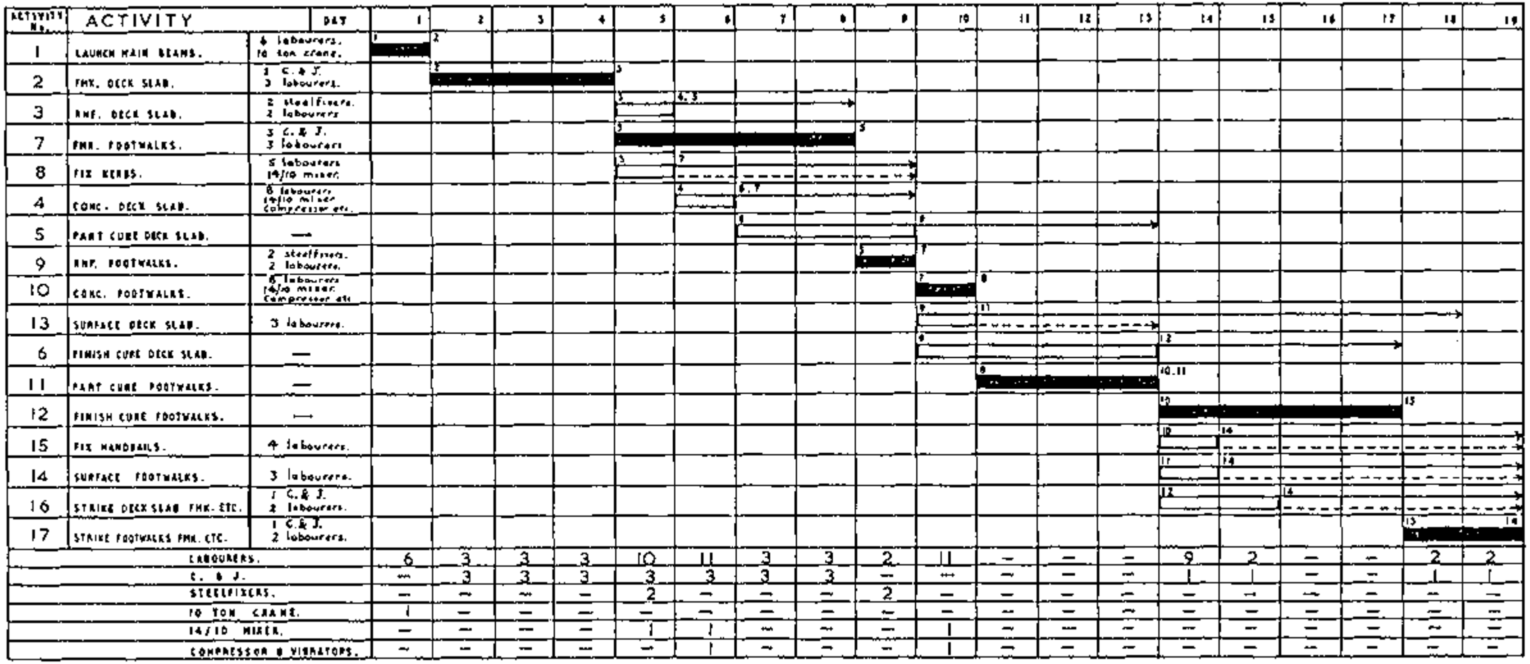

FIG. 18 ~ INITIAL BAR CHART.

(4) The calculation sheet or sheets were prepared, in this example only one sheet, and the calculations were carried out thereon. This step corresponds with Major Johnson's Figure 3, and to reach the same planning point, the arrows for the critical activities in Figure 5 of this article were thickened up (colouring or otherwise specially marking is equally effective but colouring is not suitable for reproduction). If desired, "time" and node timings could also have been inserted on the arrow diagram but this is normally of no assistance to the later planning stages, I still have to describe, and would therefore have been a waste of time.

Thus all the information on Major Johnson's Figure 3, except the supply restraints, which have been purposely omitted, is now in the calculation sheet (Figure 17 of this article) and it is this sheet, plus the labour and plant contents from the schedule of activities, that will form the basis of the further planning steps still to be taken, with only occasional references, for convenience, back to the arrow diagram. The words "for convenience" are stressed because, unless a major alteration is made, to refer back will, in fact, be unnecessary although it may sometimes be found simpler to do so for certain checks.

The Initial Bar Chart

The next stage is to prepare an initial bar chart. It corresponds with Major Johnson's Figure 4 but with the big difference that it is at this point that a break away is made from the arrow diagram method of presentation.

The initial bar chart for Major Johnson's example is reproduced at Figure 18 of this article and if you have understood the earlier part of this article when I commented on Figure 1, and you can read a bar chart, then you will have little difficulty in understanding Figure 18.

Before preparing the initial bar chart you have to decide on two things—a suitable time scale and the order in which you are going to show the activities. The latter does not matter at all, and you choose whatever order suits your convenience. Some of the more obvious choices and their possible advantages are:—

(*a*) In the order which the activities came out in the calculation sheet. This is probably the simplest way of avoiding any omissions.

(*b*) All critical activities first in order of earliest start. This simplifies later examination for any possible reduction in the over all time for the project.

(*c*) By trades. This may well be the most useful order for the final presentation of your programme and to introduce it at this stage may, therefore, be helpful later on.

(*d*) In order of earliest starts. This simplifies later adjustments.

(*e*) In order of activity serial numbers. This also helps to avoid any omissions.

There will be other orders, any of which may well be more appropriate to the particular project under consideration, but, as I have said, the choice is yours and the order really does not matter. My personal preference is to prepare the initial bar chart in order of earliest starts and it is in this order that I have drawn Figure 18.

I should mention that, by means of report codes, computers will produce the answers to your calculations in several of the different orders which you may prefer; so if your calculations are to be done on a computer, you will help yourself by requesting the answers by the appropriate report codes. However, with manual computation by the method which I have described, the answers will be in one order only and that is in ascending order of origin nodes and within the origin nodes, ascending order of terminal nodes. To pick out some other order is nevertheless perfectly simple.

The dummies are not listed among the activities shown on the bar chart, for they have no "time" and so cannot be represented by a bar. However, the existence of a dummy is clearly indicated when the terminal nodes are inserted on the bar chart at the end of the bars representing activities. Similarly the origin nodes are inserted at the beginning of the bar.

Activity 3 starts at node 3 and ends at two nodes, 4 and 5; 4.5 is therefore a dummy and if you refer back to Figure 5 you will see it is dummy 101. But node numbering on the bar chart has a much more important function than this. It tells you where to look for the preceding and succeeding activity or activities. Again look at activity 3. It started at node 3 and, therefore, the preceding activity or activities must end at node 3. There is only one in this case, activity 2, although there are two others which also start at node 3. This can be verified from the arrow diagram, but as I have said earlier reference back to the arrow diagram is not essential, for, to insert the node numbers, you needed to refer only to the calculation sheet. The activities succeeding activity 3 are those beginning at nodes 4 and 5, ie activities 4 and 9. Activity 9 is a critical activity and limits to three days the total float available on activity 3. Activity 4 is a non-critical activity and limits the free float available on activity 3 to nil. Activity 4 also has a total float of three days.

Let us suppose for the moment that activity 4 had only two days total float. This in turn would have limited the total float of activity 3 to two days and this would have been so determined by the calculations. But dummy 101 (4.5) would still have had three days total float and three days free float. What has happened to this free float and what would have happened to the third day of its total float had activity 3 been limited to two days total float by the sequence of activities following through activity 4? The answer is that both are valueless to the project. The free float does not, therefore, in this case come out in the bar chart and had activity 3 had only two days' total float the arrow on the bar chart representing its total float would have stopped at the end of day 7 notwithstanding that node 5 is not reached until the end of day 8.

Thus the system of plotting direct from the calculation sheet means that any total or free float or part thereof available on dummies is automatically omitted if it is no practical use. The same is true in reverse as regards total float but not necessarily free float. Any total float, or part thereof, available is automatically included but with the type of dummy illustrated in Figures 9 and 10, if you draw the situation in your arrow diagram as in Figure 10, then the free float has to be picked out and added on the relevant activity. If, however, you draw the situation as in Figure 9 the free float will come out against the relevant activity in your calculations and you will automatically include it in your bar chart. There is no example of this in Figure 18, but I have mentioned it again here to stress the importance of positioning this type of dummy as in Figure 9. Provided you do this, then there is only one type of dummy which you still have to seek to see if it includes free float which is of some practical use and has not automatically been picked up when the initial bar chart is drawn. It is the dummy of expediency which I illustrated in

Figure 7. Had there been another activity coming in at node 555 in Figure 7, then the last of the fifty dummies inserted, ie No 1192, could possibly have had free float which it would have been necessary to pick out and add on to activity 176 when plotting the initial bar chart. This, however, is a rare exception which occurs only when the dummy is inserted as a more simple way of correcting the arrow diagram than renumbering the nodes.

When drawing the initial bar chart do not be tempted to start moving the non-critical activities around within the limits of any free float. This is a later step in the logical CPM procedure. In the initial bar chart always draw the bar representing the duration of an activity from its earliest start to its earliest finish and indicate thereafter any total or free float by arrows as illustrated. You may take note, however, that the arrows indicating total float must finish at the latest finish and the broken arrows representing free float cannot go beyond the latest finish although they may not go as far. If you find otherwise you have made a mistake.

Adjusting the Bar Chart

Having completed the initial bar chart you have before you not only one plan based on earliest starts, but also by virtue of the total and free floats shown thereon, a number of alternative plans. To go back to the headings for a military appreciation, in the initial bar chart you have before you the "courses open". All the courses open? Not quite, for your plan is at present based only on the most economical execution of the separate activities. Again it must be remembered that your plan is as accurate, but no more accurate, as was your estimate of "times" and of labour and plant content. These were based on practical experience and perhaps some other aids. It may be that some of them can be bettered if you examine them in more detail. When you made these estimates you had to consider every single activity and while there were only seventeen activities in the example in Figure 18, this is an unusually small number. But now you know which are the critical activities and there are only eight of them and this is, in practice, a much higher proportion of the total than you will usually have.

Re-examine your estimates for the critical activities very carefully indeed, for if you can shorten any of them without taking any uneconomical steps you can shorten the critical path, and thus the time it takes to complete the project.

This is the first and very important adjustment in your plan to consider. It is at this stage that you should take into account any possible overlapping which you deemed it advisable to ignore, in the interests of simplicity, when you drew the arrow diagram. When you make adjustments to the bar chart do not rub out the original although it will almost certainly still be in pencil. Put a piece of tracing paper over it and make any adjustments thereon so that you can see exactly what you have done. If you do make any adjustments watch out for consequential amendments. For instance in the example in Figure 18, should you decide after careful review that activity 17 can be completed in one day instead of two without any increase in labour, you have not merely to shorten the bar for activity 17, but also to cut back by one day any total and free float for all other activities ending at node 14, ie activities 15, 14, and 16.

However, as Major Johnson did not shorten any of the critical activities, I must, for the moment, assume that, in the example in Figure 18, no such reduction was possible.

The next steps will depend on the particular project under consideration. I will take them in the order considered by Major Johnson, but in so doing, I do stress that it might in some cases be advisable to take them in a different order, and in particular that it will often be advisable at this point to take the step which I shall consider after reaching the final bar chart corresponding with Major Johnson's Figure 6.

Major Johnson's next step was to level out his manpower and plant requirements. This is a most important step in the interests of economy. In the civil engineering world no contractor normally wants to use, say, two RB22s for a quarter of the duration of a project when it is possible, with some adjustment to the programme, to use one over half the duration of the project. Again labour may be scarce and a levelling of the manpower requirement may be necessary on this score. It is always advisable to keep the peak labour force as low as possible as this may not only save supervisory staff but also it may, when the project is in an isolated area, save in the amount of housing for labour that has to be erected. There are other similar considerations.

The activities to be examined in this step are normally the non-critical ones. In spite of Major Johnson's claim that the arrow diagram to a time-base scale is a clear and simple visual aid for briefing, issuing of orders, and hand-over duties, I do suggest that for adjusting the programme for the levelling of manpower and plant it is far simpler to see where the adjustments can be made on Figure 18 than it is on Major Johnson's Figure 4.

Major Johnson has drawn his Figure 5 to illustrate the adjustments made. I assume that he has drawn it for this reason only, and that in practice he would make the adjustments by an overlay in the same way as I suggested earlier. The fact that he worked on an arrow diagram does not rule out this particular method. I have not drawn the corresponding bar chart to Major Johnson's Figure 5 but I would not like any reader to conclude wrongly on this account that the considerations which this Figure illustrates, are ones which can be omitted.

Now we come to the last step. Can any further over all economy be effected? Usually in the civil engineering field this factor is considered in terms of money. The theory is well described in the RSME's publication and I shall not attempt to add anything to what is written therein.

In Major Johnson's military engineering example, the overall economy considered is the need to level out manpower still further. His final plan is based on a requirement to reduce the maximum number of labourers to the overall figure of eight. In fact he refers to a labour force of eight but as his Figure 6 shows the maximum labour force on any one day to be eleven, including tradesmen, I think my statement of the requirement must be what he really had in mind.

To meet this requirement, Major Johnson accepts some uneconomic working in activity 4. His final plan requires five labourers, a mixer, compressor and vibrators for two days for this task, compared with eight labourers, a mixer, compressor and vibrators for one day as originally envisaged. This is clearly less economic working than originally planned, but overall he has effected the economy of reducing the peak requirement of labourers to eight.

I think it is a great pity that Major Johnson did not consider what further overall economies could be made in this way. He states that, if the Commander had instructed that the bridge must be constructed in eighteen days instead of the estimated nineteen days, then it would be necessary to shorten certain activities by increasing the manpower and plant used on them. Quite so, but I suggest that the period of construction can, in fact, be shortened with overall economy and yet still keeping the peak number of labourers to eight.

The activities to examine are, in the first instance, the critical ones, but it must not be overlooked that some non-critical activities may be affected.

Refer to Figure 1 of this article which is the final bar chart for Major Johnson's plan, and examine the critical activities in turn.

Activity 1. One day—there is nothing much that can be done about this.

Activity 2. Three days, but only three labourers and three C and J employed on each day. Surely this task can be speeded up even if uneconomically for the activity when considered in isolation. I suggest that five labourers and five C and J could do the task in two days. This is still below the maximum permissible ceiling for labourers, and as Major Johnson set no ceiling for C and J, I hope I am not cheating by increasing their number, particularly as the total labour on these two days will still only be ten compared with the peak of eleven on the sixth day. Thus I suggest that one day can be saved at the expense of some uneconomic working on activity 2.

Activity 7. At first sight, the same consideration as for activity 2 applies here but it is of no avail to shorten the time for this activity because of activities 8, 3, and 4. Juggle as you will with these you can never avoid an overlap between them which does not increase the labourers above eight. So it is no use shortening activity 7 and nothing can be saved over this period.

Activities 9 and 10—both one day. There is nothing that can be done about these.

Activities 11 and 12. Three days and four days respectively but these times are determined by the need for the concrete to set to a certain strength. There is nothing that can be done about these activities for it must be assumed that, as the programme allows only seven days for curing the use of rapid hardening cement is already envisaged.

Activity 17. Two days and only two labourers and one C and J on each. It must be possible to do this task in one day with five labourers and three C and J even if it is not possible to do it with four labourers and two C and J. But if this activity is shortened by one day then activity 16 must also be shortened or moved. It has one day free float at the beginning so it can be started one day earlier with impunity

Now what about labour totals?

Due to the move of activity 16, the seventeenth day that was, has been increased by one C and J and two labourers, and the total for the day is one C and J and six labourers which is acceptable.

On the eighteenth day that was, the labour has been increased by three labourers and two C and J and the total for the day is seven labourers and four C and J which is acceptable again assuming that there is no ceiling for C and J. Assume for a moment that four extra labourers would be required to accelerate activity 17. This would still only raise the labourers to eight, but it would raise the total labour to twelve which is one more than the current peak of eleven. If this increase could not be accepted, then it would still be worth examining a further movement forwards in time of activity 16 although such further movement would entail the adjustment of other activities. I leave the reader to ponder over this possibility.

To sum up, at the price of some uneconomic working on activities 2 and 17, it would seem that two days can be knocked off the time for completion of the project. In return the labour force earmarked for the project, and any supervisory staff, would be released for other work two days earlier. I suggest that this overall saving of two days is a valuable economy which might well justify the uneconomical use of labour on activities 2 and 17.

Conclusion

My article has been directed mainly to those who are not yet fully initiated into the subject of CPM. I hope that some of my suggestions may be useful to others and I trust that in stressing what may seem some very elementary and simple points I shall not be accused of stressing the obvious .They are not all such obvious points as they may seem as I have found out in practice.

If I have done nothing else, I sincerely hope that I have thrown into the lap of controversy the suggestion that the bar chart is out-moded and the CPM dispenses with it. I firmly adhere to the view that what has been outmoded is the method by which the bar chart is produced, and that in its enhanced form the bar chart is a better method of presenting a works programme than any other which has yet been produced.

In conclusion I draw the reader's attention to Major Munro's closing remarks. Ultimately it is the human element that counts, and this is particularly true in the estimating of "time", labour and plant, for on the accuracy of these depends the accuracy of the final answer. As Major Munro states "CPM is not a 'cure-all' to ensure success", but it is an aid and a very valuable aid to success if properly applied.

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Karamoja Caper

By Major R. E. Everton, BSc, AMICE, RE

All views expressed are solely the writer's personal ones. Any inaccuracies which may exist are solely attributable to the faulty memory of the writer.

Background

The Karamoja is a large area in the north-east of Uganda, bordering Kenya to the east and the Sudan to the north, inhabited by wild, warlike, near-naked and nomadic tribes, who, since time immemorial, have indulged in the twin pursuits of tending their herds of cattle and plundering those of their neighbours. During this latter pastime they tend to slaughter all members of the owners' families they find. These may well be on the other side of the border. Cattle raiding is largely tied up with the rainfall and the bride-price (currently high, at about forty head, and therefore to be stolen before the wedding can be arranged). The north of the area tends to suffer minor incursions from dissident Sudanese who lick their wounds there preparatory to a hostile return to their own land.

The Karamoja is largely semi-desert, on the whole fairly flat, about 3,000 to 4,000 ft above sea level, but with a number of groups of mountains rising to about 10,000 ft. There is an annual rainfall of up to about 20 in, mostly in two rainy seasons, with up to twice as much over mountains. It is the expressed policy of the Uganda Government to develop the Karamoja—it has not, however, been disclosed what development it is intended to pursue there.

In about April 1963 the Government of Uganda decided to raise a second battalion for their army, 2nd Battalion The Uganda Rifles, and that this would be stationed at Moroto, the administrative centre of the Karamoja. This area was selected since the rule of law and order and a civilising influence amongst the inhabitants are prerequisites to any form of development. From there 2 UR could also look after the eastern and part of the northern frontiers if required.

HQ Uganda Army produced a "Q Brief" which was passed to the Ministry of Works for them to design and build a permanent barracks on a site acquired by the Army immediately to the north of Moroto township, at the western foot of Mount Moroto (10,007 ft). In October 1963 HQ Uganda Army discovered that MOW appeared to have taken no action on the Q Brief, other than to file it. Since 2 UR were starting to form up, it was clear that urgent measures would have to be taken if any accommodation were to be available when they began to arrive in Moroto in 1964. It was therefore decided that:—

(*a*) The accommodation, although to full African scales, would largely be in semi-permanent construction, for the sake of speed.

(*b*) Construction would be by Uganda Prisons Department, using their standard designs, and convict labour.

(*c*) Royal Engineers would be asked to send personnel on secondment for the planning and supervision of the works.

In the event it was agreed to send one officer on three weeks loan, plus a Warrant Officer Class I Clerk of Works (Construction) on secondment for one year. Being on leave at the time, awaiting a new appointment, the writer was sent on the short loan, flying to Entebbe from Gatwick during the night 18–19 November 1963 by British United Airways regular scheduled non-stop flight (comparing very favourably with trooping flights under the same management!) and WOI Sutton was earmarked for the year's secondment instead of a posting to Cyprus.

The Requirement

On arrival I was given the above briefing, in rather more detail, and introduced to the Superintendent of Works of the Uganda Prisons Department, who had started off what had been done so far. In Uganda the Prisons Department do their own building and civil engineering work, which includes the construction of semi-permanent prison camps in remote areas.

Summarized, the requirement (including subsequent minor amendments) was:—

(*a*) Barrack accommodation for 50 per cent single Askaris of HQ Company and four Rifle companies (each of four platoons).

(*b*) Married quarters for 50 per cent R & F, sited within company lines.

(*c*) Married quarters for African junior WOs and Sgts, sited within company lines.

(*d*) Offices/Stores for each company.

(*e*) MT lines for approximately 100 vehicles, including inspection ramps, washdown, offices, stores, LAD workshops, and petrol point.

(*f*) Battalion HQ offices.

(*g*) Signals centre (with stores and classrooms).

(*h*) Drill shed.

(*i*) Rank and file mess (for single Askaris).

(*j*) Male medical centre (with two small wards).

(*k*) Families medical centre (with maternity ward).

(*l*) Battalion pay office.

(*m*) Officers' mess.

(*n*) Single officers' quarters (four junior and one field officers' blocks).

(*o*) Warrant officers' and Sergeants' mess.

(*p*) Quartermaster's compound.

(*q*) Canteen/shop for African families.

(*r*) Servants' quarters for: Officers mess staff (six men); WOs and Sgts mess staff (four men); each married Officers quarter (three men); and each married WOs quarter (two men).

(*s*) Twelve married Officers quarters (with garage each).

(*t*) One married quarter for Commanding Officer (with garage).

(*u*) Ten married WOs quarters (for seconded personnel or senior African WOs).

(*v*) Guard room (including detention cells).

(*w*) Armoury (separate bay for each company).

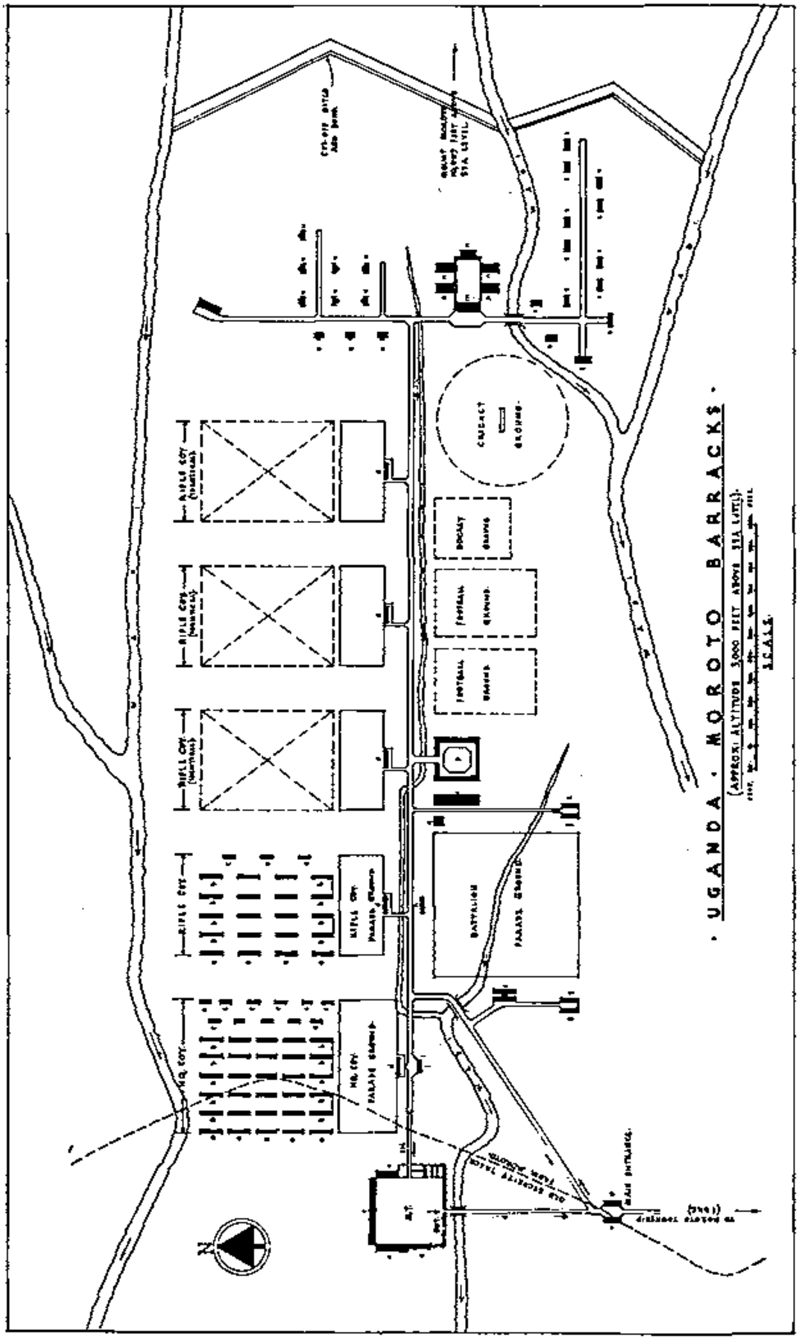
(*x*) Parade grounds (for battalion and for each company).

(*y*) Sports grounds (two soccer, one hockey, one cricket).

(*z*) Roads, foul drainage, stormwater drainage, water reticulation, electricity supply.

(*a*) to (*r*) were to be in semi-permanent and (*s*) to (*w*) in permanent construction.

A layout for the barracks had already been decided (see plan, in which letters refer to the list above). This envisaged: a straight main road through


UGANDA · MOROTO BARRACKS ·
SCALE
RIFLE COY
H.Q. COY
CRICKET GROUND
HOCKEY GROUND
FOOTBALL GROUND
FOOTBALL GROUND
BATTALION PARADE GROUND
MAIN ENTRANCE

the area; MT lines at the foot of the slope; all company lines (including their married quarters, offices/stores, and parade grounds) in blocks to the north of this road; the entrance road from the south (with guard room and armoury) joining the main barracks road near the foot of the slope, with, above it, other installations. At the top, the main road ended in a "T" junction, the north branch leading to the WOs and Sgts mess via the married WOs quarters, the south one to the married Officers quarters via the officers mess.

The Site

The next morning I flew to the site with the Prisons Department Superintendent of Works. Clearance of the line of the main barracks road had begun, under the direction of the Prisons Department's Sikh foreman; but it soon became obvious that he had made an error of some 20° in setting it out! It also became clear that the survey upon which the original site layout had been based was far from complete in a number of aspects.

The site proved to be a good one, on a steady slope of about 1 : 30, intersected by a number of wadis (dry most of the year, but clearly raging torrents when rain broke over the mountain), some 20 ft wide and 10 ft deep on average, some of which had escaped the notice of the surveyors. The survey instruments at our disposal were a 100-ft linen tape, four banderoles, and an unlimited supply of wooden pegs. By primitive means we plotted the courses of the "missing" wadis, and set out the correct alignment of the main barracks road.

The site had a number of cleared areas (where some form of primitive agriculture had once been carried out), but was mostly covered by sparse scrub and trees, with two areas of thick and vicious thorn scrub (MT lines MOQ) through much of which it was only possible to progress in the wake of a dozer.

The area was mostly "red coffee" soil interspersed with boulders and stony patches. "Red coffee" is a clay which is excellent for agricultural purposes and presents no building problem, even in the rains. Considerable patches in HQ Company lines, and some in those of the lowest Rifle Company, were of "black cotton" soil. This is a clay of high organic content which behaves rather like a bath sponge, and has normally either to be cut out or avoided like the plague, unless its moisture content can be kept steady.

Planning Buildings

To overcome the twin problems of unsuspected wadis and black cotton soil, the site layout really needed scrapping and starting again! Clearly this would have set back the start of construction appreciably, and was therefore unacceptable. So I decided we would alter details only of the layout to avoid the wadis (only one of which would be very inconvenient), and accept black cotton areas. The buildings on the black cotton areas would all be of light construction, and, provided we installed a good stormwater drainage system, should not prove troublesome.

The decision had already been taken that the majority of buildings would be Dexion frame with CGI cladding, a form of construction which had been widely used by the Prisons Department in places with a similar climate and had proved quick, effective, and (surprisingly) cool. A "guesstimate" of the quantities had already been ordered by the Superintendent of Works. This exhausted the stocks of both CGI and Dexion in Uganda, and therefore the considerable quantities of Dexion in the stands erected in Nairobi for the Kenya "Uhuru" celebrations were earmarked, and the decision taken to change all roofing to asbestos cement, made in Uganda.

After this visit to the site I obtained from the Army Commander a decision on the priorities with which the various buildings would be required, since it was obvious that none could be provided within about four months at the very earliest, and then only if we concentrated all efforts on Priority 1 works. Needless to say, Priority 1 turned out to be almost 50 per cent of the work! I also obtained agreement that the barracks would be built in two phases, phase 2 consisting of internal linings, ceilings, sealing roads and parade grounds, sports grounds, and the provision of waterborne sanitation.

The next thing was to go through the Prisons Department and other Government standard drawings to see if they would really prove suitable for army use, and what amendments to them would be needed. These designs were no doubt most suitable for their original purposes, but in many cases were not entirely satisfactory for the army. The principal amendments resulting from this study were:—

(*a*) Barrack hut for single Askaris: adapted from prison hut; ablutions and latrines increased; cleaning/dhobi room provided; Corporal's bunk to be partitioned off (in phase 2).

(*b*) Married R & F quarters: very minor changes only to married R & F quarters at Jinja Barracks, and adaptation of design to Dexion and CGI to speed construction.

(*c*) Married senior NCOs (African) quarters: redesign of African foreman's quarter to provide an extra room.

(*d*) MT lines, Bn HQ offices, signals centre, drill shed, Bn pay office, Officers mess, single Officers quarters, WOs and Sgts mess, QM compound: design from scratch, no standard designs existing which were of use.

(*e*) Company offices/stores, medical centres, servants quarters: adaptations of various standard designs in hollow concrete block to Dexion and CGI, to speed construction.

(*f*) Married Officers quarters: adaptation of standard Government bungalow to improve the kitchen and living-room. (To save time, no distinction was made between types IV and V.)

(*g*) Commanding Officer's quarter: adaptation of the same design to provide a study in addition.

(*h*) Married WOs quarters: adaptation of standard Government rest-house to improve the kitchen and provide a store. (To save time no distinction was made between types B and C, all being three bedroom, to house either three single or one married seconded WO/Sgt, or an African senior WO (RSM, RQMS, etc).)

(*i*) Guard room: designed from scratch in permanent construction.

(*j*) Armoury: adaptation of the one at Jinja Barracks.

The drawing office staff to cope with this work consisted of myself and an African tracer belonging to the Prisons Department.

Determination of these designs enabled a setting-out plan to be drawn which took into account the actual wadi positions, and a flight to site for 48 hours setting-out followed. This setting-out consisted only of pegging out the corners of each group of buildings or other construction so that prison labour could start Priority 1 site clearance. To minimise erosion before a proper stormwater drainage system could be designed and built, cut-off ditches (10 ft deep and 20 ft wide, with spoil forming bunds on the downhill side) were sited, and a 200 ft belt of untouched scrub was left between each lot of company lines, whilst in other areas clearance was allowed only in the immediate vicinity of building sites.

Setting-out was hampered by the non-availability of any further survey equipment. In order to minimise, and to assess, the error inevitable in such circumstances, setting-out was done by starting at two points of known chainage along the camp main road centreline and working round in opposite directions. Considering that the starting points were 3,400 ft apart (representing bottom end of lowest company lines and T-junction to messes) and right angles were all set out by 3 : 4 : 5 triangle, the closing error of 2 ft was considered fair enough (and adequate confirmation of the proposition of the late Mr. Pythagoras!).

The next item on the agenda was the design of foundation rafts for all Dexion and CGI buildings—other buildings were to have orthodox foundations. We decided that on red coffee soil a 4-in slab singly reinforced with BRC mesh should suffice, but that on black cotton soil a doubly reinforced 6-in slab would be needed. In phase 1 these would have a hardener added to the surface, but a better finish could be added if desired in phase 2. Expansion and construction joints would be combined approximately every 20 ft along the length of a hut, being of three layers of building felt. A toe would be provided all round the slab, and verandah slabs, with their own toe, joined on where called for. Dexion columns would be erected in holes boxed-out of the slabs, subsequently being concreted in when the building frame had been aligned and bolted tight.

Buildings not in Dexion and CGI were to have been of hollow concrete blocks, manufactured on site. However, it was discovered that a large quantity of hollow clay blocks were available very cheaply and we decided that, to save time, these would be used for superstructures (being concrete filled where greater strength was needed, such as in the armoury, detention cells, and a round door and window openings). Substructures would be of concrete block, made on site in the Prisons Department's hand-operated block-making machines.

Planning Construction

The geography of Uganda has to be borne in mind at this point, and the map should be consulted. Such as it is, the industrial and commercial heart of the country is along the north shore of Lake Victoria between Kampala and Tororo, and it was from here that all materials, bar sand and stone, would have to come. Running north of, and roughly parallel to, that coast lies Lake Kioga, through which flows the Victoria Nile, and which is surrounded by vast marshy areas. North of Lake Kioga lie a number of swampy lakes stretching northwards almost to the Karamoja. The main railway and road run parallel to Lake Victoria, crossing the River Nile at Jinja at Owen Falls dam. Branches of both tarmac road and railway leave the main routes at Tororo, at the east end of Lake Kioga, and run along its north shore, the tarmac road ceasing at Soroti and the railway continuing, eventually to the River Nile at Pakwach. Two roads run northwards into the Karamoja, joining near Moroto: the eastern one runs along the hills from Mbale, and is very liable to be washed out during the rains (as happened during the time I was there); the western one crosses the swampy lakes on narrow causeways, but is rarely washed out, even in the worst rains; neither is tarmac. Moroto is some 110 miles from rail and tarmac road by the western road, and 130 miles by the eastern. The transport of stores to site was therefore going to be quite a considerable undertaking, for which a small fleet of vehicles would clearly be needed. The use of the railway was not considered, since this involved at least double handling and the branch line boasts only about one train a week each way.

Sand of poor quality was readily available near the site. Supplies of better sand were known to exist some 12 miles away, but whether any lay nearer had still to be determined when I left.

Stone was readily available from the adjacent mountainside without quarrying, and the Prisons Department reckoned to crush it by convict labour (44 gallon drum per man per day). Tippers had already been arranged for the transport of sand and aggregate to site from local sources, being used to take stores to site on their way up there.

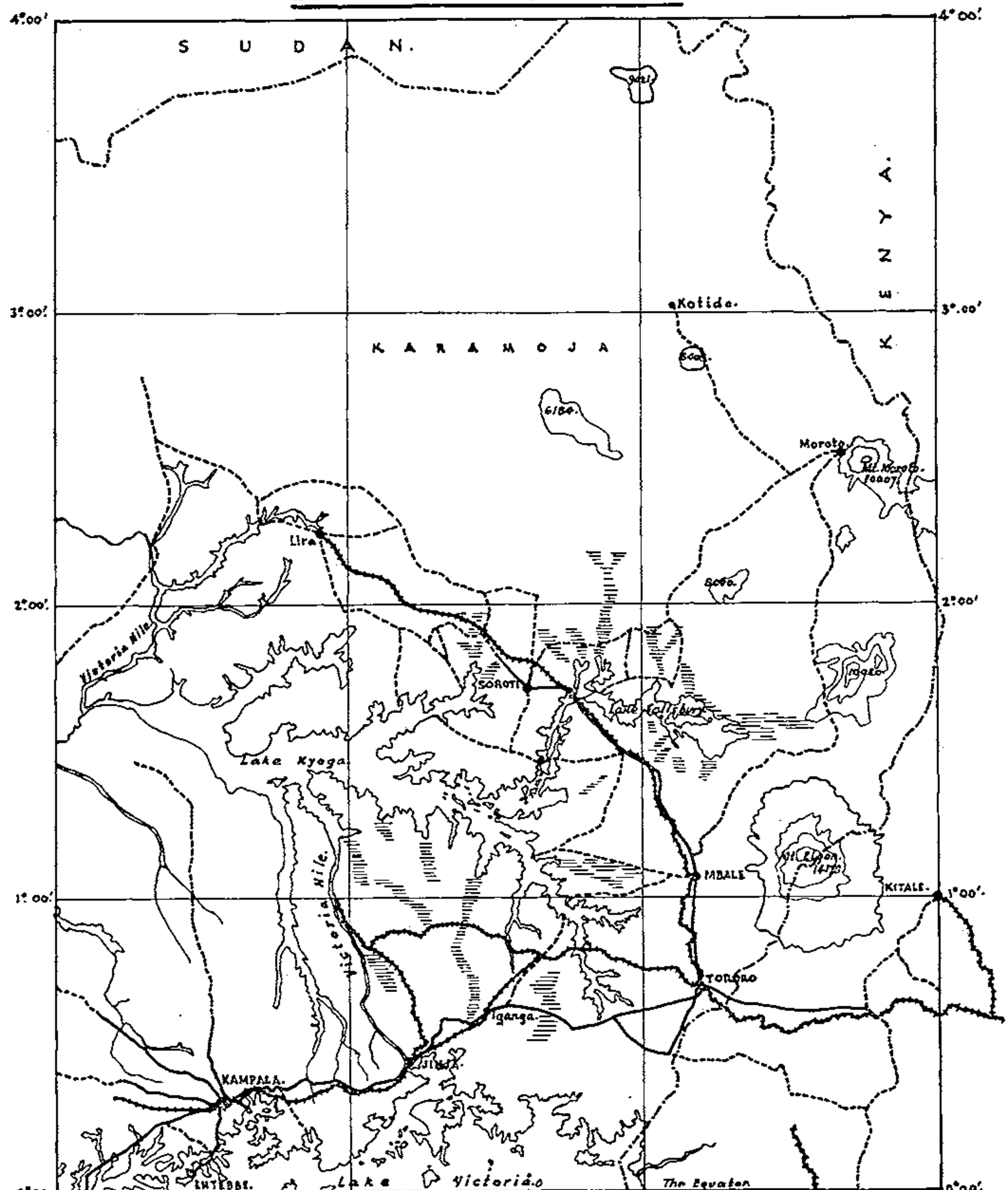
Water for Moroto township comes from several boreholes, and is pumped to an elevated tank, whence reticulation is by gravity. The system is run by MOW. The final demand for the barracks was estimated to be about the same as that for the township, and double the capacity of the existing system. A 250,000 galls tank for the barracks had already been ordered, to be erected on a bluff overlooking the site. MOW were to sink further boreholes and interconnect them and this tank with the township system. However, these boreholes were not meeting with the success which had been hoped for, and the solution of the water supply problem had not been found by the time I left.

Moroto is without electricity, apart from the odd house boasting its own generator. The army requirement was for the barracks to be supplied with electric light and power, although all cooking and water heating would be by Shell Afrigas (in cylinders). The Uganda Government's policy was to give Moroto electricity (as a part of Karamoja development), and they therefore decided to get the Uganda Electricity Board to build a generating station at Moroto to supply both town and barracks. To make this a viable proposition, UEB required an assured demand by the Army of £8,000 worth of electricity a year, which the Army commander agreed. From there on the scheme ran into trouble (which seemed only to be attributable to some inexplicable behind-the-scenes political manoeuvring), and by the time I left no firm decision had been taken whether or not the town and barracks supplies would be one, or even if the town would be supplied at all. We therefore decided that the barracks EL system would have to be designed to be fed either from an army-owned generating station in the camp or a sub-station at the same site fed from the town supply.

The Prisons Department were only willing to let about seventy-five of the prisoners from Moroto Prison out to work (and then only on winning stone and breaking it) since they were Karamojong and thus liable to vanish amongst their friends. They had therefore imported into a tented camp, erected within the prison compound, some 250 good-conduct prisoners of different tribes from other prisons, who were allowed out on all other works for the barracks. It is understood that there was little desire on the part of the latter to escape, two previous escapers having been found by the police, one dead and one almost so, at the hands of the Karamojong!

Building design envisaged the use of standard Dexion trusses of 10, 20, and 30 ft spans, for mass-production of trusses. There was not time to go

· EASTERN UGANDA ·



Sketch Map based on Edition 2 - GSGS 4646 - 1/1,000,000 - ENTEBBE - Sheet NA 36.

Miles 10 5 0 10 20 30 40 50 60 70 80 90 100 Miles.

Scale.

thoroughly enough into the question of standardizing panels of wall cladding. The same amount of mass-production of these could therefore not be achieved, although it could be arranged for a good deal of this work, especially as buildings were standardized in 10-ft bays (to reduce the cutting of Dexion to a minimum). Windows and doors were of standard sizes and were being manufactured in Prisons Department workshops.

Works Programme

The point had now been reached where a works programme, in outline at least, could be prepared. This coincided with the arrival and installation on site of the RE Clerk of Works (Construction). Together we drafted out a tentative programme from which it soon emerged that:—

(*a*) Ferrying stores to site would need six 10-tonners all the time, reinforced by Army 3-tonners from time to time when available.

(*b*) A total of six 5-ton tippers would be needed to ferry sand and aggregate to site—two more than originally envisaged.

(*c*) Hand-loading of tippers would prove unacceptably slow, so a mechanical loader would have to be acquired.

(*d*) Hand-crushing of aggregate would prove too slow, so MOW would have to be asked to lend a mobile crusher.

(*e*) Water for construction would present a problem. MOW had sunk a bore on site for this purpose, but it produced a mere 300 gallons a day. We therefore decided as an urgent measure to lay a temporary 2-in pipe from the town reservoir a mile away, to the site, which would give sufficient water for concreting, provided the tanks on site were filled over the 24 hours. This temporary pipeline would be taken up when the final water supply was working, the piping bought for it being incorporated in the reticulation system. Water for compaction of roads and hardstandings would have to be brought by bowser from a small permanent stream above the site, which went underground, except during the rains, before reaching the site.

(*f*) Prison labour would have to be increased. Apart from the stone gang, all Karamojong prisoners, it was arranged, should be removed to other prisons and be replaced by 300 working numbers. A suitable number of extra warders would also be imported. This would give an effective labour force of about 600.

(*g*) Roads and hardstandings would be best let out to contract, a remarkably favourable offer being available. Due to other commitments, including a road to connect the barracks to the township, MOW would not be able to compete in time on this work.

Our programme indicated that, provided everything went smoothly (which it was felt was a highly unlikely contingency bearing in mind a well-known factor in the repuation of the Karamoja!) the first company of 2 UR might be able to move in before mid-1964 (less piped water to buildings, electricity, and married quarters for Officers and Warrant Officers). This was accepted by HQ Uganda Army—indeed it would be really remarkably fast going if it came off!

Clerk of Works

He has probably the best job the Corps has to offer at present! The reader may judge for himself the type of man needed. He would have, with my departure on 21 December 1963, to "wear two hats":—

(*a*) Engineer adviser to the Army Commander over changes in plans arising from contingencies unforeseen during planning due to shortage of time, or changes in the Army's requirement.

(*b*) Site representative of the project engineer (ie Superintendent of Works, Prisons Department), in which capacity he would have to deal with prisoners and warders, MOW, Contractor, UEB, District Commissioner, Town Council, etc.

I wrote, therefore, a firm brief for him on his duties in both capacities (and cleared it with HQ Uganda Army, the Commissioner for Prisons, and the District Commissioner), to prevent him being placed in a difficult position in any of his dealings with other departments, and to prevent him being badgered by CO 2 UR to make unauthorized deviations!

Outstanding Design Work

The only survey available was not altogether reliable, and the only heights given were contours, apparently put in by eye. No survey points or known heighted spots existed on site. Time had not permitted this survey work to be done during my time there (although I had managed to scrounge a theodolite, level, and staff and delivered them to site before I left), and thus no design work had been begun for the following:—

(*a*) Foul drainage.
(*b*) Stormwater drainage.
(*c*) Water reticulation.
(*d*) Levels of roads, hardstandings, etc.

It was clear that to have, even on a "get-you-in" basis, any buildings ready on time, foundations would have to be put down at the easiest levels from the point of view of excavations. Hence items (*a*), (*b*), and (*c*) above would have to be designed to fit in with the as-built levels. It was felt that this was unlikely to prove any great hindrance to their eventual design. Item (*d*) would be unlikely to be affected by building levels except in a very few and minor cases.

The decision had been taken that all latrines would be bucket in phase 1, floors being boxed out or P-traps used for the installation of WCs in phase 2.

Stormwater drainage on this site would prove vitally important, and it would be necessary to put in some temporary system around buildings in advance of the design and construction of the final system, before the onset of the next rainy reason.

The 250,000 gallon tank above the site would give ample head of water at any building, so the design of the water reticulation system should present no problems.

All levelling preceeding any of the above design would have to be done by the Clerk of Works as he could fit it in with his other work. This might well apply to some of the design work, too. He would have to establish a BM on site, give it an arbitrary height (say 4,500 ft, until the Uganda Survey Department tied it into their triangulation), and then set out TBMs as required.

A "security track", good enough to take a four-wheel-drive vehicle for police patrols at any time of the year (except when wadis got too full), existed between the township and the site. The camp entrance was therefore so arranged that the permanent road from the township should be clear of the alignment of the track, so that the former could be built without hindrance to the use of the latter by construction traffic. That road, a mile or so long, was to be built by MOW and would require about six bridges in its length.

Within the barracks there would be three road crossings of major wadis. It was envisaged that these would be by bridges of RSJs with timber decking (treated against white ants) on concrete abutments. A laden 3-tonner would be their heaviest load. Footways would be provided for two of them—the third would be the exit from MT lines (in phase 2).

Conclusions

This was a most interesting (and busy!) attachment, which one would have liked to have been able to see through.

A project of this magnitude can *not* be undertaken satisfactorily with such a small engineer staff. This is particularly true when there is no engineer representation at HQ Uganda Army, and when the project's Chief Engineer (Superintendent of Works, Prisons Department) is only doing it as a spare-time job!

Military Fuel Hydrant Systems for Temporary Airfields

By Lieut-Colonel P. W. E. Kidner, MC, BSc, RE

Introduction

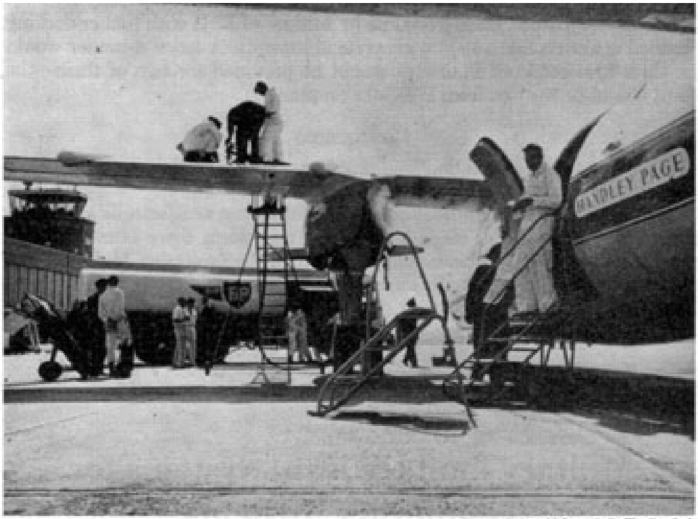
The Corps is responsible for the design and construction of the bulk aviation fuel supply system required by the Royal Air Force for temporary airfields in limited war. These temporary airfields will serve Forward and AirHead Maintenance Areas (FMA and AHMA), and their construction and maintenance is, of course, also a Corps responsibility. The aircraft operating from these airfields will be mainly Andovers (AVRO 748) based at the FMA and helicopters based at the FMA and further forward. Argosy, Beverley and, later on, HS 681 aircraft will fly into the FMA airfield but will not normally be refuelled there. Some other types, including fighter and tactical strike/reconnaissance aircraft, will also use the temporary airfields from time to time and may need refuelling.

The fuel supply system will be based on the use of the 4-in and 6-in aluminium pipeline already in service, and the 30,000 gallon capacity fabric storage tank which is in an advanced stage of development. The fuel will be brought to the airfield in bulk, possibly by air in the very early stages but as soon as possible by pipeline from a sea terminal.

It is the purpose of this paper to describe current commercial practice for handling aviation fuels on airfields and to see how commercial methods may be applied to the military problem.

Commercial Practice

Aircraft refuelling. There are two basic methods of refuelling an aircraft. The older method is by means of hand-controlled nozzles similar to but larger than those used for motor spirit on kerbside pumps, discharging into an



By permission of Messrs B.P. Trading Ltd.

Photo 1. A Herald aircraft supplied from a refueller vehicle—overwing method. One nozzle can deliver up to 120 gal/min

By permission of Messrs B.P. Trading Ltd.

Photo 2. A DC8 supplied by a dispenser vehicle from a hydrant system. Note the two delivery hoses each supplying up to 210 gal/min. The aircraft can accept four hoses, two under each wing

Military Fuel Hydrant Systems for tempoary airfields 1 & 2

orifice on the top surface of the aircraft wing. This is known as "overwing" fuelling and is becoming obsolete for all but the lightest civil aircraft. The newer method is "underwing" fuelling in which fuel is delivered under pressure through quick-acting self-sealing couplings located on the underside of the aircraft. By this means refuelling can be accomplished very rapidly with much less chance of dust, dirt and water entering the system. The two methods are illustrated in Photographs 1 and 2.

Fuel delivery rates obviously vary with the type of aircraft, but delivery pressures are standardized at 30, 35 or 60 psi, the latter being most commonly used. Fuelling characteristics of some typical aircraft are given in Table 1.

TABLE 1

FUELLING CHARACTERISTICS OF TRANSPORT AIRCRAFT

Fuelling method	Type of aircraft	Total fuel capacity	Normal fuelling rate (gal/min) No. of hoses × each hose			Normal fuelling pressure (psi)
UNDERWING* (Note 1)						
	VC.10 (S)	19,315	2	×	500	50
	DC.8	19,155	4	×	210	35
	Argosy (AW 650)	3,300	2	×	150	50
	BAC 1–11	3,050	1	×	300	50
	Andover (AVRO 748E)	1,140	2	×	75	50
	Beverley (Note 2)	6,590	2	×	200	50
	Wessex (Note 3)	527	1	×	75	50
OVERWING						
	Belvedere	1,083	Multiple filling points. Max delivery per hose is 120 gal/min or less dependent on circumstances			
	Twin Pioneer	371				
	Wessex (Note 3)	527				
	Whirlwind	292				

NOTES

1. All aircraft fitted for pressure refuelling also have overwing refuelling points for emergency use.
2. Earlier versions of the Beverley required overwing refuelling.
3. Fuelling equipment in the Wessex varies with mark.

Fuelling systems. The fuel may be supplied to the aircraft by a refueller vehicle like that illustrated in Photograph No 1, or through a piped hydrant system and a much smaller dispenser vehicle as shown in Photograph No 2. Both vehicles incorporate a filter, meters, hoses and pressure control equipment. Whereas a refueller must carry a pump, the dispenser need not, since sufficient pressure is available from the hydrant to provide the final delivery pressure required plus any losses incurred. A few systems have been built requiring a booster pump on the dispenser, but they are rare. The hydrant system has therefore two important advantages over the use of refueller:—

(*a*) The vehicles required on the apron to refuel an aircraft are smaller and cheaper.

(*b*) The total number of vehicles required at a given airfield is fewer, because they do not have to reload and can proceed directly from one aircraft to the next.

There is therefore a saving of both men and equipment, but this is offset by the cost of installing the pipework.

Since the RAF have specified hydrant systems for temporary airfields in limited war, a more detailed examination of their design is justified.

Hydrant system design. The major design factors to be considered are:—

(*a*) *Peak demand*

The number of aircraft to be fuelled simultaneously, and the maximum demand of each. Only the largest systems would cater for more than two or three simultaneous refuellings of major civil aircraft, each of which may demand up to 1,000 gal/min.

(*b*) *Airfield layout*

The number of aircraft parking stands, which may be anything up to a hundred or more.

(*c*) *Types of fuel to be supplied*

Up to three grades of fuel are commonly supplied by hydrant at each stand, with one or two hydrants for each fuel. It is often found to be economical to supply Avtur—used in ever-increasing quantity—by hydrant and the lesser used grades by refueller. Where two grades are supplied by hydrant, they are normally Avtur and Avgas, though the latter may in future be replaced by Avtag which is becoming increasingly popular as a turbine fuel owing to its lower cost.

(*d*) *Hydraulic characteristics*

The maximum system pressure is usually dictated by the strength of the intake and delivery hoses on the dispenser. Aircraft tank valves and dispenser pressure control valves must close very rapidly (0.5 to 0.2 sec) to protect the aircraft system from overfilling and from excessive surge pressures. As a result, high surge pressures are induced in the hydrant system and must be limited by the use of low flow velocities (large diameter pipes) and shock alleviators.

These characteristics indicate the outline design required. In all but very small installations, two or more pumps in parallel are required and their proper control is a critical point of design. The principle is to maintain pressure in the hydrants at all times. When there is no flow, pressure is trapped in the line by a non-return valve usually assisted by a hydraulic accumulator. The pumps are automatically controlled by pressure and flow switches and the operating sequence is:—

(*a*) *Start-up*

When fuel is taken from the system there is a sudden drop in pressure which is sensed by a pressure-switch, starting up the first pump. As soon as a measurable flow is established a flow-switch over-rides the pressure-switch to keep the pump running while flow continues, irrespective of pressure fluctuations.

(*b*) *Varying demand*

Additional pumps are started or stopped by separate flow switches according to demand. These are differential pressure-switches connected to a venturi in the line.

(*c*) *Shut-down*

When all flow has ceased and normal pressure re-established, the first pump is shut down. But to prevent hunting at very low rates of flow and during topping-up, a 30 sec delay is incorporated in the pressure switch.

By these means, the pressure at the hydrants can be maintained within the required limit at all rates of flow up to the design maximum. The shock alleviators required to limit surge pressures are normally mounted on the dispenser. The delivery pressure into the aircraft is controlled by means of a restrictor pressure control valve either mounted on the dispenser or incorporated in the delivery hose coupling. Hose-end control valves (Photograph No 3) are favoured as they are compact and light, and give maximum protection to the aircraft.

Quality control problems. The fuel cleanliness standards required at present are:—

Water: not more than 15 ppm free and suspended water.

Solids: not more than 0.4 mgs per litre.

These levels can only be attained by extremely good house-keeping throughout the system from refinery to aircraft. The following precautions are taken at commercial airfield installations:—

(*a*) Aviation fuels are fully segregated, since no contamination of one fuel by another is permissible.

(*b*) Water is never allowed to enter the system, and every practicable measure is taken to minimize the absorption of water from the atmosphere. When a new system is commissioned, compressed air is used for initial testing, followed by fuel for full pressure testing and flushing.

(*c*) On receipt into airfield storage fuel is filtered through a 200-mesh or finer filter and allowed to settle in the storage tanks for at least 1 hr per ft of depth.

(*d*) Storage tanks are fitted with floating suction arms, and their floors slope towards a sump from which water and sediment is drained daily.

(*e*) On leaving storage the fuel is passed through a micronic filter and water separator before entering the hydrant system. These give filtration of the order of 98 per cent efficiency at 5 microns.

(*f*) Dispenser vehicles incorporate a final filter/water separator to guard against dirt or water in the pipework and hoses, and as a protection against the very rare failure of the upstream filters or water separators.

It must be remembered that fuel always contains dissolved water, and a rapid fall in temperature often results in the precipitation of free water. The presence of water encourages rusting of the steel storage tanks and pipes, and rust itself is the most common solid impurity. The use of inert-lined or aluminium alloy tanks and pipework is often considered, but is usually ruled out on grounds of cost. For these reasons, successive filtration and water separation stages are necessary and indeed the only way of keeping within the required contamination limits.

The Military System

Design factors. The RAF require the hydrant system to supply small air-portable dispensers which will not incorporate a prime mover or pump. Taking the design factors in turn, we find:—

(*a*) *Peak demand*

We are now required to supply fuel at a maximum rate of 150 gal/min to up to three aircraft simultaneously, so the system must be capable of delivering each fuel required at a rate of 450 gal/min.

(*b*) *Airfield layout*

A hypothetical layout is shown in Plate 2. Fuelling hydrants are required of eight aircraft parking stands, but these are to be divided into two groups of four, each group provided with one fuel only. There will be additional stands for aircraft not requiring refuelling.

(*c*) *Types of fuel*

The two grades required are Avtur and Avgas, although the demand for Avtur is increasing and that for Avgas is falling and will eventually disappear.

(*d*) *Hydraulic characteristics*

The system is shown diagrammatically in Plate 1. Fuel has to be delivered into the aircraft at a pressure of 50 psi (Table 1) in order to obtain the normal refuelling rates, and the hydrant pumps, situated in the storage area up to half a mile away must provide this plus all the system head losses. The required pump delivery head is obtained as follows:—

Head losses

Main filter and water separator, in the storage area	15 psi
2,500 ft of 6-in pipe carrying fuel at 450 gal/min, including an allowance for fittings	15 psi
200 ft of 4-in pipe (or hose) carrying fuel to the hydrant at 150 gal/min, including fittings	5 psi
Intake hose, dispenser and delivery hoses, say	25 psi
Total head losses	60 psi
Add required delivery pressure	50 psi
Required pump delivery head	110 psi

The surge pressures which can occur when the flow of fuel is suddenly stopped, as by the simultaneous closing of the pressure control valves, are very high—of the order of 350 psi—and sufficient to damage the dispenser hoses whose safe working pressure is 225 psi or less. It is therefore essential that the dispenser should incorporate shock alleviators. These are specially adapted hydraulic accumulators in which the fuel pressure is balanced against a chamber of compressed air, the fuel and air being separated by a flexible diaphragm. They are manufactured in a standard 6 gal size, two of which would be sufficient to limit the peak pressures in the system described to 200 psi. Alternatively, fabric hoses serve to reduce surge pressures by virtue of their elasticity, and it has recently been shown that 100 ft of a terylene hose under development by MEXE is at least as effective as two 6 gal shock alleviators.

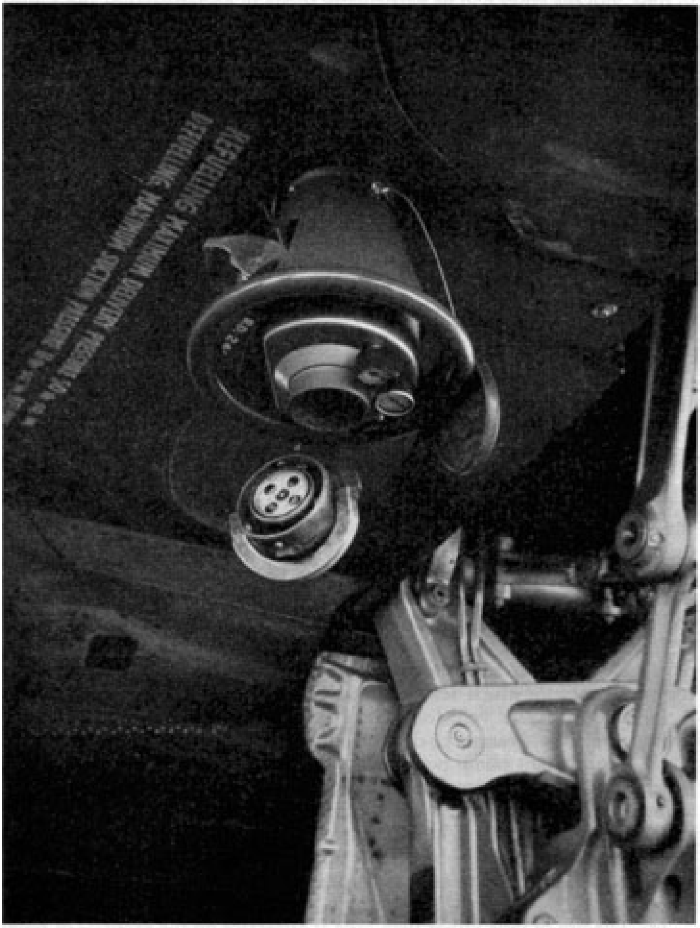
PUMPS

The requirement calls for a pump set (or sets) with an output of 450 gal/min at 110 psi (minimum) when pumping Avtur or Avgas. But Avgas is required only for piston-engined aircraft which, in general, use "overwing" fuelling (1) with less critical pressure requirements, and it is reasonable to specify the full pump performance for Avtur only. It should be possible to obtain a single unit to meet this specification within the War Office weight limit of 4,000 lb, skid mounted. But if for any reason two units are required they must be designed for use in parallel rather than in series, since this greatly simplifies automatic control. The control system should be similar in principle to that used in commercial practice. The pumps should be designed to run at constant speed with their delivery head falling by not more than 10 per cent between the stalled and full-flow conditions, say from 120 to 110 psi.

(1) The only known exception is the Beverley.

Filters and Water Separators

These are commercially obtainable "off-the-shelf", and call for no special comment. They should be skid-mounted assemblies as they are unavoidably heavy and bulky; and they should have the necessary valves, back-flush circuits and pressure gauges permanently incorporated for convenience and speed in installation.



By permission of Messrs Flight Refuelling Ltd.

Photo 3. Hose-end pressure control valve fitted to aircraft fuel coupling, but with hose removed to show detail. The gauges show pre-set delivery pressure and actual fuel pressure

Storage Tanks

The fabric storage tanks under development by MEXE have several advantages over the rigid tanks used commercially, and one major disadvantage. They incorporate, in effect, floating suction arrangements and, since they have no air space, they do not draw in dust and moisture through vents from the atmosphere. However their shape, and the need to lay them on level ground hinders the removal of water and sediment settling out of the fuel. Small puddles of water will inevitably form on the tank floors from time to time, and the tanks will be particularly prone to bacteriological and fungal infection which, in Avtur, can become serious in as short a time as thirty days in warm climates. Should such contamination be detected—an RAF or RAOC responsibility—it will be necessary to replace, clean and sterilize the tanks. Although perhaps outside the scope of this paper, this aspect deserves special attention in the planning of the shore reception and storage installation, where water separation is very desirable between the reception of fuel ashore and base storage.

Aircraft Parking Arrangements

The ground movement and parking plan for aircraft is wholly the responsibility of the RAF. But it must be known in advance if the hydrants are to be correctly located, for the dispenser hoses are short and the latitude small. SRT aircraft requiring to be refuelled must be parked round the apron perimeter, for it is impractical to bury the hydrants and pipework under the apron as is usual in civil practice. An Andover aircraft requires a parking area approximately 100 × 125 ft and an Argosy—125 × 200 ft. A possible layout of an apron for eight SRT and six MRT aircraft is shown in Plate 2. It will be noted that the area to be surfaced is large and approximately equal to that of the main runway.

Conclusions

As in all joint projects, proper co-operation between the people concerned is very important. In this case responsibility is divided between the RAF on the one hand and the RE and RAOC on the other, all of whom are likely to be preoccupied with the larger task of airfield construction. The efficient planning of the fuel system may therefore be more than usually difficult. But it is an essential part of the project, calling for a high standard of technical skill, and any failure in planning will be dearly paid for later on.

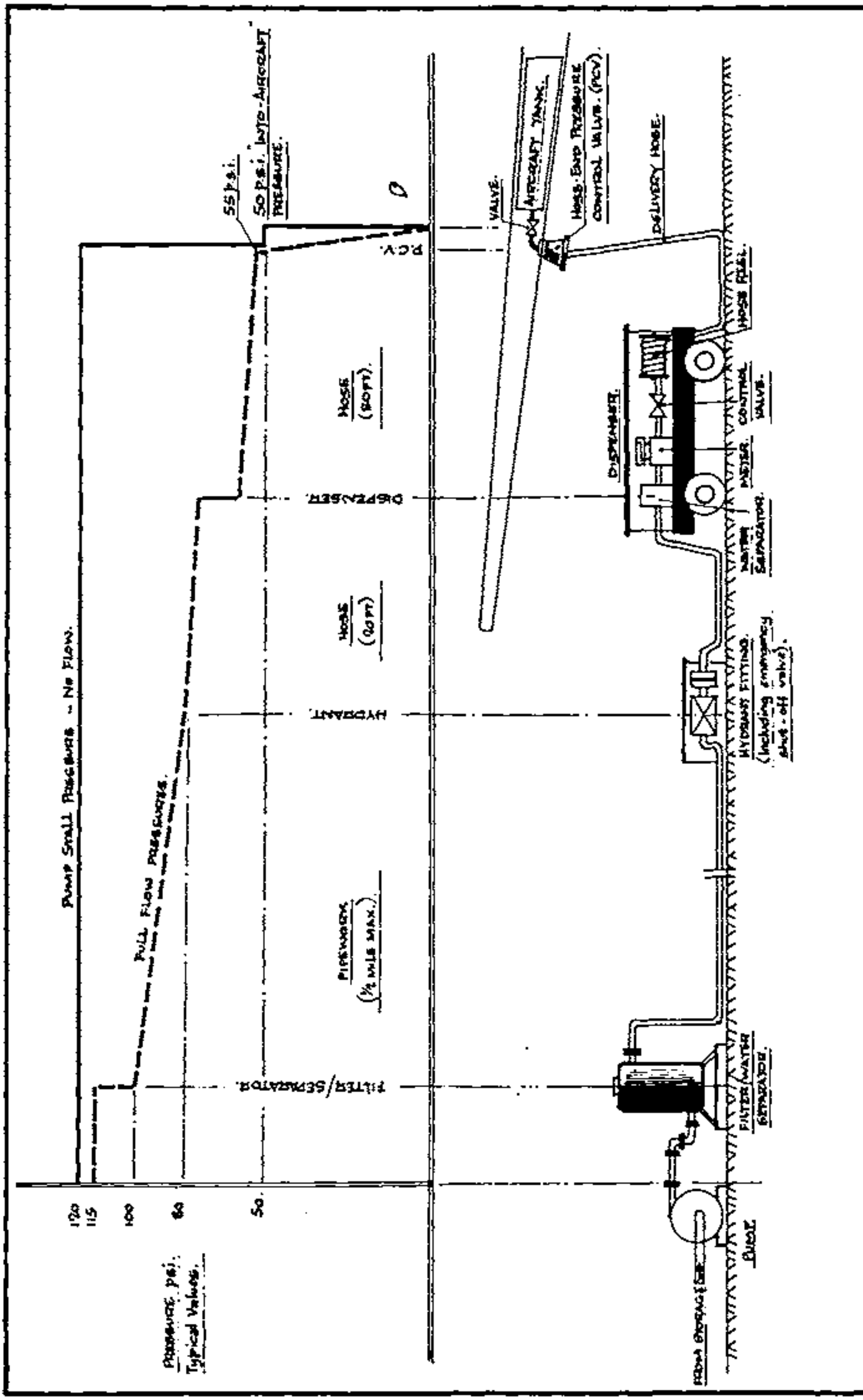
It is apparent that the new range of POL equipment in service or under development is very suitable for the airfield task. There are, however, four technical problems which deserve special attention:—

(*a*) The dispenser vehicles, which are RAF provision, are part of the hydrant system and cannot be designed in isolation.

(*b*) The hydrant pump performance is critical. If use is to be made of a general purpose pump set, the hydrant requirement is likely to be its most arduous duty, and must dictate its design specification.

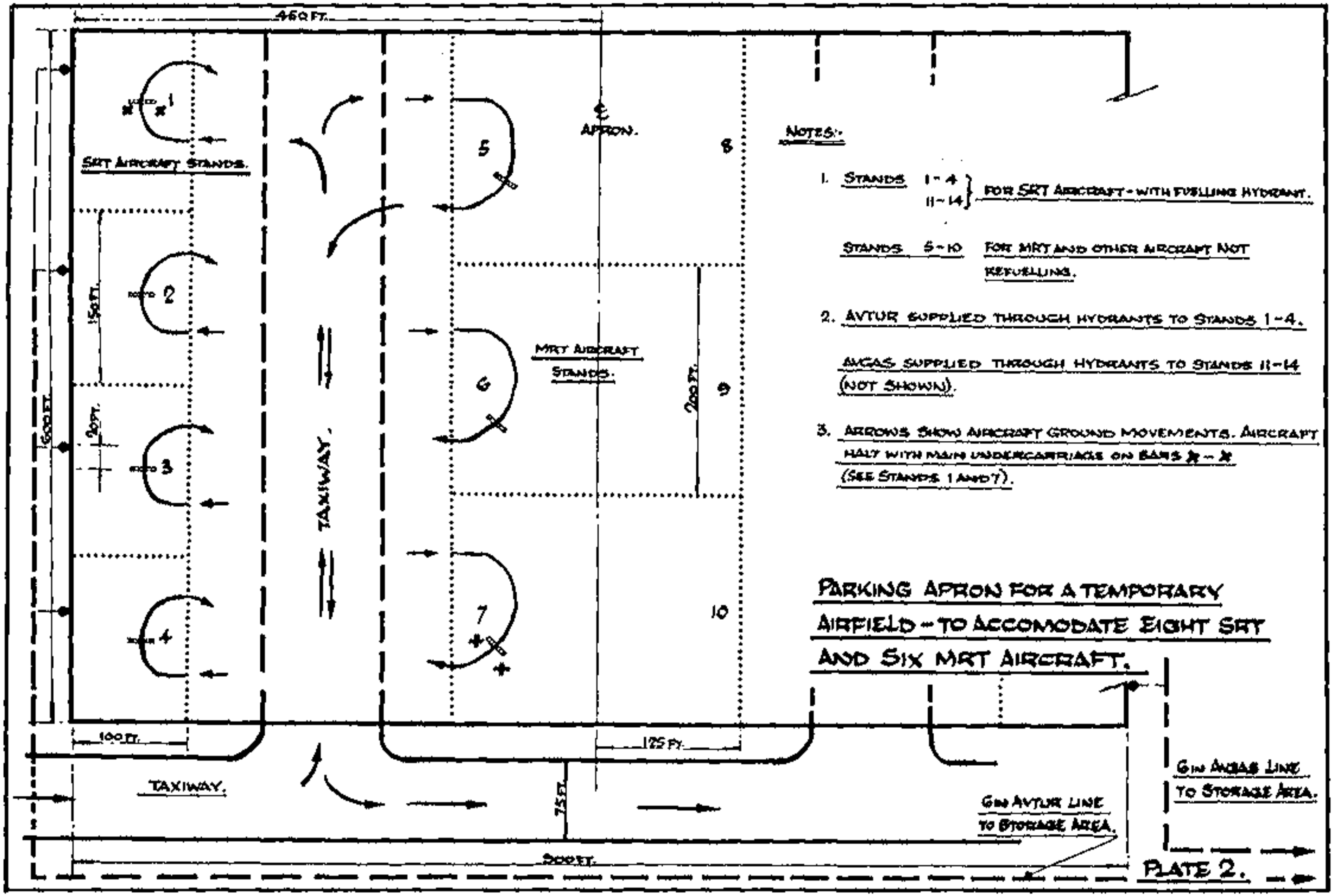
(*c*) The use of lightweight hose may overcome the problem of surge pressures, but short lengths of hose must not be incorporated in a system built largely of aluminium pipe unless the peak surge pressures are known to be acceptable.

(*d*) The use of pipe rather than hose is attractive on the grounds of reliability and reduced maintenance. The airfield area will carry a great deal of road traffic, and hoses are vulnerable. Fuel lines will need to be buried at least where they cross taxiways and roads, and it may not always be possible to restrict vehicles to marked routes.



DIAGRAMMATIC LAYOUT AND HYDRAULIC CHARACTERISTICS OF A HYDRANT SYSTEM.

PLATE 1.



460 FT.
SRT AIRCRAFT STANDS.
1
2
3
4
150 FT.
200 FT.
600 FT.
100 FT.
TAXIWAY.
TAXIWAY.
5
6
7
℄ APRON.
MRT AIRCRAFT STANDS.
8
9
10
200 FT.
125 FT.
75 FT.
500 FT.
NOTES:-
1. STANDS 1-4 } FOR SRT AIRCRAFT - WITH FUELLING HYDRANT.
11-14 }
STANDS 5-10 FOR MRT AND OTHER AIRCRAFT NOT REFUELLING.
2. AVTUR SUPPLIED THROUGH HYDRANTS TO STANDS 1-4.
AVGAS SUPPLIED THROUGH HYDRANTS TO STANDS 11-14 (NOT SHOWN).
3. ARROWS SHOW AIRCRAFT GROUND MOVEMENTS. AIRCRAFT HALT WITH MAIN UNDERCARRIAGE ON BARS
(SEE STANDS 1 AND 7).
PARKING APRON FOR A TEMPORARY AIRFIELD - TO ACCOMODATE EIGHT SRT AND SIX MRT AIRCRAFT.
6 IN AVTUR LINE TO STORAGE AREA.
6 IN AVGAS LINE TO STORAGE AREA.
PLATE 2.

The "MAB"

By Major A. M. Pyne, RE

Introduction

A recent addition to the world family of amphibious bridges is the Mobile Floating Assault Bridge/Ferry, developed by the United States. This somewhat cumbersome title is correctly abbreviated to MFABF, but users, finding this unpronounceable, frequently refer to the equipment as Mobile Assault Bridge or MAB.

The MAB, which is intended to serve the same purpose as the Gillois and Federal German M2 bridges, was designed by the US Army Engineer Research and Development Laboratories. Design started in September 1959 under the direction of Mr Howard H. Mullins. Twelve units were assembled by the Chrysler Corporation for engineering and service tests, and these were delivered in March and April 1963. The initial tests were completed in June 1964, and an order for limited production of further units has been made.

General Description

The hull. The body of the MAB is a riveted aluminum alloy hull 12 ft wide, 5 ft 6 in, deep and a little over 39 ft long. This hull is mounted on a four-wheeled chassis, which brings the overall height up to 9 ft 1 in with the tyres fully inflated. A cab, which can be removed if necessary, is located at the bow, and this brings the total height up to 10 ft 6 in. A propeller at the stern increases the length of the vehicle to slightly over 42 ft.

The hull, which weighs about sixteen short tons, is constructed of $\frac{1}{8}$-in thick alloy plate on the sides and deck, and $\frac{3}{16}$-in plate on the under surface, including the upswept bow. Additional strength is provided by reinforcing ribs located on the sides and underneath from the stern to the top of the bow. The hull is weldable, and repairs have been successfully carried out during tests by welding, or by attaching plates with rivets or bolts.

The hull consists of one main compartment running all the way from bow to stern, and four separate wheel well compartments, each of which may be pressurized to provide additional buoyancy in the water. Though it is not physically subdivided, the main compartment is made up of a large engine compartment located centrally between the four wheel wells, smaller bow and stern compartments and two narrow "passages" between the two pairs of wheel wells which join the engine compartment to the bow and stern sections.

Two types of superstructure may be mounted on the hull—interior bay and end bay. They are interchangeable.

Interior bay superstructure. The interior bay consists of a welded aluminium alloy deck weighing approximately 7 short tons. A MAB rigged as an interior bay unit has a total weight of some 23 short tons. The deck is carried along the length of the hull for road travel. When in use it is raised 10-in, rotated clockwise through 90 deg and then lowered ready for connexion to the deck of an adjoining unit Both ends of the deck are provided with a pair of male fittings on one side and a pair of female jaws on the other. Interconnexion of adjoining decks is achieved by pins driven hydraulically. One interior bay superstructure provides 26 ft of bridge or raft.

During road travel the deck width is the same as the width of the hull, 12 ft. When in use, however, the deck is widened to 13 ft 6 in by kerbs at each side, which are raised into position after the units have been linked.

End bay superstructure. The end bay superstructure consists of welded aluminium alloy and steel girders carried in two layers, the upper layer incorporating two hydraulic rams. The superstructure weighs nearly 10 short tons, giving an end-bay MAB a total weight of some 26 short tons. Since the top layer is higher than the cab, the overall height of the MAB with end-bay superstructure added is increased to 11 ft 9 in. In use the superstructure is raised, rotated, lowered and widened in a similar manner to the interior bay. The upper layer is a 23 ft long ramp, and the lower layer a 14 ft long deck, which is provided with one set of male and female fittings for connexion to an adjoining unit. After connexion, the ramp is unfolded, thus producing 37 ft of continuous roadway.

General data. A table at the end of this article lists some of the vehicle characteristics which have not yet been mentioned.

Performance of Individual Units

On land. The MAB is equipped with a General Motors eight-cylinder diesel engine, developing 335 bhp at 2,300 rpm. This engine powers the vehicle on land and in the water. One hundred gallons of fuel is carried in two tanks, giving a range of between 400 and 500 miles on roads. The vehicle is capable of 40 mph, but is normally restricted to a maximum of about 35 mph.

The wheels are independently sprung and cross-country performance is excellent. There is little of the bouncing and swaying which will be familiar to those who have driven the Gillois, and the MAB can climb firm slopes up to 1 in 1.7. Four gear ranges are available for forward travel: 1–2, 3–4, 3–5, and 3–6. The transmission will shift automatically between the gears within the range setting selected. The 1–2 setting can be selected only when four-wheel drive has been engaged. One reverse gear is available.

The vehicle is not at all difficult to drive once the driver has become used to its size. The centre of gravity is, however, on the high side, especially on the end bay unit, and sharp cornering at speed is best avoided.

With two-wheel steering, the MAB can be turned in a radius of 65 to 70 ft. These figures may be reduced to 40 to 45 ft if four-wheel steering is employed.

In water. The MAB is ready for the water without any preparation. As the unit enters, the propeller is lowered from the stowed to the operating position. The maximum speed of a single unit in still water is about 8 knots.

Once the vehicle is in the water the wheels may be retracted and the wheel wells pressurized. However, for reasons which will be explained later, it is normal to delay these steps until connexion with adjoining units is being effected.

The propeller, which has a diameter of 28-in, may be turned through 360 deg, and can be extended up to 16-in lower than the operating position for extra efficiency in deep water. Maximum propeller speed is 994 rpm and the maximum thrust in excess of 5,000 lb. The first MAB models were provided with a safety device which caused the propeller to be kicked up under the influence of a hydraulic ram if it struck an underwater obstruction. At the same time the marine power take-off was automatically disengaged. This arrangement did not operate properly if the vehicle was moving sideways into

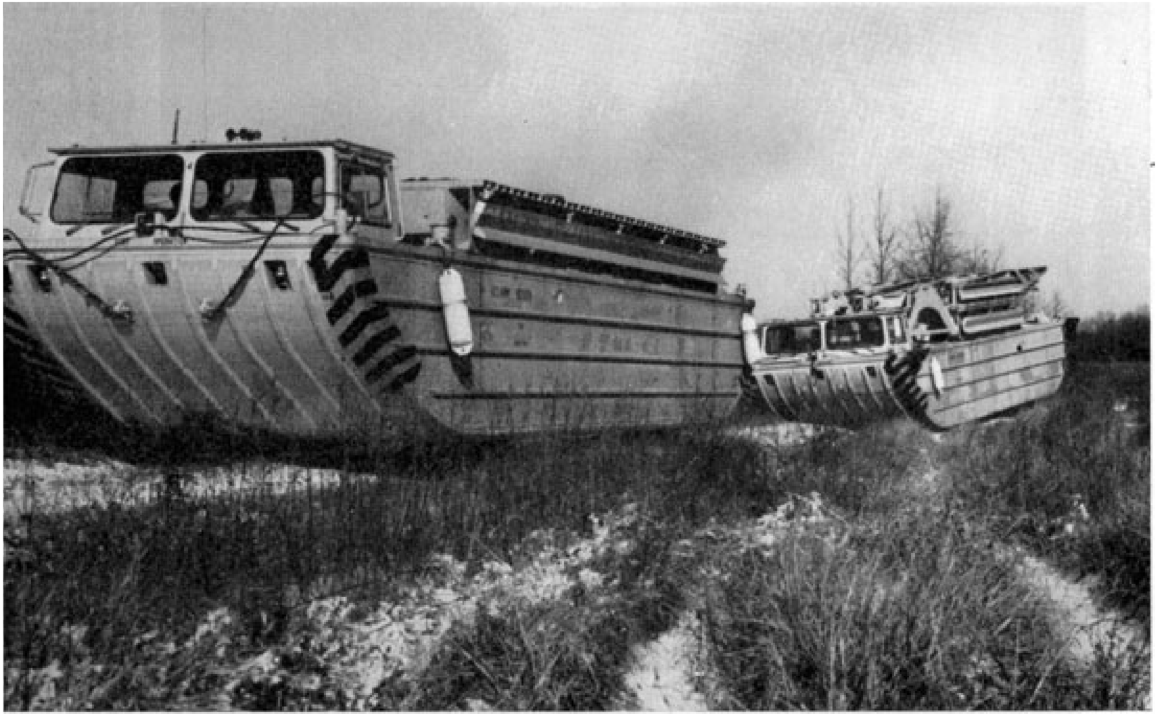


Photo 1. An interior bay unit followed by an end bay unit on a cross-country course. (Note the kerbs in the stowed position at the sides of the deck; the forward capstan between the cab and the deck; and, just behind the capstan on the leading vehicle, one of the female deck fittings with nose of a pin just visible)

American Mobile floating assault bridge ferry 1

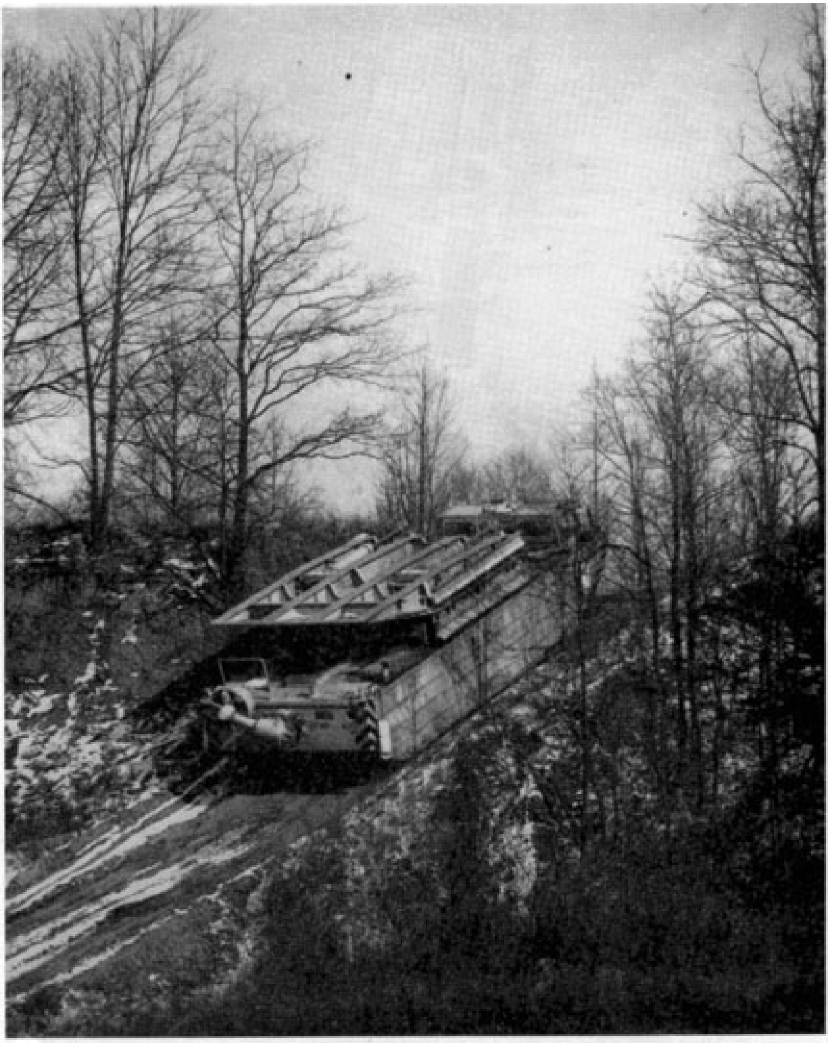


Photo 2. An end bay unit on a cross-country course. (The rear operator's pilot station is folded down into the hull just in front of the tubular backrest. Note the propeller in its stowed position; the hydraulic cylinders in the ramp; the male and female fittings on the lower layer on the deck; and the raised engine cooling system air vent between the aft capstan and the superstructure.)

American mobile floating assault bridge ferry 2

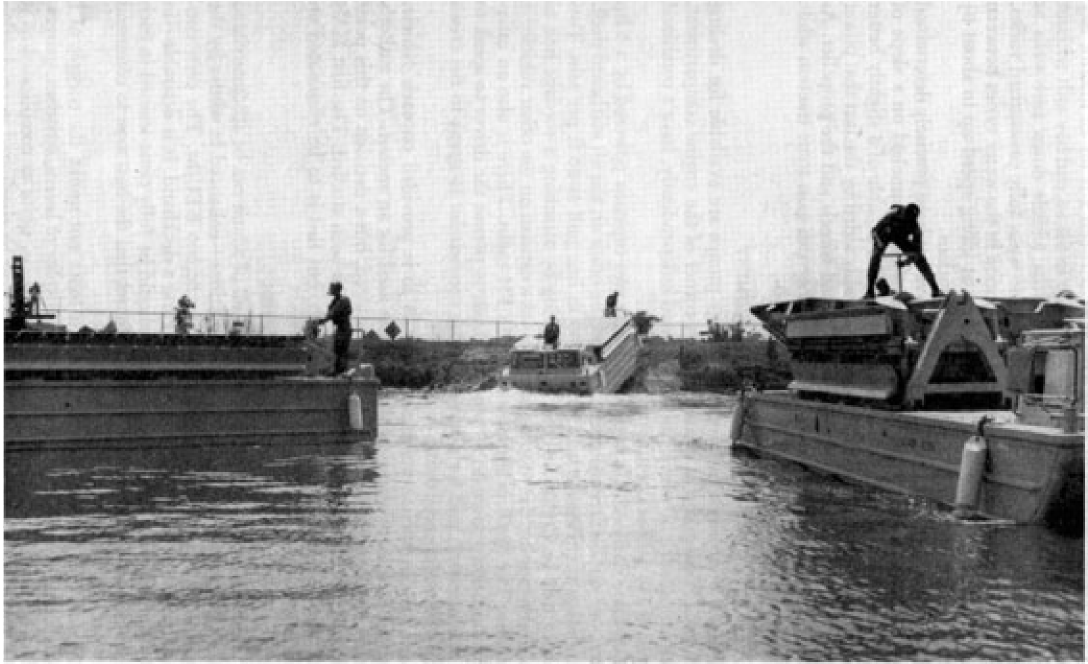


Photo 3. An interior bay unit enters the water. (Note the deckhand on the right loosening the tie-down bolts, and the rear operator's pilot station, which is clearly visible on the unit on the left)

American mobile floating assault bridge ferry 3

the obstruction, and a modification incorporating a steel bolt as a shear pin has proved more successful during service tests.

The unladen draught of the MAB varies between 2 ft for an interior bay unit with wheel walls pressurized, up to 2 ft 9 in for an end bay unit without pressurizing. The difference in draught from wheels down and wells at atmospheric pressure, to wheels retracted and wells fully pressurized varies, with a maximum of some 7-in. Fuel consumption in the water varies between about 1 gallon per hour for a single vehicle at idling speed up to about 6½ gallons per hour per unit during ferrying operations.

Limiting slopes for launching the MAB have not been precisely determined as yet. However, the vehicle has been successfully launched on a slope of 1 in 2.2 with a cross fall of 1 in 5, and it may be capable of a slightly better performance. Exit from the water is considerably aided by the fact that power can be transmitted simultaneously to the road wheels and the propeller. As soon as the wheels touch down, therefore, they can gain some traction while propeller thrust remains available at the stern.

Auxiliary Equipment

Pumps. Four electrically operated bilge pumps are available for dealing with leaks. One pump is located at each corner of the engine compartment. The pumps, each of which can be operated independently, have a combined output of 184 gallons per minute.

Capstans. Each vehicle is provided with two capstans powered by a 5 hp motor, one on the forward port deck and the other on the aft starboard deck. The design requirement was for a 5,000 lb line pull at 50 ft per min. Two vehicles may be drawn together for pinning by attaching a cordage line to one, and wrapping the running end around a capstan on the other vehicle.

Radio. The MAB is equipped with an FM radio. There is also an inter-communication system on a "plug-in" basis to permit the driver to speak to his rear operator, and for a raft or bridge commander to speak to the crews on all of the connected units.

Anchor. An anchor weighing about 65 lb is provided on each vehicle. Some differences of opinion exist as to the need for an anchor. The author's view is that a much heavier anchor is required, but a decision on this point will no doubt be made when test results have been studied. The first MAB units were equipped with a 7½ ton winch, but this is to be eliminated on production models.

Crew Duties

The MAB's crew consist of three men, all of whom can be accommodated in the cab in reasonably comfortable conditions—enhanced in winter by the provision of a personnel heater developing 30,000 BTU/hr. The crew consists of a driver, a rear operator or pilot, and a deckhand. It is desirable—in fact practically essential—that all three should be fully cross-trained in each other's duties. During tests it has been found that the best man to command the vehicle is the rear operator.

The driver. The driving compartment looks not unlike the cockpit of a sophisticated aircraft, with a bewildering display of levers, switches, gauges, and indication lights. Though it is not, perhaps, quite as complicated as it looks, it is possible that some of this array may be eliminated in production models. It is from this compartment that the driver performs such diverse functions as raising and rotating the superstructure, unfolding the ramp, driving the connecting pins and raising the kerbs; retracting the wheels and pressurizing the wheel wells; and operating the capstans and bilge pumps. He is also provided with controls enabling him to carry out all the functions normally performed by the rear operator, such as raising, lowering and steering the propeller. It is in this field, perhaps, more than any other, that simplification may best be achieved, since this duplication of controls can hardly be regarded as essential.

The rear operator. A pilot station, which folds down into the hull deck, is available at the stern of the MAB for use by the rear operator. When four wheel steering is required during land travel, the rear operator can steer the rear wheels with his marine steering wheel. Alternatively, this function can be performed by the driver, using the forward marine steering wheel in the cab. In water, the rear operator normally takes full control of the vehicle, including the steering and selection of engine speed and propeller depth. The rear pilot station includes dials indicating direction of propeller thrust, propeller depth and engine speed. These are all duplicated in the driving compartment. The driver is also able to override the rear operator in any of his functions.

The deckhand. The deckhand's task is to perform all the necessary operations which cannot be effected by the two other crew members from their stations. One of his functions is the loosening of the four superstructure tie-down bolts which fasten the deck of both types of superstructure to the hull. This task, performed manually with a wrench, must be carried out before the deck can be lifted or rotated. After the deck has been rotated, lowered and connected to an adjoining deck, the deckhand must tighten the four bolts again. When two MABs are to link, the two deckhands are responsible for exchanging lines and using the capstans to draw the two units together. After the link-up, the deckhands may plug in the intercommunication leads between the two decks. This is not always required, since in daylight hand signals are usually perfectly adequate for control purposes.

Rafting

General. Rafts of varying sizes have been constructed during tests. It is perhaps fair to say that the precise classifications of the different types have not yet been determined. The designer has suggested the following provisional limitations (all short tons):—

two bay raft (ie, two end bays linked): 25 tons
three bay raft: 47 tons
four bay raft: 72 tons
five bay raft: 90 tons
six bay raft: 108 tons
} with the proviso that no single vehicle in the payload should exceed Class 62

There is no doubt now that these loads can, indeed, be carried. An approximation of 20 tons capacity for each MAB in the raft has recently been suggested as an alternative. It seems probable that all these figures are on the conservative side. The displacement provided by one unit works out at an average of 1 short ton per-in of depth of the main hull (5 ft 6 in). Those who are mathematically inclined may determine for themselves the buoyancy theoretically available after deducting the dead weight of the vehicle and superstructure and allowing a handsome margin for freeboard.

Loading and operating conditions. The draught of a laden raft is of the order of 3 ft 6 in. It is considered at present that 4 ft should be regarded as the

Photo 4. An end bay about to link to an interior bay. (Note the end bay's slightly lower position in the water; and the deckhand preparing to make use of the powered capstan at his feet to achieve the final alignment)

American mobile floating assault bridge ferry 4

Photo 5. A three-bay raft (almost a bridge!) carrying four M113 APCs (approximately 44 tons total load.) (Note the raised kerbs; and the use of the ramp to support part of the rear APC. This raft is exactly 100 ft in length)

American mobile floating assault bridge ferry 5

normal minimum water depth for raft operation, with 5 ft desirable. The MAB is designed to take its full load when grounded if necessary. Maximum speed for laden rafts should normally be limited to about 6½ knots, since at greater speeds there may be a danger of waves washing over the top of the hull and entering the cooling system air vents.

The rafts may be used to carry a mixed load of vehicles, provided that the heaviest ones are loaded as near to the centre as possible. Light vehicles may be loaded on the ramps. The ramps can be lowered up to about 2 ft 6 in below water level so that vehicles can ford out to the inshore ramp if necessary. In view of the method by which the ramp is unfolded, the upper limit in the bank height is dictated by the length of the ramp and the proximity of the end bay hull to the bank. Sometimes the ability of the payload vehicles to negotiate the ramp slope will be a more critical factor than the height of the bank itself.

The time for construction of rafts varies, as is to be expected, with crew experience and the river conditions. A four bay raft has been built in as little as four minutes, timed from the moment the first MAB entered the water. Seven to ten minutes might be regarded as a good average.

Construction procedure. Raft construction normally starts as follows (a four-bay raft is taken as an example):—

(*a*) First end bay and first interior bay units (Pair A) enter the water, switching to marine drive.

(*b*) Second end bay and second interior bay units (Pair B) enter in the same manner.

(*c*) Deckhands loosen tie-down bolts on all units.

(*d*) All superstructures are raised, rotated and lowered.

At this point a small problem arises, in that the heavier end bay units float lower in the water than the interior bays, and the decks are therefore at slightly different heights. This can be solved in two ways: first, by starting to pressurize the wheel wells on the end bay units, which will thus raise them; or secondly, by raising the end bay superstructure slightly, using the same hydraulic control that is activated for its initial raising prior to rotation. The second method is probably the quicker of the two. If that is the one adopted, construction proceeds as follows:—

(*e*) Pair A units are brought alongside each other by the rear operators, the end bay superstructure is raised slightly, lines are exchanged and capstans used for final alignment. Pins are driven and the end bay superstructure is lowered.

(*f*) Exactly the same process takes place for Pair B.

(*g*) Both pairs are now brought together with the interior bays next to each other. Final alignment is as before. Here any difficulty in linking may be overcome by partly pressurizing wheel wells. The interior bays are then pinned together.

(*h*) All wheels are retracted and wheel wells pressurized. Simultaneously the kerbs are raised, and the deckhands tighten the tie-down bolts.

(*i*) Finally, ramps are unfolded to complete the raft. (An end bay unit is not stable on its own with the ramp unfolded and connexion to an adjoining unit first is essential.)

Bridging

The technique for bridge construction is virtually identical to that for rafts, and the site requirements are similar. A MAB bridge is classified as

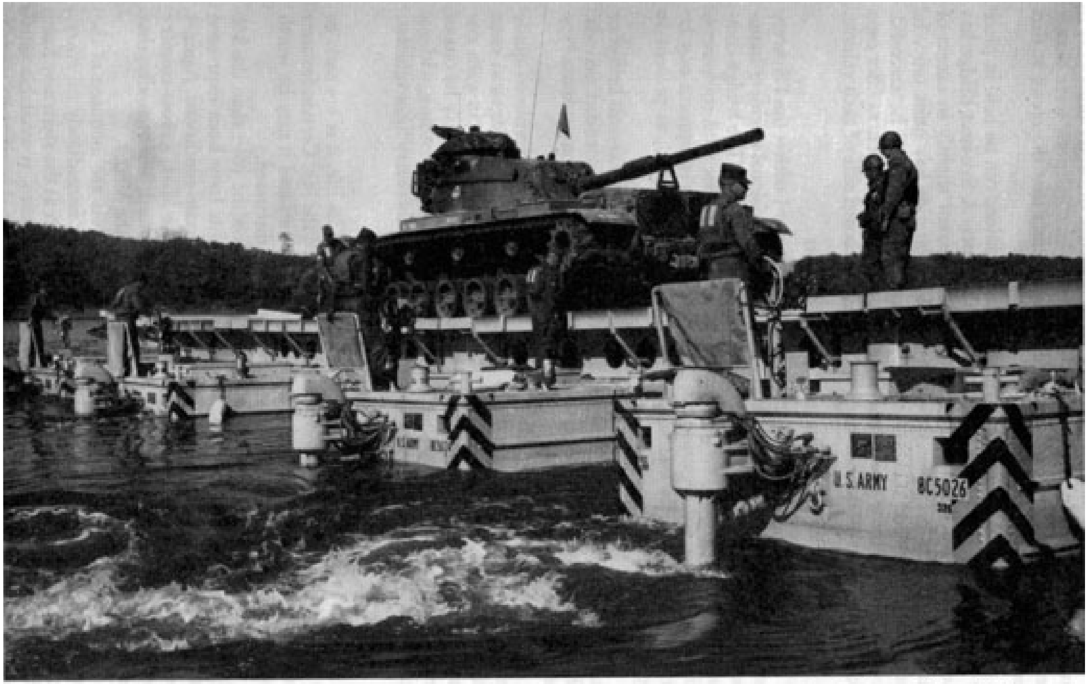


Photo 6. A four-bay raft at speed with an M60 tank (Class 55). (The normal loading length of this raft is 80 ft, the overall length being 126 ft. Light vehicles can be loaded on the ramps).

American mobile floating assault bridge ferry 6

Class 60, since this is the maximum capacity required by the US Army. Once again, there is little doubt that this is a conservative estimate.

Few long bridges have been constructed. A bridge of twelve units (334 ft long) has been built in 25 minutes. Admittedly the conditions were almost ideal, but this advantage was partly offset by the fact that the crews at that time were relatively untrained.

It is anticipated that bridges in most river conditions can be held in place by the propeller thrust of a proportion of the units. A five-unit bridge has been held in place without any difficulty in a current slightly in excess of four knots by the propeller thrust of the three interior bay units only. In much faster currents, it may be that the use of anchors will be essential. Refuelling of the units while "in bridge" is perfectly practicable as filler caps are provided both on the hull deck and on the starboard side of each vehicle.

Tactical Considerations

Allocation. The proposed allocation of the equipment within the US Army is sixteen interior bay and eight end bay units to a divisional engineer battalion. This is sufficient for four rafts or a bridge 490 ft long. The bridge company is subdivided into two platoons, each with half of the total equipment. It is expected that for organizational purposes a platoon's equipment may be further subdivided into two six-unit rafts. It is not planned, at present to equip corps or army units with the MAB.

General use. The US Army regards the MAB purely as an assault bridge or assault raft, and does not expect it to remain in use for extended periods. When the assault phase of a river crossing is over, a conventional-type pontoon bridge will be constructed.

Rafting versus bridging. Though it is perhaps not practicable to quote figures, it is considered that narrow rivers might as well be bridged at once with the MAB. Little advantage can be secured by rafting first in such circumstances. For wide rivers it is thought that the six-unit raft may be one of the most useful versions. This has 132 ft of deck available for loading, without counting the folding portions of the ramps which can also carry light vehicles.

Comparisons

General. With the MAB still in the early stages of its life, it is too early to try to judge it against its elder sisters, the Gillois and the M2. Certain features of the MAB have, however, been seized upon by critics and it may be worth mentioning some of the points which are frequently discussed.

Width. At 12 ft, the MAB is significantly wider on the road than the M2 and the Gillois in their "land rigs", and some doubts have been expressed as to whether the MAB can get to its destination in certain conditions. Against this criticism, it seems fair to point out first that the MAB's cross-country performance is so good that it is by no means road bound; and secondly, that it is no wider than the US Army's main battle tank, the M60.

Propeller position. Propellers on the M2 and Gillois are mounted at the front of the vehicles so that their thrust is available immediately on entry. Some observers believe that the MAB with its propeller at the stern may have difficulty when entering strong currents, since no control is available until the last moment. At present the MAB has not been tested in currents greater than about 4¼ knots, but at that speed no problems have arisen. The units have also been taken in backwards on several occasions with complete success.

Only experience in really severe conditions will indicate whether or not the propeller position is a truly significant factor. It is also worth mentioning that the MAB's propeller is certainly in the best position for the purposes of exit.

Partitioning of the hull. The Gillois has five main compartments, in addition to the two side float tubes, each of which is further subdivided. The M2 has three main compartments, plus two subdivided side pontoons and its four wheel wells. Against these the MAB can muster just one main compartment and the four wheel wells. Again, only experience will show if this is going to be significant. The author would suggest—with due diffidence—that it may well be important; and that it would be possible now to incorporate internal walls across the wheel well "passages", and so convert one compartment to three. The problems involved in producing tight seals around the various drive shafts would seem to be capable of solution.

Conclusion

Although detailed test results remain to be published, it seems safe to say that the MAB represents a most significant addition to the world's slowly growing family of amphibious bridges. Although it has many points in common with the Gillois and M2, the MAB has certain new features, and its performance in the field should be of considerable interest to all the NATO armies.

Acknowledgment

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Table

Mobile Floating Assault Bridge/Ferry Characteristics

Overall length: 42 ft 3½ in
Overall width: 12 ft
Overall height:
 Interior bay: 10 ft 6 in
 End bay: 11 ft 8¾ in
Ground clearance under hull: 1 ft 5 in
Wheel base: 19 ft 6 in
Wheel tread: 7 ft 8 in
Tyres: 16 ply 18.00 × 25

Unladen freeboard
End bay:
 Normal: 2 ft 9 in
 Wells pressurized: 3 ft 3 in
Interior bay:
 Normal: 2 ft 11 in
 Wells pressurized: 3 ft 6 in

Unladen draught
End bay:
 Normal: 2 ft 9 in
 Wells pressurized: 2 ft 3 in
Interior Bay:
 Normal: 2 ft 7 in
 Wells pressurized: 2 ft

Engine
Manufacturer: General Motors
Type: 8-cylinder diesel
Displacement: 567.4 cu in
Compression ratio: 17 : 1
Governed speed: 2,300 rpm
Maximum torque: 860 lb/ft at 1,600 rpm
Fuel capacity: 100 gallons (US)

Gear ratios
1: 4.000 : 1
2: 2.824 : 1
3: 2.000 : 1
4: 1.412 : 1
5: 1.000 : 1
6: .706 : 1
Reverse: 4.769 : 1

Water propulsion
Manufacturer: Steel Products Engineering Co
Type: Model 3000
Rated thrust: 5,000 lb

Turning radii
Front wheel steering: 65 ft
Four wheel steering: 40 ft

Man Management

By COLONEL G. H. PANNETT

THE following is a reprint of a lecture given some time ago to the officers and senior NCOs of 119 Field Engineer Regiment, now 44th Home Counties' Div/Dist RE.

Colonel Pannett wishes to acknowledge that parts of the lecture were taken from the booklet *Talks to Future Officers*, written by Colonel Donald Portway, CBE, TD, DL, JP.

I have been asked to give you a lecture on Man-management. On looking into this subject, I find it a very wide one and extremely difficult to tie down. In the first place, I should like to disagree with the word "man-management" which seems to me a rather sloppy way of talking about the "command of men".

Now the "command of men" I have broken down into four parts:—

(1) Leadership, (2) Morale, (3) Psychology and (4) Discipline.

(1) *Leadership* because no matter how small or large a body of men, there must of necessity be leaders. If the leaders are not chosen by the rest of the body they will assume leadership by one method or another and it is usually those with outstanding qualities, such as ability or personality, who will succeed.

(2) *Morale* because the higher the morale the greater the success, be it an army, the smallest single unit, or a football team.

(3) *Psychology* because in dealing with men it is not only necessary to know a man superficially, but also to know the inner man as it were, the way men think, and what influences their thoughts. In other words trying to put yourself in his place and understand his point of view.

(4) *Discipline* because without discipline nothing can be achieved. In everyday life we must discipline ourselves, for success or failure in life depends on our own self-discipline. We know we have man-made rules to obey but they by themselves are insufficient and the type of discipline I shall refer to is the new kind of positive discipline which a man must be taught when entering a new or strange type of life like army life.

Gentlemen, it is said that to quote from one book is plagiarism and to quote from several is research, and I make no apology for saying that a good deal of research has gone into this lecture. We start with our first sub-heading —Leadership.

The War Office pamphlet *The Conduct of War* defines leadership as the will to dominate together with the character that inspires confidence. Let us consider the will to dominate. The word "dominate" means to rule over, to predominate or to tower above. "To rule over" certainly does not apply to leadership in the Army, although some have the mistaken idea that it does. I believe that "to tower above" does, for nobody can "tower above" another unless he can inspire confidence by setting an example to those he wishes to lead.

It is a mistake to confuse a powerful and rigid machine of discipline with the elusive qualities of leadership. Discipline we must have in all walks of life, but it is of little value in times of strain and worry such as exist in active operations of war when soldiers will only risk their lives when being led by men in whom they have every confidence and who are as brave, if not braver, than themselves.

I do not believe that the powers of leadership are made. They may be improved through experience and training, but the basic ingredients of leadership are born in men and are developed. A classic example of this is the Churchill family, the First Duke of Marlborough and his many victories on the field of battle and his descendants down to our great Winston Churchill.

One of the essential ingredients of leadership is to know the men you command and under the dull and deadening load of army routine it is all too easy to forget that the soldier is intensely human with all the difficulties, worries, joys and sorrows of an individual human being. Very often he is in need of real sympathy and it is the NCO or Officer who shows him this who gets his devotion and, more important, his service. The Duke of Wellington in stating the qualities of a great captain said "One must understand the mechanism and power of the individual soldier". Personal courage is necessary and valuable but by itself utterly inadequate. In discussing Sir John Moore, Wellington said, "He was as brave as his sword, but he did not know what his men could do or not do".

There are, of course, many different types of leaders. Some men are good soldiers on the parade ground, who inspire the utmost confidence during training, but turn out to be very different characters during the stress of battle. One squadron commander I knew during the war had the habit of inspecting his troops on early morning parade in his pyjamas and would make or break an NCO on the spot for the smartness or otherwise of his turnout. This highly irregular conduct would, I am sure, appal most of us; however this officer was twice decorated for bravery and was greatly respected by his men. I do not say that bravery in itself excuses soldiers behaving in a very irregular manner, of course it cannot, but this case does tend to emphasise the many different ways in which leadership develops.

In the manual *Training for War* many requirements for a leader are laid down and one of them says he must be cheerful. This, I believe, is one of the essential parts of leadership. A man with little or no sense or humour cannot possibly aspire to leadership. Good humour is infectious. It runs through people like an electric current and can revive most despondent folk. I remember when 209 Field Company were covering the retreat of the Infantry to Dunkirk and were holding the well-known Flanders Height of "Mont des Cats". We were dug in and being heavily shelled from the enemy position at Cassel. Unfortunately our HQ clerk, a very nice boy from Steyning was hit by shrapnel and paralysed in the legs. He lay on the ground crying, when along came Sergeant Major Wright, a pre-war PSI and said "If you don't stop making that noise I shall hit you over the head with your typewriter". This humorous touch was much appreciated by the wounded soldier who not only stopped crying, but joined in the laughter. Some hours later when we evacuated this position, this sergeant-major carried the boy for over one mile under very heavy shell fire before he came to a main road and was able to place him on a lorry going to Dunkirk. Unfortunately, the lad died and the sergeant-major despite being highly recommended, received only a mention in despatches. Many higher awards than that have been given for much less courage than this warrant officer displayed, but that, unfortunately, is an anomaly of war.

Next to sense of humour is the power to bestow praise at the right moment. I have not seen this mentioned in any of the books which I have read on this subject and yet I believe it is most important. The officer or NCO who takes for granted everything his men do and cannot bring himself to say "Well done" at the right moment, even if inwardly he feels otherwise, cannot be called a leader.

My impression during the war when commanding an independent field company, for over two years, and when I suppose I came into contact with more CsRE than most company commanders, was that most regular COs were blameless in this respect and I held them in very high regard.

Now let us consider for one moment the other part of the dictum—to inspire confidence. Obviously to inspire confidence the leader must have courage, both moral and physical. He must set an example to his subordinates in the way he conducts himself on and off the parade ground, or on the field of battle. We have already discussed some of the physical aspects of courage. What of the moral side? This is a wide subject covering many aspects, but I believe it is best summed up in the motto of one of our most famous public schools—"Manners maketh man". I am sure that if we all practise good manners, not the type of good manners which are turned on for the occasion, and are allowed to drop as soon as the occasion passes, but the good manners which become a part of the individual, then I think that the moral qualities of leadership are very largely attained.

We can, of course, discuss such cases of bad manners or bad leadership as using foul language to troops and ticking men off in front of others, or the most heinous offence of all, deliberately making men look fools. I do not think it is necessary, if you always behave to others as you would have them behave to you, then you will not be found wanting in your moral leadership.

Napoleon, who had a very good opinion of the English soldier, once remarked that with British troops and French officers he could conquer the world. As a British officer I cannot necessarily subscribe to this view, but as NCOs it is up to you to maintain a very fine reputation. I cannot do better than to conclude this part of my lecture by quoting the then CIGS in the first number of *The British Army Journal*. This is what he said, "In the British army there are no good units and no bad units, only good and bad officers and NCOs. They make or break the unit. Today one cannot afford other than good ones. No man can be given a more honourable job than to lead his fellow countrymen in war. We, the Officers and NCOs, owe it to the men we command and to our country that we make ourselves fit to lead the *best soldiers in the world*. That in peace the training we give them is practical, alive and purposeful and that in war our leadership is wise, resolute and unselfish. You all have leadership in you. Develop it by thought, by training and by practice."

In a famous broadcast Winston Churchill said: "It is not material things which make a nation—it is character and leadership".

Now I turn to the second part of my lecture which concerns morale. Professor Bartlett in the "Psychology of a Soldier" defines morale as follows: "Obedience to authority under external circumstances which impose great strain, the source of authority being within the man that is obedient". In other words the man recognizes within himself the necessity for that obedience.

Morale produces a steadier and more persistent conduct than discipline.

Discipline may break down when punishment is relaxed, when a leader is killed or the external symptoms of authority degraded. Morale depends on none of these things and so may continue when all external sources of command have broken down.

The main secret of a thoroughly sound man, of a cohesive and powerful group, depends upon the development of morale. How can this best be done? Of all the forces that influence the battle spirit of a soldier, his morale is most important. It is, therefore, the first task of every commander, whatever his rank, to ensure that the morale of his troops is high. Morale is a state of mind, it is an intangible force which moves men to courage and endurance in the face of hardship, fatigue and danger, and it makes each individual in the group, without counting the cost to himself, give his last ounce to achieve the common purpose. It makes him feel that he is a part of something greater than himself.

If morale is to be created or revived, still more if it is to be maintained over a long period, and the essence of morale is that it is maintained, it must be based on certain firm foundations. These foundations are spiritual, intellectual and material in that order of importance. Spiritual first, because only spiritual foundations can stand real strain. Religion is and has always been the greatest foundation of morale, especially of military morale, yet the spiritual basis of morale is not so much religion in the strict acceptance of the word, as belief in a cause. The soldier must believe that the cause for which he fights is worthy of the sacrifice he is called upon to make and here, Gentlemen, I quote Oliver Cromwell, who was one of the greatest leaders of men in the history of this country, he said: "I will have men of conscience, who know the cause for which they fight and love the things they know." Nor is it enough to have a worthy cause. Morale must be positively agressive and not merely defensive and "anti-something". It must be a crusading fervour, not so much to defend as to destroy, to smash the enemy forces as something evil. It must too, be part of the spiritual foundation of morale that every man in the army, no matter what his task or location, feels that what he is or what he does really matters and that it has a direct bearing on the result of the campaign. He must feel that the honour of his regiment or unit, its great traditions, are in his hands to maintain or mar. Thus he will gain self-respect, develop a sense of comradeship and welcome discipline.

Men are swayed by reason as well as by emotion, morale must, therefore, have its intellectual foundations. First, the soldier must believe that the job he aims at is not out of reach but is attainable. He must be confident that the organization to which he belongs, his army, his division, his unit, is efficient. Above all, he must have confidence in his leaders. By every means in his power, the commander must gain and keep this confidence, not only by his decisiveness in action and his calmness in crisis, but also by allotting tasks in the battle to his troops, within their capabilities, and thus building up a tradition of success. This Montgomery practised to the nth degree in the last war.

The highest kind of morale is often met when material conditions are at their worst and yet the material foundations of morale are important and no commander may neglect them. Good administration will ensure a reasonable amount of leisure and comfort to troops not actually engaged in operations and the highest possible standard of feeding and supply when in battle. The rapid evacuation of casualties to a well equipped hospital, good mail facilities however remote the theatre and all measures to keep the soldier in touch with his home life help to raise morale.

Morale in modern war depends increasingly on equipment, especially upon weapons, yet all soldiers must anticipate at times to find themselves at a disadvantage in this respect, either compared with the enemy or against conditions of climate and terrain. The effect of this on morale can be minimized if the troops can be convinced that the shortages are realized by their commanders and that everything possible is being done by everyone concerned to redress the balance.

Man is still the first weapon of war and the morale of the soldier is the most important single factor in the war. If commanders, by their own example and influence build the morale of their men on these foundations, spiritual, intellectual and material, it will endure.

Throughout history wise commanders have realized the importance of morale. Napoleon laid down the ratio of morale to the physical as 3–1 and although conditions of war have changed, this is still a fair assessment. During the Crimean War the Earl of Cardigan commanding the First Light Brigade had his yacht sailed from England to Balaclava Harbour where he slept each night and had his food cooked by a French chef, and mounted his charger each morning and rode off to join his troops. This kind of conduct was accepted in those days or, shall we say endured, but would not be tolerated today. Tennyson's famous poem describing the Charge of the Light Brigade included these words, "Theirs not to reason why, theirs but to do and die". But soldiers in the modern army do reason why and would not be very impressed if officers behaved as this Earl did. In fairness, however, to his Lordship it must be noted that when he received orders to make a frontal attack on the Russian gun positions with his Light Cavalry Brigade, an order which was against all the principals of Cavalry warfare, he did not hesitate and was in the van of attack until the positions were overrun and even went on to attack the reserve positions.

During the wars of George III against the Americans for the British possessions there, the Americans called the British "bloody backs" or "lobsters", because of their frequent floggings and I do not think modern soldiery would take kindly to that type of treatment.

Morale is an essential factor and must be maintained at all costs and if, as Officers and NCOs we aspire to lead the best soldiers in the world, this is one of the tasks which must always be uppermost in our thoughts. I will not go into the details of example, bearing and looking after the comforts of the troops such as food, recreation, mail from home, giving men the opportunity of discussing private affairs with his OC or CO or the Chaplain. All these points and many others affect morale and we as leaders must always be mindful of them.

Now, Gentlemen, for the third part of "The Command of Men" as I see it—psychology.

I have included this heading, not because I think everyone who has dealings with men should be trained psychologists, of course I don't, but I do believe that most people who wield authority, be it over men or children, should stop to think, if either digress from normal everyday rules of life, or if the soldier strays from the rules peculiar to the army, why they have done so, for to know the reason why people misbehave themselves is often a long way towards correcting them.

Psychology, of course, ranges far beyond the bounds of discipline, and so far as the army is concerned, studies the reactions of soldiers under training, and in war conditions, and in particular tries to determine how men behave under the stress of battle. It is the result of these studies which guide our training for the future and although perhaps subconsciously, guide the Officers and NCOs in their dealings with their men. To put its imply, psychology is the study of different individuals' reactions to various situations.

In the First War many casualties were suffered from what was called "shell shock" and many thousands of men were crowded into hospitals with this complaint. Most of them no doubt thought that they were genuinely hurt, although no doubt too, many malingerers crept in with them. The Medicos also thought it was a genuine complaint, but during the years between the wars research into the subject discovered that shell shock was not a complaint at all. It was more like hysteria which could be corrected by a firm action, and although at the time this seemed rather harsh treatment, no doubt it was right. Some of you might have had experience or a mild form of hysteria when a person seems to lose all sense of proportion or sane thinking and breaks down and cries bitterly, or laughs continuously. One approach to this type of breakdown is one or two hard slaps on the face and the hysteria is overcome fairly promptly. Although I do not say that similar treatment was applied to shell shock, but I do know that it was not recognized in the last war as a genuine complaint and as a result it was rarely heard of.

I have already told you of the "bloody backs" of George III's Army in America, caused through flogging. Such a blind approach to discipline was common in those days, when for any offence there was only one kind of treatment, but we have moved a long way along the road of understanding humanity since then and much of that understanding has been due to the study of psychology.

Such an approach must, however, be tempered with common sense for there is always the type of individual who is prepared to sit back and be psychoanalyzed with his tongue in his cheek and thereby escape much of the unpleasant part of a war or any other grim situation, but I am afraid these types are always bound to get through although, I trust, in small numbers.

I am not going to elaborate on this subject for it is a very specialized one and much above the head of the ordinary soldier. Suffice I think it is to say that soldiers like everyone else are human beings and, like all human beings, each one differs in outlook and in make-up and therefore in your dealings with soldiers bear these points in mind and remember that what is good for one individual might be quite the reverse for another.

Now for the last part of my lecture—discipline.

"Training for War" says, "Discipline is the basis of all military effort and the highest standard is needed to stand the test of war. The leader must discipline himself before he can expect a high standard of discipline in all those under his command".

Discipline is the means by which the other qualities of courage, endurance, alertness and comradeship can be rolled in together and converted from civilian virtues into a definite military asset. Without discipline men remain civilians in uniform. They may be high class civilians, but they are still civilians.

Discipline in men must be based on confidence, confidence in his leaders, in his fellows and in his weapons, and in himself. The greater the confidence the higher will be the morale. Discipline can be instilled into a soldier by the example of his superior officers, fear of punishment, drill and environment.

The example of his superior officers is a most important part of discipline and that is why NCOs and officers should be sure that their treatment and attitude towards superior officers at whatever level is beyond reproach. Somebody once wrote, "In an organization of which one is officially superior to another, the superior (if he is a gentleman) will never think of it, and the other (if he is a gentleman) will never forget it."

Saluting is another acknowledgement of discipline and it is to be noted that all successful armies are very keen on this. The Russian Army is very strict on saluting, and there one might have thought that such a rule would be relaxed, but it is not so and they obviously realize the value of saluting to discipline.

Saluting is a visible sign of the common loyalty and obedience that we all owe to the Queen. It is said to date from the days of armour, the salute representing the motions of a Knight raising the visor of his helmet with his open hand to the front showing that, although raised it contained no missile. Whether that is true or not, the salute is the mark of a free man and not a gesture of servility as some would have us believe. Units are judged by senior officers and members of other regiments by the standard of saluting just as people in civil life are judged by their behaviour and good manners. Experience over many years has shown that slackness in such matters as saluting and turn out, quickly leads to the deterioration of discipline and was certainly shown by France in 1940.

Fear of punishment is a negative approach to discipline whereas we should try to be positive in such matters, but punishment we must have, whether in the army or in civilian life. I am not going to consider major crimes but I would like to say a word or two on petty offences.

I always feel that as far as possible the punishment for small offences should be made to fit the crime. A soldier with a dirty rifle on parade, instead of being given three or four days CB should be made to bring his rifle spotlessly cleaned to the squadron sergeant-major for three or four days running. This has two effects. It soon teaches the man that to have a dirty rifle on parade does not pay, and in addition, does not start a chap off with an entry on his crime sheet which is psychologically bad, and I was always very reluctant to do this during my regular army service in the war. I am very surprised to see even to this day that some young soldiers have such entries on their conduct sheet as "one day CB". This I feel is no way to command men and is a great mistake for it gets the chap off on quite the wrong foot and may warp his outlook to army discipline for a long time.

Discipline in its true sense is the training of the mental, moral and physical powers, by exercise and instruction, and that is why one of the best methods of achieving the foundations of discipline is drill. It is the first experience a recruit gets of working in a controlled body under the command of one man, and of giving immediate obedience to that one man. It is comparatively easy to teach the elements of drill, thereby enabling a man to aim at perfection quite early in training, but drill must not be allowed to become boring or it would do more harm than good. Drill should be taught in short snappy periods under a good instructor. Drill by itself, however, is not enough to teach modern discipline because it makes all the men do the same thing at the same time, whereas in the modern army men are often doing different things at the same time. This particularly applies to ourselves, especially in bridge building and even in field works such as this, we see the basic drill training being used to great advantage, particularly when heavy loads are being lifted and carried.

On *environment* I can say little except that providing in your unit a good example is set by all Officers and NCOs in turn-out and behaviour, your drill is of a high standard and your saluting beyond criticism, then the environment will be right and your discipline will be right and your unit first class and your right to command *the best soldiers in the world* undoubted.

New Silver Centrepiece for RE Cyprus

(ΑΦΡΟΔΙΤΗ)

By Captain C. Spottiswoode, RE

In October 1962 the following RE units in Cyprus were co-ordinated and collected under the banner of a newly formed Headquarters Royal Engineers Cyprus:—

33 Field Sqn RE
Cyprus Park Sqn RE
Cyprus Port Unit RE (incl 471 Lighterage Tp)
Movement Control Section RE Famagusta
HQ Armed Forces Courier and Postal Services
275 Courier & Postal Unit RE

Integral with this reorganization was the formation of a new RE Cyprus Officers' Mess which took over from the old 33 Independent Field Squadron RE Officers' Mess. Part of this handover was a project under way for a silver centrepiece.

Negotiations had begun with a well known firm of Silversmiths for the centrepiece, but difficulties had arisen over the design of the chosen object—the Goddess of Love Aphrodite who, according to Greek legend, had risen from the waves off the coast of Cyprus at Paphos. The officers had preconceived ideas about their Goddess and the first design met with a mixed reception. Under the new management it was decided that several firms should be approached with a rather more exact design specification. The well-known Botticelli painting of "The Birth of Venus" was chosen as being an excellent basis for design, and from three firms who forwarded drawings one was chosen by the Corps Committee as being the most acceptable in price and design.

The total cost of the piece, including engraving, came to £290 of which the Corps Committee very generously gave £250, the rest being found from Mess funds and donations.

Inscriptions on the plinth read:—

Front central panel: (The Corps Monogram)
To Commemorate the Service
of the
Royal Engineers in Cyprus
since 1876

Side: Bought in 1963 by the Officers
of the
Royal Engineers in CYPRUS
with the generous help of
The Royal Engineers Corps Committee

Side: After "The Birth of Venus" by Botticelli

The height of the silver figure is 8 inches.

No function of the RE Cyprus Officers' Mess is now complete without the

New Silver Centrepiece For RE Cyprus

Royal Engineers and the George Medal

This article and its list of RE recipients of the George Medal was compiled by the Royal Engineers Historical Society.

THE heavy attacks by the German Air Force in 1940 on the cities, ports, and towns of Great Britain demanded from civilians and servicemen alike a high standard of morale and personal courage. Acts of great gallantry were performed by day and night in an all-out effort to save life and reduce the destruction of factories, shops, and private property. In order officially to recognize and reward those who risked their lives in carrying out these duties King George VI instituted the George Cross and the George Medal on 24 September 1940, and in a broadcast on that day to Britain and the Empire said: "Many and glorious are the deeds of gallantry done during these perilous but famous days. In order that they should be worthily and promptly recognized I have decided to create at once a new mark of honour for men and women alike of all walks of life. I propose to give my name to this new distinction, which will consist of the George Cross, which will rank next to the Victoria Cross, and the George Medal for wider distribution".

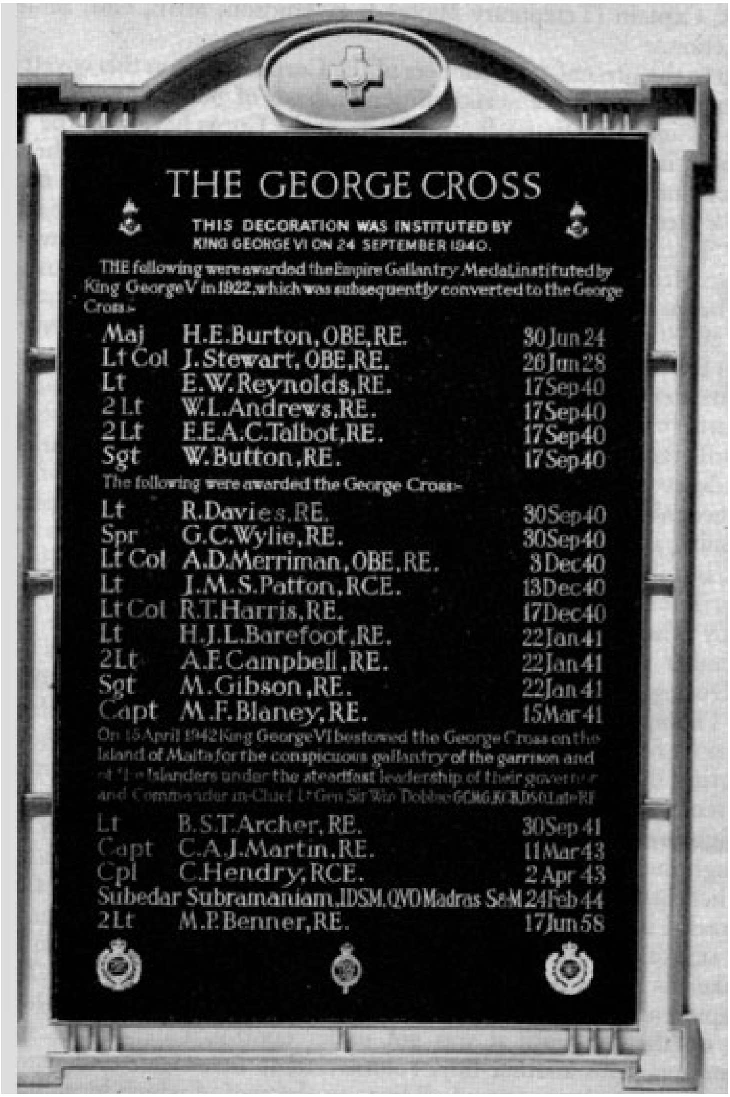
The George Cross was intended primarily as an award for civilians for acts of outstanding heroism and most conspicuous courage in circumstances of extreme danger; it was, however, also awarded to members of the Fighting Services for acts of the greatest heroism for which purely Military Honours are not normally granted.

Prior to 24 September 1940 the only award comparable to the George Cross was the Empire Gallantry Medal. With the institution of the George Cross the award of Empire Gallantry Medals ceased and holders of the Medal, whose number included five Royal Engineer officers and one sergeant, had their awards converted to the George Cross. Since then eleven officers and men of the Corps have won this coveted "mark of honour", and this number exceeds by far the awards made to any other Corps. In tribute to their gallantry their names have been inscribed on a George Cross board which is proudly displayed at the head of the stairs leading to the gallery of the RE Museum, Chatham. When the new, revised short history of the Corps is published in the near future it will contain a complete record of the acts of gallantry which resulted in the awards of the George Cross to members of the Corps.

The conditions of eligibility prescribed by the Royal Warrant for the George Medal were almost the same as those for the George Cross, the distinction being that the Medal was to be awarded in cases not considered equal to the degree of bravery and risk meriting the award of the George Cross.

The George Medal is circular and of silver, 1·42-in in diameter. It is ring-mounted, provided with an ornate claw, and suspended from a 1·25-in wide riband coloured with six red and five medium blue stripes. On the obverse is the crowned effigy of the Sovereign with the legend GEORGIVIS VI DG BR OMN REX ET INDIAE IMP. The reverse shows, in relief, St George on horseback slaying the Dragon on the coast of England, and is inscribed THE GEORGE MEDAL. Naming is impressed on the edge.

RE and the George Medal



RE and the George Cross Decoration

The Medal was designed by Mr Stephen Gooden, ARA, as a bookplate for the Royal Library, Windsor Castle, then modelled and adapted by Mr George Kruger Gray, OBE, ARCA, FSA. Two Medals have been struck, the George VI Medal, that bears the effigy of His Majesty, and the Elizabeth II Medal bearing the effigy of Her Majesty.

Bars are awarded for subsequent acts of bravery and one member of the Corps, Captain (Temporary Major) J. P. Hudson, MBE, GM, achieved this distinction.

Up to the present 127 members of the Corps have won this coveted award, and most of these were in recognition of deeds of gallantry performed during 1940–5. Since that time a few members of the Corps have won the Medal for gallantry in the United Kingdom and in Cyprus. Owing to the need for secrecy during the Second World War the citations published in the *London Gazette* were normally short, undetailed statements that merely announced that "The King had been graciously pleased to approve the award of the George Medal for conspicuous gallantry in carrying out hazardous work in a very brave manner", followed by the name or names of recipients. In some cases the statement included a brief reference to the field of operations, such as "in the Middle East". A few rare cases gave a detail of the act of gallantry, the citation for Captain (Temporary Major) J. E. Dale, RE, as published on 8 February 1945, is typical of these. This example, however, together with the full citations given for awards made since 1947 illustrate clearly the very high degree of personal bravery that was expected. In the case of the Corps the recognized acts were chiefly done in the field of bomb disposal or the disarming and removal of live ammunition which threatened lives or installations, but there were exceptions and the gallant acts of 1878304, Boy Melville Searle Thompson, RE, and Major B. J. Coombe, RE, are typical of these.

Boy Thompson won his award for acts of gallantry on the 23 and 30 November 1940, and his hitherto unpublished citation reads as follows:—

"During an enemy air attack on Southampton on 23rd November, 1940, Boy Thompson was assisting a Sapper as lookout on a high building in the Ordnance Survey offices. He remained on duty throughout the raid, accurately reporting the fall of high explosive and incendiary bombs. When the attack was renewed on the 30th November, Boy Thompson was a member of the fire-fighting party under Captain Keleher. When an incendiary bomb fell through the roof of a map store and fired large piles of maps inside, Captain Keleher broke into the room, which was full of smoke and fumes, and succeeded in playing on the fire with a hose. After a time he was overcome with smoke and fumes and had to withdraw. Two other men then attempted to take his place, but both were beaten back. Thereupon Boy Thompson, wrapping a wet cloth round his face, went in and succeeded in holding the hose on the fire until it was got under control. Later in the night, Boy Thompson, with another boy, volunteered to investigate and report on the state of a large three-storey building, on the roof of which incendiary bombs had fallen. He forced his way into an attic which was found to be ablaze, and made an accurate report to his superior officer. Though only 17 years of age, Boy Thompson throughout the night showed remarkable initiative as well as great devotion to duty and complete disregard of danger.

All the above actions were carried out during a heavy bombardment with high explosive and incendiary bombs falling on an enclosure closely packed with large buildings, six of which were ablaze."

ROYAL ENGINEER RECIPIENTS OF THE GEORGE MEDAL

(As at 31 August 1964)

Name	*London Gazette Supplement*
Capt Geoffrey Lewis Galloway Lieut Eric Russell Raby 2nd Lieut (A/Capt) Harry Mitchell 2nd Lieut Francis Robert Martin (since deceased) 2nd Lieut Harold Alfred Manser (since deceased) 145307 Sgt Sidney Ernest James Thorne 1924892 Sgt William Arthur Jones 2968034 Cpl William Owen Bean 2006164 Spr Stanley Chesher	17 December 1940
Lieut (T/Capt) John Richard Filgate McCartney Lieut (T/Capt) Alfred John Biggs Lieut Kenneth Dickinson Lieut Douglas Stanley Frederick Rayner Lieut Evlyn Jolliffe Halstead-Hanby 2nd Lieut James Barnes 2nd Lieut Ralph Henry Lee 2067513 Sgt Charles Morris Cann 1883537 A/Sgt John Sidney Jelley 2021663 L/Sgt John Henry Hinton 1986577 A/Cpl Bertie McIntyre Lawson	22 January 1941
Lieut (T/Capt) Jack Keleher Lieut Daniel Hunter Ramage 2nd Lieut (A/Lieut) Clifford Henry Green 2nd Lieut Charles Russell Wood 2nd Lieut James Ford 1903322 Spr Joseph Williams 1880745 Spr John William Carter 1878304 Boy Melville Searle Thompson	11 March 1941
1871236 L/Sgt Reginald Charles Mons Parker 1984892 Driver (I.C.) Charles Michael Mitchell	27 May 1941
2075187 L/Sgt Harry Fred Hardy Capt (T/Major) Arthur Henry Musgrave Morris, MC Lieut Brian Leolin Richards	8 July 1941
2nd Lieut Fred Milnes 2nd Lieut (A/Lieut) Frederick Radford Lieut (T/Capt) Clifford Percy Shelbourne Lieut Louis Norwell Taylor	22 July 1941

Lieut (T/Capt) Alexander George Bainbridge 2nd Lieut (A/Lieut) Frank Herbert Butler Lieut (T/Capt) William Arthur Dixon, MC Lieut (T/Capt) Samuel Garside 2nd Lieut (A/Lieut) Lewis Gerhold 2nd Lieut (A/Capt) Henry Arthur Grover 1880443 Cpl William Hone 2217011 Sgt Edward Laing Lieut (T/Capt) Charles William Lea Lieut Lionel Charles Meynell 2074517 Cpl (A/L/Sgt) Andrew Saunders Lieut (T/Capt) Thomas Henry Sharman Lieut (T/Capt) Charles Coulton Stewart 1883145 Spr (A/L/Cpl) Ernest Wilfrid Suttle	30 September 1941
2068288 CQMS Peter Neville Denison 4967723 Sgt (A/CSM) Francis Smith	21 October 1941
1888309 Cpl (A/Sgt) Robert John Chester 2nd Lieut (A/Lieut) Charles Ernest Davies Lieut William Anderson Feather Lieut Brompton Hacker Philip Price 2nd Lieut (A/Lieut) John Percy Walton 2326064 Sgt Thomas James Williams	28 October 1941
Capt T. L. V. Brown	January 1942
13005511 Cpl Charles Frederick Bristow Lieut Michael Arthur Clinton Lieut Thomas James Deane Lieut (T/Capt) Donald Alfred Wilkinson	17 February 1942
1864311 Sgt Thomas Taylor	10 March 1942
2nd Lieut (A/Lieut) Reginald James Broadbridge Maitland 2nd Lieut (A/Lieut) Clive Nevil Hewitt 1895955 Sgt Gordon Harold Quarendon 2205689 Sgt George Anderson Wardrope	24 March 1942
2090980 Spr (A/L/Cpl) Terry George Hicks 2nd Lieut David Alexander Methven	10 July 1942
Lieut (A/Capt) James Boyd Smith	4 August 1942
2035313 L/Sgt John Hillis	9 September 1942
2112009 Spr George Cyril Hasley	18 February 1943
Lieut Ralph Willis Deans	11 March 1943

1987012 L/Cpl John Arthur Fenner	20 April 1943
Capt (T/Major) John Pilkington Hudson, MBE	
Lieut (T/Capt) Leslie Thomas Starr, MBE	9 July 1943
Lieut (A/Capt) John Stanley Bartholomew	30 November 1943
1856619 WOII (CSM) Frank Henry Harris	3 December 1943
1868224 Spr John Buckley	6 January 1944
6004651 WOII (CSM) Leonard James King	11 January 1944
2126849 Cpl (A/Sgt) William Henry Bailey	10 March 1944
Lieut John Havelock Gray	
Capt (T/Major) Henry Kenneth Roseveare	17 March 1944
1898514 Spr Ivor George Robins	23 March 1944
2014046 Cpl Arthur Phillip French	27 April 1944
Lieut James Girton Allen	5 May 1944
Lieut Kenneth Lanhain	
Lieut Kenneth Hugh Robinson	28 July 1944
Lieut John Warren	25 August 1944
Capt (T/Major) John Pilkington Hudson, MBE, GM (Bar to GM)	15 September 1944
1990980 Sgt John Brabin	
Lieut Patrick Adair Canning	
Lieut Warner Charles Swinson	
1910603 Sgt (A/WOII-QMS) John Albert Billing	10 November 1944
Lieut Ernest Thomas John Fairbrother	
Lieut (T/Capt) Alwyn Brunow Waters, MBE	
Lieut (T/Capt) Richard Frederick Festubert Williams	
Lieut (T/Capt) Arthur Graham Burdett	1 December 1944
1885636 Cpl Frederick John Jackson	
551064 Spr Thomas Wilson	15 December 1944
Lieut Philip Richard Hennings	2 February 1945
Lieut Eric Wilfrid Sivil	
Lieut Ronald George Walker	
2191812 L/Sgt Frederick White	

Capt (T/Major) John Edward Dale (See citation at the end of article)	8 February 1945
Lieut George Henry Galor 1893345 Driver Wilfred Reece	2 February 1945
Lieut Robert Alfred John Woods	24 August 1945
Lieut Lionel Haydn Morgan Capt (T/Major) William Gregg Parker, MBE	5 October 1945
Lieut Philip Arthur Bays	19 October 1945
892090 Sgt William Taylor Dalgarno 1877511 Sgt Frederick Charles Hodgson 2002278 Sgt Charles McGee 4208733 Spr Thomas Lawford Walker	9 November 1945
Lieut William Sangster Borthwick	28 December 1945
Lieut (T/Capt) John Ernest Arthur Deacon 1895857 Sgt Alfred Parker	25 January 1946
Lieut Walter Messer Brown 1913900 Sgt John Hodgson Lieut (T/Capt) William Wills Kirby	15 March 1946
Capt Harold Briggs	9 July 1946
Capt Godfrey Vernon Bird	5 December 1946
Capt Richard Hedley Hough	3 November 1953
Major Brian Jackson Combe (See citation at end of article)	23 December 1955
Major Arthur Bamford Hartley, MBE (See citation at end of article)	25 March 1960

Typical Citations

"London Gazette" Supplement, 8 February 1945

The King has been graciously pleased to approve the award of The George Medal, in recognition of conspicuous gallantry after an explosion following an outbreak of fire at the Bombay Docks in April, 1944 to:—

Captain (T/Major) John Edward Dale, Corps of Royal Engineers

"As a result of an explosion the complete stern of a ship was blown into a main road in the docks area and fell against a building which was already on fire. This pile of steel, weighing about 20 tons, contained the ship's magazine with live shells and ammunition inside.

It became urgently necessary to remove the shells to make the road safe for traffic and this officer working with an oxy-acetylene cutter successfully accomplished this hazardous task, although several shells exploded within a few feet of him and the whole magazine might have exploded at any time from the heat of the fire underneath.

The work continued for eight days under exceedingly dangerous and adverse conditions and throughout the operation this officer's coolness, courage, and devotion to duty were outstanding."

"*London Gazette*" *Supplement, 3 November 1953*

The QUEEN has been graciously pleased to approve the following award:—

Captain Richard Hedley Hough, Corps of Royal Engineers

"On 6th May 1953, Captain Hough was acting as Officer Commanding No. 1 Bomb Disposal Troop, Royal Engineers, which was clearing Mundesly Minefield, Norfolk, when a Beach Mine containing 25 lbs of High Explosive exploded, killing Sergeant O'Doherty and Corporal Braddock.

Realising an accident had occurred Captain Hough ran to the scene and seeing Corporal Braddock's body about 25 yards inside the Minefield where it had been thrown by the explosion, he immediately crawled to the body through the Minefield, to see if he could render aid. Finding Corporal Braddock was dead, he withdrew again by crawling until he reached the swept lane. After informing his Commanding Officer by telephone, he swept his way in and recovered the body. Captain Hough was accompanied throughout by Sergeant-Major Thomas, the Sergeant-Major in charge of the Minefield. Sergeant O'Doherty's body was blown into the sea and recovered on the beach at the next high tide.

Captain Hough was of course aware that the Mines in the particular Minefield were of a type and in a state which made them liable to be set off at very low pressures. Furthermore, at this part of the Minefield, they were for the most part laid comparatively close together.

Captain Hough's action in crawling through the Minefield was correct and courageous as time was vital if aid was to be of any use. It was also an inspiration to his men, at a time their morale most required it. Throughout he showed presence of mind, leadership of a high order and courage."

"*London Gazette*" *Supplement, 23 December 1955*

The QUEEN has been graciously pleased to approve the award of the George Medal in recognition of gallant and distinguished service in Cyprus to:—

Major Brian Jackson Coombe, Corps of Royal Engineers

"On 15th December, 1955, Major Coombe was ambushed while driving on duty in Cyprus. His only escort was mortally wounded. Armed with a sten machine carbine he took immediate offensive action on foot across country under grenade and intensive automatic fire. With utter disregard to his own safety he carefully selected a position from which he could accurately locate and bring fire to bear upon the terrorists, three of whom he now saw firmly established 30 yards away. A fourth terrorist opened automatic fire on Coombe from a separate position on the flank. Although outnumbered four to one he continued to fire his sten until his ammunition was exhausted. Having returned to the vehicle to get the escort's sten he resumed his position. After a further exchange of fire, during which Coombe came under heavy fire from the fourth terrorist, he put two of the party of three assailants out of action. He then directed a further burst of fire on the fourth terrorist. His ammunition being by now again exhausted he drew his pistol and covered his opponents for thirty minutes. The fourth terrorist endeavoured to escape but Coombe wounded him at a range of seventy yards with his last three rounds of pistol ammunition though he was unable to capture him. When assistance arrived some seventy-five minutes after the action began Major Coombe had, single handed, killed one terrorist, wounded two and captured one. He displayed courage and initiative of the very highest order pressing home his attack against prepared positions at only forty yards range."

"*London Gazette*" *Supplement, 25 March 1960*

The QUEEN has been graciously pleased to approve the award of The George Medal in recognition of gallant conduct to:—

Major Arthur Bamford Hartley, MBE, Corps of Royal Engineers

"At 4.30 pm on the 1st July, 1959, Major Hartley identified an unexploded 250 Kg bomb which has been found in a sewer in Putney.

The particular danger of the fuze which the bomb was likely to contain is that it is unpredictable, has usually stopped within a few ticks of firing and is liable to be re-started by any small movement or vibration. It does not deteriorate after years in the ground and is fitted with a booby-trap to prevent withdrawal.

Major Hartley applied an electric stethoscope to give warning if ticking should start. After careful digging round the bomb he discovered at 9.15 pm. that it contained not one but two clockwork fuzes.

The bomb was lying awkwardly with the fuzes underneath it. At 10.30 pm a start was made to move the bomb but this resulted in the blocked sewer releasing its contents into the shaft. From then on Major Hartley was severely hampered by the stench and fumes in the dark airless space at the bottom of the small shaft. Work continued knee-deep in sewage. Passing a sling around the bomb and lifting it clear of the sewage he applied heavy clock stoppers to replace the light stoppers which had come off due to the exhaustion of their batteries. At one o'clock in the morning he was able to start steaming out the explosive filling. This was completed after two hours. At 5 am he detonated the fuzes in their pockets in the bomb casing, after the police had warned the public of the impending explosion.

Major Hartley's courage and determination during many hours of difficult work in appalling conditions was an inspiration to the public, to the police and to his own men."

FOOTNOTE

The Curator of the Royal Engineers Museum in Brompton Barracks, Chatham, is anxious to display a George Medal that was awarded to an ex-Member of the Corps; and Lieut-Colonel H. S. Francis, OBE, would be grateful if any reader could obtain a George Medal for this purpose, or give information that might lead to its acquisition.

Correspondence

Engineer Branch,
Headquarters,
British Army of the Rhine.
British Forces Post Office 40
16 September 1964

The Editor,
RE Journal.

ST MARTINS CHURCH, LONGMOOR CAMP

Dear Sir,

I was interested to read in the September *Journal* the brief report by Major Williams on the dedication service at St Martin's Garrison Church, Longmoor Camp, and see from the photograph that the refurbishing was a success. However, I would appreciate it if the record could be set right in respect of the design.

The designs were in fact prepared as a minor service in the offices of the Command Works Officer at HQ Southern Command, by a team of Sappers, both serving and retired. The architectural aspects of the refurbishing were designed by Major (retd) Percy Haine, MBE, ARIBA, for many years the Command Architect, assisted by Captain (retd) Charles O'Farrell, ARIBA. The lighting was my responsibility as the M & E Planning Engineer and the drawings were prepared by Mr Arthur Ibbit, who served at Longmoor in the early days of the war.

The design of church lighting does not often come the way of Sapper officers and a few details might be of interest to others. The object aimed at was a standard of lighting in the nave to facilitate the reading of small print without eye strain, a higher intensity in the chancel, leading to a very high intensity in the sanctuary so that the eye was naturally drawn to the altar. Various problems had to be overcome.

Firstly we were asked to eliminate shadow in the sanctuary and to illuminate the beautifully painted reredos to the best advantage. As the wings of the reredos were angled the elimination of shadow presented a minor problem because the main lighting was by flood lights. Secondly, the view of the reredos had to be uninterrupted from the nave as far as possible, which ruled out pendant fittings in the chancel. Ceiling fittings were considered but ruled out because of the glare from the high intensity lights necessary. Transparent ceiling panels were also considered but ruled out because of cleaning problem. The "eggcrate" ceiling with fluorescent tubes above it was the solution.

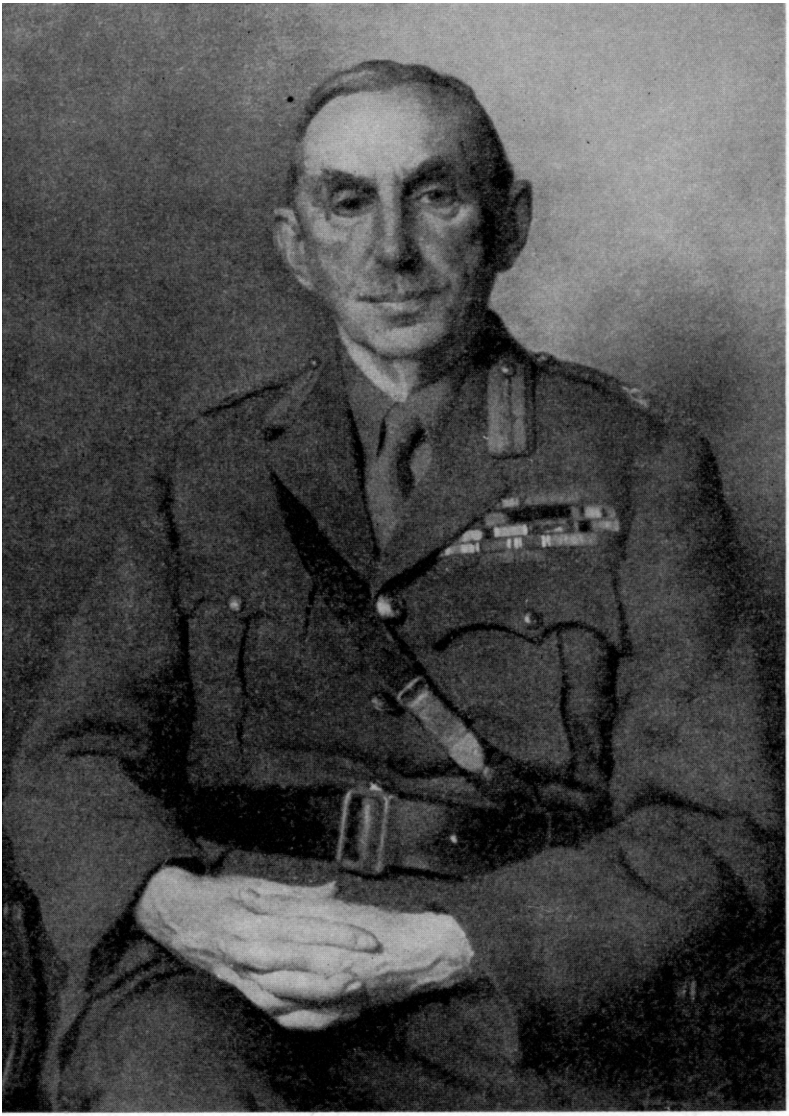
To assist concentration on the preacher during the sermon a spotlight, previously in the sanctuary, was to be positioned to shine on the pulpit. (This appears to be incorrectly adjusted in the photograph.)

The idea of using something connected with the locality was suggested to me after visiting a rural church in Sweden where the fittings were shaped like cow bells. We wanted the lamps mounted on a ring and the locomotive driving wheel was ideal. We could not afford to have fittings especially made as the cost had to be kept within the AWO's powers of approval, so the training centre was asked to produce the fitting to our design. It was in any case appropriate for the centre to produce the fitting for its Church.

I had hoped to see the work carried out, especially as the lighting was unusual and might have required modification to achieve the desired effect, but I was posted before the work commenced. I trust that it really is a success.

I apologise for writing at length on this subject, but as I said before, modern church lighting does not often come the way of serving Sappers.

Yours faithfully,
J. C. COURT, Lieut-Colonel, RE



From a portrait by Sir James Green, RA, in REHQ Mess

Lieut General Sir William Dobbie GCMG KCB DSO LLD
Colonel Commandant RE

Memoirs

LIEUT-GENERAL SIR WILLIAM DOBBIE, GCMG, KCB, DSO, LLD
Colonel Commandant RE (retd)

The following tribute was published in *The Times* of 5 October.

Lieut-General Sir William Dobbie, GCMG, KCB, DSO, who became famous in the Second World War when he was Governor and Commander-in-Chief of Malta during the historic siege from 1940 to 1942, died at his London home on Saturday night, 3 October 1964. He was 85. Before the war he had had a distinguished career in the Army, and had been Commandant of the School (now Royal School) of Military Engineering Chatham, and Commander-in-Chief in Malaya.

William George Shedden Dobbie was born at Madras on July 12 1879, the son of W. H. Dobbie, CIE, an Indian civil servant who became Accountant-General of the Madras Presidency. He was educated at Charterhouse, where he was a classical scholar, and the Royal Military Academy, Woolwich, from where he was commissioned in the Royal Engineers in August 1899. During the latter part of the South African War he saw service in the Transvaal and the Orange River Colony. In 1913 he graduated from the Staff College, Camberley, and at the outbreak of the 1914–18 War he went to France as adjutant to the CRE of the 4th Division and took part in the retreat to the Marne and the subsequent advance to the Aisne. His later service in the 1914–18 War was entirely on the staff, at Divisional, Corps and Army Headquarters, and finally, in 1918, he became GSO 1st Grade in the Operations Section at GHQ. As a member of Earl Haig's staff he signed the order which brought hostilities to a close in 1918. He was awarded the DSO, created CMG, and was mentioned five times in dispatches, and received the Legion of Honour.

For the ten years following the war, except for one year with his Corps, Dobbie continued to serve on the General Staff in the Rhine Army, at Aldershot, in the War Office and in Western Command. Then in 1928 he was given command of the Cairo Brigade, a post which he held for four years. While he was in Cairo in 1929 he was called upon to deal with a serious outbreak of racial and religious hostility between the Jews and Arabs in Palestine, arising from the question of access to the Wailing Wall in Jerusalem. Riots and disorders spread all over the country, but Dobbie, acting with great energy and promptitude, surrounded hostile villages and arrested the ringleaders, and soon restored order by vigorous offensive measures. In recognition of his services he was created CB.

His next appointment, on promotion to Major General in 1932, was as GOC Chatham Area, Commandant the School of Military Engineering and Inspector RE. After three years in this post he was made GOC, Malaya at a time when the development of the Singapore base was increasing the importance of the Malayan Command. This was his last employment on the active list, and when it came to an end in August 1939, he was retired from the Army under the age rule.

It was particularly galling to be put on the shelf at the outbreak of war, and for a long time his offers to serve in any capacity went unanswered. Then one day in April, 1940, he was lunching in the United Service Club in London, and there he met General Ironside, then CIGS. Ironside said to him: "Will you go to Malta?" He replied: "Certainly. In what capacity?" Ironside to his astonishment, said "As Governor". He arrived in Malta ten days later, a few weeks before the siege began. He was to prove the soul of the defence for the next two years.

When the war came to Malta the garrison and the defences were hopelessly inadequate. At the outset Dobbie had only five weak battalions, 16 obsolescent anti-aircraft guns and four out-of-date fighter aircraft, which were found in cases in the dockyard stores. And the problem of defence was immensely complicated by the size of the civilian population, estimated at 2,700 persons to the square mile, nine tenths of whose food had to be brought in by sea. In the desperate situation following the fall of France there was little that could be spared from home to reinforce him. The CIGS sent him a telegram. "Deuteronomy, Chapter 3, Verse 22" (Ye shall not fear them: for the Lord your God he shall fight for you).

Dobbie's first act was to issue an Order of the Day invoking divine aid and protection, and having done this he immediately turned his practical mind to the consideration of material difficulties and dangers—the rounding up of fifth columnists, and the digging of air raid shelters (13 miles of tunnelling were excavated in the limestone rock), the defences of the beaches and aerodromes, and institution of conscription, and a thousand and one other details. His energy and foresight proved invaluable in preparing the community to withstand the cruel ordeal that awaited them.

The story of the heroic endurance of the garrison and people of Malta under the almost daily bombing of the next two years need not be retold. It was not until the early summer of 1942 that the Luftwaffe were finally deprived of command of the air over Malta. By that time the civilian casualties averaged 1 in 70, as a result of some 2,000 air raids. But, although the bombing of the island began to diminish, the supply convoys were still under heavy attack; the population were suffering from malnutrition, and feeding them became a critical problem. It was at this point that Lord Gort was sent out to relieve Dobbie as Governor. The long strain had worn him down, and Mr Churchill, who had described him as "a Cromwellian figure at the key point", decided with deep regret that there was nothing for it but to bring him home. The end of his term of office was marked by the award of the George Cross to the Island and, on his arrival in England Dobbie was decorated by the King with the GCMG, the citation referring to "the steadfast and gallant bearing of the garrison and civil population" under his guidance and leadership. He was not bitter at being relieved, but when he went to the War Office to see the Director of Military Operations he remarked, rather wistfully: "I could have stayed perfectly well."

Dobbie's conduct of the siege was a remarkable feat of leadership. Never once did disaffection rear its head. It was his example and his courage that inspired the people of Malta, while his deep and openly-expressed religious faith accorded exactly with their own tradition of piety.

In 1945 Dobbie published a little book entitled *A Very Present Help*, in which he told the story of his life. The book was designed as "a tribute to the faithfulness of God", and he wrote it in order to encourage others to rely upon the never failing help of God. It is a complete revelation of his own fine character and his mentality. Few who read the book can fail to be moved at the humility with which the author related with touching simplicity his conviction that at every step he received divine guidance. One chapter is a reprint of a pamphlet he had written in 1936, setting out his belief that the profession of arms, in the light of the teaching of the Bible, is an honourable and lawful one.

He wrote another book in 1948, *Active Service with Christ*. He was a Colonel Commandant RE from 1940 to 1947 and was Bailiff GC of the Order of St John of Jerusalem.

He married in 1904 Sybil, daughter of Captain Orde-Brown, RA, and had two sons, one of whom, Captain Arthur Dobbie, RE, was killed in action, and a daughter. Lady Dobbie died in 1962. Two of his grandsons are serving in the Corps.

After the war he devoted himself to the London City Mission, an organization of missionaries, mostly ex-Servicemen, engaged on house-to-house envangelism. He retired as the Mission's Chairman in 1956.

R. G. A. J. wrote thus in *The Times* of 9 October 1964:—

"As it is now very improbable that the full story of the defence of Malta during World War II will ever be written, may one who had the good fortune to work at the right hand of Lieutenant-General Sir William Dobbie during the critical years of 1940–41 add a little to the obituary published in *The Times* on Monday?

His faith in God was complete, and was of the greatest importance in preserving, and indeed strengthening, the morale of a civil population whose own faith was also strong and confident, but who found themselves suddenly subjected to the horrors of modern warfare. He shared the confidence of his predecessor, the late General Sir Charles Bonham-Carter, and of his Lieutenant-Governor, the late Sir Edward Jackson, in the people of Malta, and both of them invariably rejected the inevitable proposals made from time to time that martial law should be introduced. He had a microphone on his desk through which he could speak to any town or village in the fortress, and immediately after any bombing attack, he would speak to the people who had suffered most, invariably emphasizing the faith both he and they shared in the Almighty, expressing his sympathy in their suffering, emphasizing again that God was on our side and that right must prevail, and ending with a message that he was on his way to see them.

General Dobbie did not give his confidence easily, but when he did so it was complete. His confidence, in the judgment of one member of his staff, was fully demonstrated in July and August, 1941, when he fought and fought, up to the Prime Minister himself, for the vital convoy which arrived in Malta in October 1941. On three occasions his proposals were rejected (the war with Japan was on the horizon) but his final, personal approach to the Prime Minister led to the convoy which was probably the decisive element in the ability of the fortress to hold out in 1942. History will judge the importance of Malta to the success of the entire Middle Eastern campaign. General Dobbie's initiative and determination should never be forgotten."

General Dobbie was buried at Charlton Cemetery on 8 October 1964, a Memorial Service was held for him in St Paul's Church, Onslow Square on 17 October. The Rev K. F. W. Prior officiated, Brigadier J. V. McCormack read the lesson and the Ven. I. D. Neill (Chaplain-General to the Forces) gave the address. Those present included:—

Colonel and Mrs Orde Dobbie (son and daughter-in-law), Major and Mrs Percy Johnson (*son-in-law* and daughter), Mr Robert Dobbie, Mr Charles Dobbie, Miss Carol Dobbie, and Mr Jocelyn Johnston (grandchildren), Mrs H. Cottingham, Mr J. Abbot, Mr and Mrs C. A. Lyster, the Rev D. C. H. Michell, Mr John Michell, Mr and Mrs Michael Browne, Miss R. and Miss E. Orde-Browne, Dr and Mrs T. Goodwin, Miss P. Johnston, Mrs D. Aldis.

The High Commissioner for Malta and Mrs Axisa, General Sir Frank Simpson (Chief Royal Engineer), General Sir Robert Mansergh (Master Gunner, St James's Park, representing Royal Regiment of Artillery), General Sir Nevil Brownjohn, Lieut-General Sir Clarence and Lady Bird, Air Chief Marshal Sir Hugh Lloyd, Major-General Sir Douglas and Lady Campbell, Major-General Sir Nigel and Lady Tapp, Lieut-General Sir Arthur Smith, Sir Henry Holland, Lady (Shenton) Thomas, Mr Horace Purshall (Chancellor, representing Prior and Chapter, General of the Order of St John), Colonel E. G. H. Clarke (Director-General, The Friends of Malta, GC), with Mr B. M. Lindsay-Fynn (Chairman); Mr N. Long-Brown (representing the headmaster and governing body of Charterhouse School), Mr David Lees (representing Old Carthusian Club), Mr J. W. Reader-Harris (representing governors, Monkton Combe School), Mr K. R. Guy (representing Monkton Combe School), Colonel C. B. Appleby (National Army Museum), General D. J. Wilson-Haffenden (representing Boys' Brigade), Mrs P. L. Phillips (Kensington and Chelsea division, British Red Cross Society), Brigadier C. Swift (representing British and Foreign Bible Society), Canon C. E. Arnold (general secretary, London City Mission), with other representatives; Mr F. H. Wrintmore (editorial secretary) and Mrs Wrintmore, with Lieut-Colonel G. G. S. Clarke (representing Soldiers' and Airmen's Scripture Readers Association).

Major-General A. J. H. Dove (with Mrs Dove) and Commander Alan Fairbairn, RN (with Mrs Fairbairn), representing Officers' Christian Union; Brigadier E. E. Robinson (representing Salvation Army), Major-General C. T. Beckett (representing Royal Artillery of the Fortress Multi-Garrison Officers' Dinner Club), Judge H. S. Ruttle, Mrs J. Light (representing Christian Alliance of Women and Girls), Mr and Mrs R. Maltby (Fulham YMCA), Mr G. Gray (Pickering and Inglis), the Rev E. E. S. Grimwood and Mrs Grimwood (secretary, Central Asian Mission), Mr A. G. Tilney (Evolution Protest Movement), Lieut-Colonel A. Quinton Carr (chairman, Fact and Faith Films), with Lieut-Colonel G. E. Aldridge, Brigadier J. G. Carr, Commandant, Royal School of Military Engineering, Major and Mrs Derek Savile, Mrs Wrey Savile, Group Captain and Mrs R. S. Sweet, Brigadier A. G. Cole, Major-General S. H. M. Battye, Lieut-Colonel Charles Hordern, the Rev Adam Macpherson, Brigadier and Mrs H. E. C. Weldon, Brigadier and Mrs E. C. R. Stileman, Brigadier G. J. Eaton-Matthews, Mrs I. D. Neill, Brigadier W. E. van Cutsem, and representatives of other Christian and welfare organizations.

The extracts from *The Times* of 5 and 9 October 1964 are reprinted by permission.

MAJOR-GENERAL N. W. NAPIER-CLAVERING, CB, CBE, DSO

Noel Warren Napier-Clavering was born on 24 December 1888. He was educated at Clifton College and the RMA, Woolwich and commissioned into the Corps on 29 July 1908.

After completing his Chatham Young Officer courses he specialized in searchlights and served with 6 (Fortress) Company at Weymouth and later with 28 (Fortress) Company in Malta. In 1913 he became Assistant Adjutant to the OC Companies Malta.

Shortly after the outbreak of the 1914/18 War Napier-Clavering was posted to the home establishment and joined 238 Army Troops Company. He did not, however, stay long with that unit and, after an attachment to the RE Training Depot at Aldershot, he was given command of the 200th Field Company in 30 Infantry Division. The Division formed part of II Corps which took part in the Battles of Pilckem Ridge and Langemarck. Three of the five divisions of this Corps were commanded by RE officers, namely Major-Generals R. L. Lee, J. E. Capper and H. F. Thuillier. A brigade commander in the 8th Division was another Sapper—Brigadier-General Clifford Coffin—who was awarded the Victoria Cross for outstanding coolness and courage at Wishoer on 31 July 1917. For his part in the battle, Napier-Clavering was awarded the DSO. From December 1917 until March 1918 he was an instructor at the RE Expeditionary Force School in France, and from there he was appointed CRE 51st (Highland) Division with the acting rank of Lieut-Colonel. This Division at that time formed part of the Canadian Corps comprising four Canadian and two British divisions. The Corps itself, with VII and XXII Corps, formed the First Army. On 26 August 1918 the Canadian Corps, with two Canadian and the 51st Highland Division "up", attacked astride the Scarpe. Wancourt and Guémappe were soon captured and the 51st Division, pushing forward, captured Greenland Hill. Then followed the Second Battle of Cambrai and the general "Advance to Victory". Early on 11 November 1918 elements of the Canadian Corps captured Mons, and the First Army reached its starting point of the war. At the eleventh hour of that day hostilities ceased on all fronts.

In the spring of 1919 Napier-Clavering became Assistant Director of Engineer Stores at HQ 4 Area France and Flanders and later he became a member of the Disposals Board of GHQ British Troops in France.

In February 1921 he was selected to become a Company Commander at the RMA Woolwich, reverting to his substantive rank of major. On completing his tour of duty at the "Shop", he became a student at the Staff College, Camberley and, after graduating from there, he was, in 1926, given command of the 23rd Field Company, then forming part of the 1st Division at Aldershot.

From February 1927 until January 1929 he was Chief Instructor of Tactics at the SME, Chatham. Then followed a staff tour as a General Staff officer in HQ Home Counties District, during which time he attended a course at the Senior Officers' School, Sheerness. In 1931 he became a brevet Lieut-Colonel and was made CRE Ceylon.

Back in England again in May 1935 he took up the appointment of CRE 2nd Division, but his stay at Aldershot was not a long one. In September the following year he was sent at only six day's notice to become Chief Engineer to Lieut-General Sir John Dill who was put in command of a Corps of two Divisions despatched from home and from Egypt to Palestine where the Mufti of Jerusalem, in an attempt to curb Jewish infiltration, organized a general strike to paralyse the civil government, encouraged Arab bands to attack Jewish settlements, disrupt communications, particularly the railways, and damage the pipe-line to the Haifa oil refinery. Napier-Clavering's task was to co-ordinate the engineering activities of the Army, the RAF Works Services and to some extent the local PWD. Roads and railways, frequently mined and ambushed, had to be kept open, RE assistance had to be provided for the infantry dealing with guerrilla bands and the "firm bases" from which these operated had to be demolished, and accommodation had to be provided at speed for the two Divisions sent to Palestine for the emergency; this latter task was a race against time before the wet weather set in and required the importation of vast quantities of hutting.

On returning home after the emergency he was made AA and QMG 4th Division at Colchester, and in February 1939 he became Brigadier i/c Administration, British Troops in Egypt whose Headquarters were then in Cairo. Shortly after the outbreak of war he was promoted Major-General and took up the onerous duties of DAG General Headquarters Middle East Forces where he was responsible for all problems connected with the personnel aspect of the enormous build-up of troops in the large area administered by GHQ Middle East. From 1942, until his retirement in May 1945, he was Head of the British Military Mission to the Egyptian Army. For his war services he was made CBE in 1941 and created CB in 1944.

He married Margaret, only daughter of Mr and Mrs T. W. Vigers of Guernsey on 14 July 1921, who survives him. They had one daughter.

He died at his Hampshire home on 30 September 1964, after a long illness in his seventy-sixth year.

BRIGADIER R. N. FOSTER, DSO, OBE

RODERICK NELSON FOSTER, known to his many friends and a host of admirers as "Roddy", was born on 22 July 1904, the son of H. C. Foster, Esq of Kilrenny, Bideford, Devon. He was educated at Cheltenham and the Royal Military Academy, Woolwich where he became the Senior Under Officer and was awarded the Sword of Honour.

He was commissioned into the Royal Engineers on 26 August 1924 being third of his batch of twenty-eight YOs. After two years at Chatham he was posted to Aldershot where he spent a short time as a Company Officer in the 5th Field Company before being posted to the 1st Field Squadron. Then followed six joyous years, first as a Troop Leader in the Squadron. The Squadron at that time formed part of the 1st Cavalry Brigade, stationed at Aldershot, and it took part in combined training with the 1st and 2nd Cavalry Brigades on Salisbury Plain each year. To anyone who has experienced the thrill of training with six mounted cavalry regiments and two RHA regiments the memory cannot be effaced, nor can the pride of "belonging", and being as well mounted, ever be forgotten. Roddy was quickly spotted as an outstanding officer and selected to attend a nine months course at the Equitation School, Weedon. From there he returned to Aldershot as an Equitation Officer at the RE Mounted Depot. He was a competent and dedicated horseman, a great man across country in the hunting field and on a point-to-point course; he achieved many successes in the show jumping and handy hunter arena. He jumped at the Royal Tournament at Olympia. It was, however, perhaps the RE Coach that was his great love. He spent hours breaking-in a team of young liver chestnut hackneys. He invented a device, consisting of reins attached to strong springs, to practise handling the "ribbons" of a four-in-hand and executing turns and that essential manipulation known as "shortening your centres" required when the leaders and the wheelers deviate out of line. The device also strengthened the forearm muscles and the fingers of the bridle-hand, not that Roddy's powerful arm and hand needed any strengthening, but he wanted to be quite sure that he could drive the team over an exacting Marathon course without ever having to bring his right hand to the help of an aching left hand fist-full of reins. On summer evenings, standing on a soap box on the lawn of the Officers' Mess at Gibraltar Barracks, he would perfect that delicate operation of "catching your whip" when the lash had to end up in a perfect figure of eight. All this work and enthusiasm was not without avail. Notable successes were obtained by the RE Coach in the Coaching Marathon at the International Horse Show and at many Military and leading Country Shows. There was also the social side with Sunday coaching picnics

Brigadier R N Foster DSO OBE.

and the coach drive from the Mess to Ascot Heath each day of Royal Ascot Week. In spite of all this equestrian involvement he still found time for cricket. He had made his debut into Corps Cricket as a Second Lieutenant in the summer of 1925 and heralded his arrival by scoring a century in each of his first two matches against the MCC and Aldershot Command respectively. He followed this up with another century against the Free Foresters. In 1931 he headed the Corps batting averages, his best innings being 124 against I Zingari and 124 against the Band of Brothers. In inter-unit games at Aldershot he could be relied upon to secure a win literally off his own bat. He was also a great rugger player, and was scrum half in the RE Aldershot XV that reached the Final of the 1927 Army Rugby Cup. The Sapper team lost by 9 points to 8 against the South Wales Borderers, of Rorkes Drift fame, holding a winning lead until the dying minutes of the game. He was also a doughty performer in the boxing ring and fought regularly in the Aldershot Inter-Unit Boxing Competitions. In a catch weight fight he once faced a very rugged opponent, not exactly over popular with the soldiers. The shout of joy (mixed with amazement) as Roddy felled his adversary stone cold in the first round almost lifted the rafters of the Maida Gymnasium. And as if this were not enough, such was his unbounded vitality, that he also found time to perform as a saxophonist in Lady Harington's Dance Band—Lady Harington being the wife of the GOC-in-C Aldershot Command—and play merrily away to all hours of the night at the gay parties held in the Aldershot Officers' Club.

From Aldershot he went to India where inevitably he was soon posted to a Field Troop becoming a troop officer in 31 Field Troop, Bengal Sappers and Miners then stationed at Roorkee. A year later he moved with his troop to Risalpur. After a short leave home he returned to Risalpur in the summer of 1935 and he was selected as a field engineer to CRE "Mohforce"—a force sent against Mohmand discontents stirring up trouble on the frontier. The chief RE tasks were water-supply, including an eight mile pipe line, the construction of a road over the Nahakki Pass and the maintenance of the Gandab Road from Pir Kila. For his outstanding work in this largely Sapper campaign he was twice mentioned in despatches and awarded the MBE. He returned to the home establishment after the successful conclusion of the operations.

Once more in England he was selected to become Adjutant of the Training Battalion at Chatham. In those days only the best were posted as Party Officers; to be chosen as Adjutant of the Training Battalion you had to be something "extra special". It was to be an exacting posting, the most outstanding event being the Coronation of King George VI on 12 May 1937. An RE Contingent lined part of the Coronation Route and an RE Contingent marched in the Coronation Procession. The latter consisted of contingents from the Training and Depot Battalions at Chatham, contingents from Aldershot, Bulford, Gosport and Eastern Command and from the Supplementary Reserve and the Territorial Army. Contingents from the Royal Canadian Engineers, the Royal Australian Engineers, the Royal New Zealand Engineers, the South African Engineers and the Jamaica Engineer Corps, and the Madras, Bengal and Bombay Sappers and Miners also marched in the Procession. Chatham was a forming up and training centre for these contingents and the administrative load placed on the Adjutant of the Training Battalion was indeed a heavy one. After-the-Coronation visits and social functions had also to be arranged in advance. Roddy took all this in his stride. He also personally supervised the extremely strenuous training programme and marched in the

Coronation Procession with the best of them, a splendid and outstanding figure.

He was retained with the Training Battalion after the outbreak of war in 1939 and it was not until September 1940 that he was given command of a field squadron in 6th Armoured Division. In April 1942 he was promoted Lieut-Colonel and made CRE 49 Infantry Division. The division formed part of XXX Corps in the June 1944 Normandy landings, the consolidation of the beachhead and the final break-out. In January 1945 he was appointed Commander 11 Army Group RE and, as such, he was responsible for all work forward of the rear boundary of 15th Infantry Division, and planned and executed the assault crossing of the River Rhine on XII Corps front. For this task he was allotted no less than twenty-nine field companies and assault squadrons. He was later similarly made responsible for the engineer tasks required for the assault crossing of the River Elbe. In recognition of his war services he was awarded the DSO and the OBE.

In November 1945 he was posted to Egypt to become SORE I to the Engineer-in-Chief, Middle East Land Forces, and in 1948 he returned home where he was given command of 1 Training Regiment RE. In 1951 he became Chief Engineer London District—the year of the Festival of Britain. The main Sapper Festival task was the construction of a 1060 ft triple-truss, standard-widened, Bailey Bridge, designed to take 8,000 pedestrians an hour, to be built alongside Charing Cross Bridge on piers previously driven by LCC experts almost directly above the line of the Bakerloo Tube tunnel. The previous Chief Engineer and MEXE had been jointly responsible for the design of the bridge and its unique method of launching necessitated by the very cramped site. Innumerable specials had to be procured from a variety of sources and accommodation had to be provided at Wormwood Scrubbs for the building parties from 36 Army Engineer Regiment (from Maidstone) and for TA units at weekends, RE Survey detachments and store-holding personnel, Royal Pioneer Corps labour and road and water transport RASC units. Bridging equipment and plant for the construction of the bridge had to be assembled in 6 CESD and at the "Scrubbs". In spite of an early mishap, before Roddy's time, greatly publicised and photographed by the Press, the Festival of Britain Bridge (Sapper Bridge), spick and plan, glistening above the flowing Thames, was opened by King George VI on the appointed day. The subsequent dismantling of the bridge was an almost equally involved task; it attracted no publicity, but it was a job well done. More sombre tasks were necessitated by the sudden death of King George VI, to be followed by a vast amount of Sapper work required for the Coronation of our present Queen and Colonel-in-Chief on 2 June 1953. The Chief Engineer London District was responsible for the erection of temporary camps to accommodate the vast number of troops brought into London from this country and from overseas to take part in the Coronation Parades. The Royal Engineer Contingent in the marching procession consisted of twenty-nine officers and 275 other ranks of the Regular Army, Army Emergency Reserve and Territorial Army all drawn, with the exception of two Maltese other ranks, from the UK and BAOR. The Commonwealth contingents included representation from the Royal Canadian Engineers, the Royal Australian Engineers, the Royal New Zealand Engineers, the Rhodesian Engineers, the Indian and Royal Pakistan Engineers, the Ceylon Engineers and the West African Engineers, and among the Colonial troops was a detachment of over fifty strong from 50 Gurkha Field Engineer

Regiment. The Corps also provided over 600 officers and men (Regular, AER and TA) to line the Piccadilly section of the Coronation Route. In spite of all his Coronation responsibilities and involvements Colonel Roddy Foster personally commanded the Sapper street-lining contingent. Surely a record for a Sapper officer to have taken part in two Coronation parades.

His last appointment was Chief Engineer, Northern Command which he held from August 1953 until his retirement on 12 January 1957.

After leaving the Army he immediately joined Hammonds United Breweries in Bradford becoming their Works Manager. He held that position until he was taken ill last May. He died on 9 October 1964 in the Duke of York's Home, Bradford after having suffered five months illness with great calm and with his customary wonderful courage.

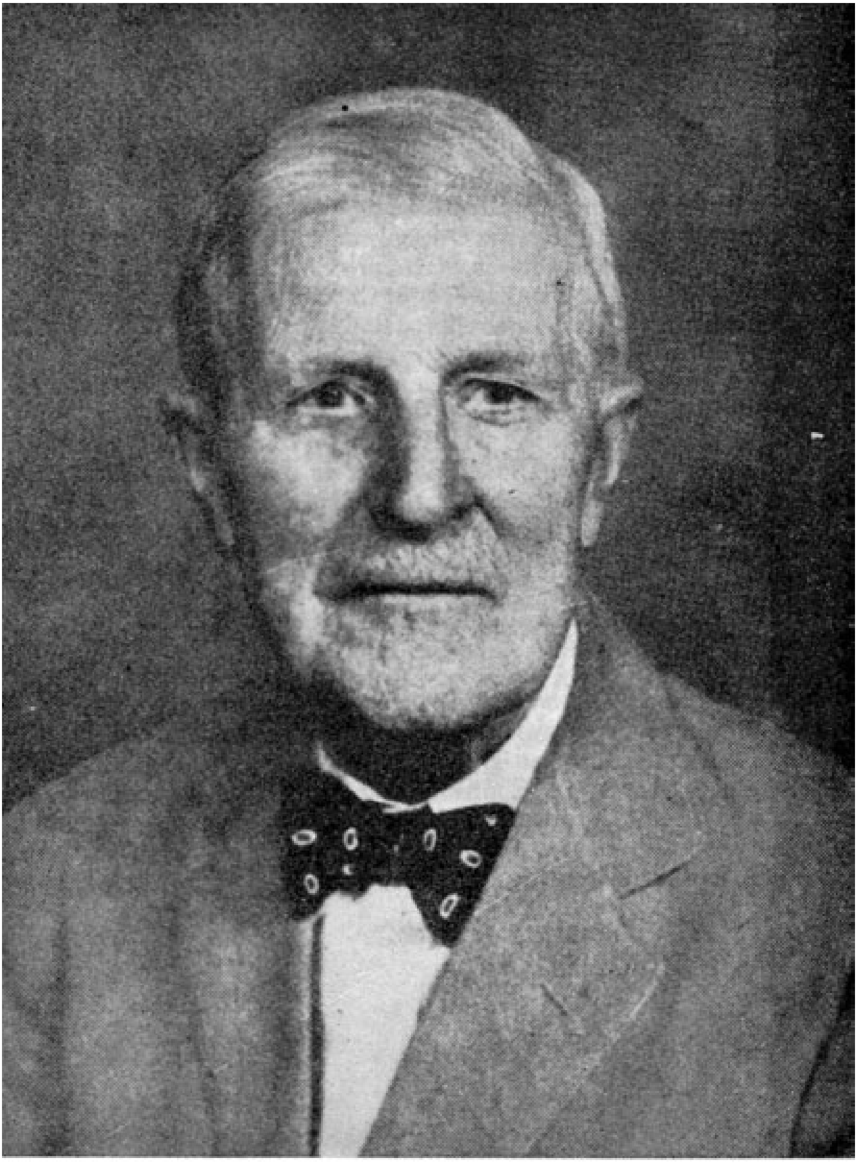
He married Moira Alice Beatrix Orr, only daughter of Mr and Mrs Oswald Orr, at Holy Trinity Parish Church, St Andrews, Fife on 5 August 1936. They had two sons, the elder became head boy at Cheltenham and gained a Scholarship to Pembroke College, Cambridge. He did his National Service in the Corps after leaving school. He is now working with British Petroleum. The younger boy is in his last term at Cheltenham and captain of his house rugger. Our deepest sympathy goes to his widow and family in their sad loss.

How can you describe Roddy? He was a born soldier, strong, manly, tall and upright, and upright in all he did. He never spared himself, yet he was always gay, kind and apparently carefree. He demanded the best of others, yet he never extracted this by force nor by intimidation. He was gifted and talented, musical and clever with his hands. He sought, worked for and achieved great perfection in all he set himself to do. He was a truly splendid Sapper officer, a wonderful friend and a great Christian gentleman.

N.A.C-R writes:—

Roddy was the man I would always have chosen to give as an example of the ideal Sapper officer. He was a man of the highest integrity. He played most games and was a keen horseman. He took an active part in local social activities.

His enthusiasm and energy, which created such a splendid spirit in any field unit in which he served, were applied with equal force to his work in the MES. He inspired confidence. As this memoir shows he was gifted and his achievements were many, yet he remained one of the most modest men I have known.



Colonel R H Philimore CIE DSO

COLONEL R. H. PHILLIMORE, CIE, DSO

COLONEL R. H. PHILLIMORE, one time acting Surveyor General of India died on 30 October 1964 in Gulmarg, Kashmir. After retirement he and his wife spent the cold weather months in Dehra Dun UP and the summers in Gulmarg. He was in his eighty-sixth year and the oldest British summer resident in Kashmir.

Reginald Henry Phillimore was born in England on 19 June 1879, the third son of Admiral Henry Bouchier Phillimore, CB. He was educated at Westminster School, where he was a Queen's Scholar, and the Royal Military Academy, Woolwich. He was commissioned into the Corps on 23 June 1898. At an early stage in his military career he opted for service in Survey of India. His eldest brother was in the Indian Civil Service in Bengal and several of his mother's family, Bourdillons, had belonged to that service.

On completing his training at Chatham he was posted to India at the end of September 1900. After a few months of Military Works at Rangoon, he was posted to a Company of Madras Sappers and Miners in the Swat Valley above Malakand. He later went to Bangalore with the Company. Finding that there was no vacancy in Survey of India, he accepted a posting to the Punjab Public Works (Roads and Buildings Department) in Simla where he joined in September 1901. Amongst his most interesting tasks there were the construction of a hill road through Naldera down to Suni on the Sutlej, and building a meteorological observatory on the Chaur Peak in Sirmur. He also made considerable improvements to Snowdon, the Commander-in-Chief's residence at Simla, on the insistence of Lord Kitchener. He was a keen footballer and he played for the Simla Volunteers in the Durand Football Tournament.

In June 1903 he joined the Survey of India at Dehra Dun and was assigned to topographical surveys. He spent the field season 1904–5 on the North-West Frontier and ran a series of triangles up the Toabi Valley. In 1905, he was posted to Burma and had six happy field seasons in the Shan States on survey of Kengtung beyond the Salween, Hsenwi to the north and Karenni to the south, up to the frontiers of China, Laos and Thailand. Shooting the rapids of the Me-hkawang River in a dug-out was quite a thrill for him. He used to collect orchids and grasses for the Government Botanist of the Sibpur Gardens during field surveying. In 1911 he was transferred to Assam, and the following year he took over survey duties in the Orissa States and Chota Nagpur where he mastered the little-known Mundari and Ho languages.

After the outbreak of the First World War in 1914, he reverted to military duty. He raised an Army Troops Company which he commanded on the Flanders front in 1915, and then took to Salonika where he was employed on roads and defence works as Assistant Director of Works. In 1918 he joined 8 Field Survey Company and organized a line of Artillery observation sections along the Vardar front. After the break-through he led the Survey of India detachment during the advance into Bulgaria. He was awarded the DSO in 1918 and made Brevet Lieut-Colonel.

After leave in England during 1919, he resumed survey duties in Bengal, having one season round Calcutta and down to the Sundarbans, and two seasons in the Santal Parganas. After attending the Senior Officers' School at Belgaum he took over No. 12 Party in Assam, working in the wild country between Pasighat and the Brahmakund. He spent four months at Maymyo as Director Burma Circle at the end of 1924 which was followed by leave to England.

On his return from leave in England in November 1925, he was placed in command of a Company engaged on military surveys on the Northern Command frontier and had several short spells as Director Northern and Eastern Circles. Subsequently he was posted as Director Frontier Circle from 1928 to 1930. He spent the next two years in Calcutta as Director Map Publication and also acted as the Surveyor General of India. A sudden crisis in the world economical situation compelled the Government of India to make heavy reductions in establishment at short notice, and Phillimore had the unpleasant task of putting this retrenchment programme into effect. After leave to England in 1932, he assumed charge of the Geodetic Branch at Dehra Dun and remained in that appointment until his retirement in March 1934.

During his last months at Dehra Dun in 1933–4, Phillimore's attention was drawn to the old correspondence volumes of the Trigonometrical Survey and, with encouragement from Sir Sidney Burrard and Sir Harold Couchman, he set to work to trace out the full story of geographical enterprise in India from the earliest days.

During the next three years Phillimore not only visited the record offices at Calcutta, Bombay and Madras, but also went home to England to collect information at the British Museum, the Public Record Office and the old India Office. He made contact with writers of repute both in India and England. He also visited the National Archives of India at Delhi. His early intention was to write a history of the survey of India covering the period from 1719 to 1880 in two volumes. But old history often makes a curiously strong demand on the present and Phillimore found that he had so much to record that the volumes kept on increasing and, in the event, took five volumes to reach up to 1861. The final Volume V was published this year, since when he had been engaged on the revision of Volume I published in 1946, which is out of print.

His work was interrupted by the Second World War when, although over 60 years old, he volunteered his services and was employed as the Officer-in-Charge of the Map Section of the General Staff at Simla, which post he held for nearly two years with the rank of Captain. In February 1942 he changed to a civil post at Survey Headquarters at Delhi and eventually took over the duties of the Assistant Director of the Military Circle looking after the interests of all Survey personnel on active military service which post he held till April 1946. He was granted the CIE in 1944.

On 2 August 1910 he married Eileen Elizabeth, third daughter of S. Crosthwait Esq of Bagenalstown Co Carlow at St Mathias' Church, Richmond. who survives him. They had no children.

Although Phillimores' active career was a most distinguished and fruitful one, it is perhaps as the author of *The Historical Records of the Survey of India* that he will be most remembered. These records tell the story of an enterprise in which for nearly two hundred years officers of the Corps of Royal Engineers played a leading and distinguished role, and when independence came to India in 1947, and to her sister nations Pakistan and Burma, the sub-continent was in many respects the best mapped area of comparable size in the world, an advantage whose value to the successor nations of the old Indian Empire in their urgent quest for development can hardly be exaggerated.

The tremendous work involved in writing these Records was undertaken as a tribute to those who helped to make the Survey of India one of the outstanding scientific departments of the Government of India. It occupied all Phillimore's spare time for the past twenty years and it was carried through successfully in spite of considerable difficulties and, at times, much discouragement.

A recent tribute to him, published in the Journal of the Institution of Surveyors of India, said that Colonel Phillimore had gone about his formidable task with consummate skill and taste. His well-chosen passages were excellently annotated and beautifully illustrated. His narrative was so precise, sympathetic and detached that it revealed him to be a reporter with unusual gifts. A great historian is the one, the tribute continued, who can emerge from long years in drab archives to create a new and vital picture of his subject, and in this *Historical Record of the Survey of India* Colonel Phillimore's efforts stand supreme. He was one of the greatest survey historians of the world.

In recognition of his scholarly and methodical researches into the development of the Survey of India, Phillimore was made an Honorary Member of the Institution of Surveyors of India.

C.G.L. writes: "Reggie Phillimore loved people. He had a prodigious memory for names and faces and up to the end kept in touch with a wide circle of friends, young and old, by his lively and amusing letters. Christmas time would never fail to bring one of these. His vitality and energy were phenomenal. At his death he was still engaged on the revision of Vol I of the history of the Survey of India. Every year up to the last summer he used to climb Apharwat (13,500 ft) in the Pir Panjal behind Gulmarg, using a pony for the easy stretches only. Kashmir was his love and we had long since ceased urging him and his wife to come home."

A correspondent writing in "*The Statesman of India*" of 9 November 1964 reports: Colonel R. H. Phillimore, died suddenly in Gulmarg and the sympathy, consideration and helpfulness of the Indian army stationed there, defy description. They undertook all arrangements for the funeral, arranged for transport to enable some of the Colonel's old friends to be present, undertook the tidying and preparation of the tiny Christian cemetery, unused since 1942, and supplied a party of fifty soldiers to carry Colonel Phillimore's coffin from his house to the grave side where a military padre and the Parish Priest from Srinagar shared in reading the burial service which was concluded by the sounding of the Last Post. The ceremony was most moving and the sense of comradeship very impressive. It would have rejoiced Colonel Phillimore's heart to know that he was borne on his last journey by brothers-in-arms. It is fitting that he should have found his last earthly resting-place amongst the beauty of the wild flowers and in sight of the mountains and the eternal snows that he loved so well.

The fact that the Indian Army honoured him with a military funeral and spared no effort to make such efficient arrangements and to show sympathy and help to his widow in her bereavement makes one realize that there are links of brotherhood and affection between the troops of India and of Great Britain which can never be broken.

LIEUT-COLONEL J. D. EDGAR

JOHN DAVID EDGAR was born on 31 December 1915, the son of Lieut-Colonel D. K. Edgar, DSO, RE, and Mrs Edgar of Toronto, Canada. He was educated at Cheltenham and passed into the Shop in 1933, being third in the Army Entrance Examination. Whilst at Woolwich he won the Saddle. He was commissioned into the Corps on 29 August 1935.

During his YO Course he became an undergraduate at St John's College, Cambridge and in 1937 he obtained a First Class Honour's Degree in the Mechanical Sciences Tripos.

Early in 1939 he was posted to India and joined the Royal Bombay Sappers and Miners. In September 1940, as an Acting Captain, he was made second-in-command of 45 Army Troops Company which took part in the 1941–2 campaign in Malaya where he was taken prisoner.

Of his activities in that campaign R.D. writes:

"For the first month of the campaign David Edgar was detached from the Company, then operating in NW Malaya. With a few men his task was to deny a hundred mile stretch of the East Coast Railway from Kota Baru to Kuala Lipis to the Japanese. This section of the railway contained four large steel truss, multi-span bridges and numerous smaller bridges. Edgar and his party carried out such a thorough series of demolitions that the Japanese were never able to put the line back into operation throughout the war.

Later, after inevitable capture, ironically he spent three years working as a PW on the construction of the Burma-Siam railway where he suffered great privation contributing, no doubt, eventually to his sad and untimely death."

After release from captivity he was posted as an SO2 RE at the War Office, and after that appointment he did a two year Long Civil Engineering Course at the SME, becoming an Associate Member of the Institution of Civil Engineers at the termination of the course.

Then followed a two-year tour in Cyprus first as SO2 (Plans) and then as SO1 (Works) where he was employed on the Dhekelia project in its early formative stages.

In 1954 he returned home and, after a short time in a Works appointment in Scottish Command, he became CRE South Aldershot. In October 1956 he was given command of 1 Training Regiment. In 1959 he became Chief Instructor, Civil Engineering School at the SME, a post his father had held before him from 1922 to 1926.

He retired from the Army in August 1961 and was employed by John Laings on the building of a section of the M2 Motorway bypassing the Medway towns. In April 1964 he obtained the appointment of the Assistant Secretary to the Institution of Civil Engineers in charge of the division dealing with election to membership of the Institution. This was a post in which he was in an extremely good position to advise serving and retired Sapper officers, of any rank or age, on obtaining Associate Membership or transfer or election to Full Membership; and, in a notice published in the *Supplement* at the time, he said how glad he would always be to give such advice.

Unhappily, with so much before him, and in the prime of life, he was not destined to develop and fructify fully this most fascinating and purposeful appointment. At the early age of 48 years he died in King Edward VII Hospital for Officers on 21 June 1964.

Lieut Colonel J W Edgar RE BA (H) AMICE

Technical Notes

THE MILITARY ENGINEER

July–August 1964

The New Tokaido Line, by Lieut-Colonel Allan P. Nesbitt, Corps of Engineers, US Army. The three largest cities in Japan are Tokyo, Nagoya, and Osaka having between them a population of over 15 million. The heavy concentration of industry, transportation and commercial interests in these three cities and extending between them along the sea-coast make up the Tokaido Industrial Belt. The existing railroad serving this area was obviously becoming unable to cope with the traffic and in 1958 the Japanese Government decided to build another railway, the New Tokaido line to take over the long-distance express passenger trains and eventually to provide fast freight trains between the two terminal cities.

The article gives in considerable detail the specifications which governed the design and construction of the track, rolling stock and control system. There are good photographs and diagrams. One of the interesting features in the design is the decision to use only railcar trains, where the motive power is shared equally by each car, instead of the conventional locomotive-hauled train. Since the railcar train is lighter, high speeds can be achieved without the provision of heavy tracks and structures and steeper gradients can be surmounted. There are many other interesting innovations in the operation of this 345-mile railway, which was started in April 1959 and on which the first passenger train is expected to run in October 1964, which make it possible to claim it as the fastest and safest railway in the world.

Counterinsurgency Clear and Hold Operations in Vietnam, by Captain Richard S. Kem, Corps of Engineers. The Clear and Hold operation is a combined military and civilian exercise in which the enemy are cleared from an area and the civil population are made to feel that the government is on their side. The article describes the various stages in the planning and execution of such an operation indicating the parts played by military and civil authorities. The importance of the contribution which can be made by the engineers is emphasized.

Equipment for Battlefield Construction, by Colonel J. H. Kerkering, Corps of Engineers. This contains a description of new types of mobile earth moving equipment which are under development at the Engineer Research and Development Laboratories (ERDL) at Fort Belvoir. It then goes on to speculate on the equipment which should be engaging the attention of the forward-looking members of the design staff. The details of the equipment which is actually in hand are given with photographs. They include the Universal Engineer Tractor which can be airdropped, has a cross country speed of 30 miles an hour and swims at 350 ft per min. In addition to performing a wide range of earthmoving tasks it can haul ammunition or supplies or carry personnel. This equipment is scheduled for test this autumn. The next on the list which is being developed is the Ballastable Earth Moving Sectionalized Tractor (BEST) which has basic front- and rear-powered axle units. The BEST can provide a complete series of earthmovers and has the greatest potential in support of air-assault forces. Other items in hand are: a high speed intrenching machine, a machine that can excavate 400 cu yds of earth per hr to provide emplacements for vehicles, command posts, etc, and light weight high performance power plants for these new machines. The future needs suggested in the article include machines for a light weight amphibious tactical tractor for use in operations against insurgents which should have a wide range of earthmoving potential. Machines for clearing the debris following nuclear attack and machines for earth tunnelling are also envisaged. There are photographs illustrating both the actual and the projected equipments.

THE ALASKA EARTHQUAKE. There are three articles dealing with the Alaska earthquake describing its effects and the contribution to recovery from it made by the Corps of Engineers and the US Navy. A fourth article deals with the action of the Coast and Geodetic Survey. This article which is entitled Coast and Geodetic Surveys of Earthquake Effects is written by Rear Admiral H. Arnold Karo Director, Coast and Geodetic Survey. It is of great interest from the picture it gives of the wide network of observatories which record and report to the Pacific Seismic Sea Wave Warning System enabling the headquarters of the system at Honolulu to send out tidal wave warnings. These four articles are well illustrated with photographs and give a comprehensive picture of the earthquake and the damage suffered.

BUILDING FOR THE UNIVERSE, by Robert W. Long. The author is the director of the National Aeronautics and Space Administration Office of Construction (NASA). The research, development, and manufacturing programme being led and financed by NASA and the Air Force has resulted in some impressive developments which will have far reaching effects. The article gives a brief summary, without detailed explanation, of advances being made and the possibilities ahead. The headings are Materials and metals, with a note on metal reducing bacteria and paints that change colour with temperature, optics and electronics, physiology and biology, agriculture, gathering agricultural information by remote sensing of the earth's cover from aircraft, balloons, and satellites, and Building maintenance.

AIR MOBILITY FOR DIVISION ENGINEERS, by 1st Lieut Edward D. Martin, Corps of Engineers. This is an account of a raid carried out by an Airborne Engineer party in which a bridge was demolished and road blocks and craters effected behind the enemy lines. The troops were carried in helicopters. The whole episode is imaginery but it is used by the author to illustrate how airborne engineers suitably trained and equipped could be employed. He goes on to describe the equipment, organization and training he recommends. An interesting and imaginative article.

TRAFFICABILITY OF SANDS, by S. J. Knight and C. W. Boyd. From tests made with a wide range of military vehicles on various sands, correlations of the strength of a sand and the performance of vehicles on it have been developed at the Army Engineer Waterways Experiment Station. In this article the authors describe the tests carried out and the methods of recording the data. The use a commander could make of the information in planning an operation involving sand crossing such as a beach landing in estimating the performance of various types of vehicle is described.

MILITARY ENGINEER FIELD NOTES

SEABEES AT GUANTANAMO, by Lieut-Commander E. C. Hughes, Civil Engineer Corps US, Navy. Early in 1942 an urgent need arose to strengthen the fortifications at Guantanamo, Cuba. This well illustrated article describes the various types of post and the method of construction. To save time reliance was placed on concrete block emplacements and deep earth cover.

CLAYMORE, by Captain James L. Murphy, Corps of Engineers. Claymore is an antipersonel mine which sounds from the description of it in this article to be very effective. Plastic explosive is contained in an arc-shaped fibreglass plastic case $1 \times 3 \times 9$-in in size. On the top is a simple sight and on the base three folding legs. There are over 700 steel cubes $\frac{1}{4}$ in square on the convex side of the explosive. When the mine is fired these cubes spray an area of about 60 degrees for a distance of 100 to 150 ft. More details are given of what sounds like a modern version of the fougasse. J.S.W.S.

CIVIL ENGINEERING

Notes from *Civil Engineering and Public Works Review*: July 1964.

MULTI-STOREY CONSTRUCTION ON THE ASSEMBLY LINE PRINCIPLE. This article describes four of the modern techniques in the construction of multi-storey buildings, Slip form, Lift-slab, Table and Jackblock. With Slipform the external walls, and often the main internal walls, are formed in a continuous pour in shutters which are jacked up. This system has been in use for grain silos for fifty years but it is now used for many other forms of construction. The second technique is Lift-slab where large parts of the structure are constructed at ground level and then lifted into position and fixed to the columns. In the Table form of construction, a central stem is first constructed and the remainder of the structure added, suspending floors from the top of the stem. As each floor is completed, the supporting framework and formwork can be lowered for the next floor. The Jackblock system entails constructing the roof and floors in succession and jacking up the structure as each floor is completed.

SLIP-FORMING A 450 FT HIGH CHIMNEY. Describes the construction of a 450 ft high reinforced concrete chimney at Nottingham using Slip-form construction. The thickness of the shell varies from 20-in to 6½-in and the internal diameter from 31 ft 2 in to 21 ft 11 in. The maximum lift achieved in a 24-hr period was 16 ft.

TIED BRIDGE IN PRE-STRESSED CONCRETE (PART 2). The first part of this article described the type of tied bridge in which the tension members were below the deck. This part describes tied bridges with the tension members above the deck, that is, tied cantilevers.

ANALYSIS OF GRILLAGES IN THE ELASTO-PLASTIC RANGE (PART 2). Completes an article on the use of a computer to solve an engineering problem, that is, the analysis of a grillage in which one or more plastic hinges have developed. The theoretical results are compared with the test results both for right or for skew grids.

THE MOVEMENT OF SOIL BENEATH MODEL FOUNDATIONS (PART 2). This part of the article compares the many theoretical modes of failure of the soil beneath a footing with the modes of failure observed in the tests. The main conclusion from the tests is that peak bearing capacity is reached before any well-defined rupture surfaces are formed.

D.F.M.

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

ELIMINATION OF NEED FOR INSITU CONCRETE OVER GLAZED VITRIFIED PIPES. The speed of laying of pipelines has already been increased considerably by the use of factory-made joints designed to accommodate rigid pipes to small ground movements. Where, however, additional support is still required, the lack of an alternative to *in-situ* concrete still entails a time-wasting process. The writer suggests some possible ways of increasing the strength of pipelines without the use of *in-situ* concrete. The Marston formula for the load per foot run of pipe is quoted, and the effects on the pipe of varying the parameters are described. The article goes on to describe with sketches such means of load reduction as hydraulic pressure redistribution, pressure deflection devices, and pressure relief bridges.

LIGHTWEIGHT CONCRETE IN NEW YORK AND LONDON. The Americans lead the world in the use of lightweight concrete. The advantages of this material are the savings in weight and the resultant savings in labour. Lightweight concrete is easy to manipulate; to cope with the large quantities required on building sites of up to 400 cu yds per day, it is normally supplied ready mixed, and then raised to deck level with lorry-mounted luffing-jib cranes. The savings, in weight, also permit the use of smaller columns, thus incurring further economies. Lytag, produced by John Laing & Son Ltd at Gravesend, is one lightweight aggregate now available in London, where it is used in tall buildings with *in-situ* frame and slab construction, and also in some precasting applications where the improved thermal insulation and fire resistant properties are advantageous.

ANALYSIS OF BRIDGE FRAMEWORKS WITH INCLINED LEGS AND OF CYLINDRICAL SHELLS. Two articles are begun in this issue covering the theoretical analysis of bridge and shell structures. The former uses a modified Moment Distribution method on what is now a popular form of motorway bridge. The latter uses tabular coefficients and a multiplicity of symbols; these are inserted in various formulae, the process being explained with an example.

THE FORTH ROAD BRIDGE. A special feature on this bridge covers its design and construction and the protection of the structural steelwork; there are also some interesting advertisements from many of the firms involved in the works. The whole project is described, with several facts and figures, including the bridge proper and the approach roads which themselves have several minor but interesting bridges. A special article on the protection of the steelwork gives details of the controlled factory procedure carried out on the large prefabricated components; this included grit-blasting, metal spraying and painting. The grit-blasting was carried out in a purpose-built chamber, using an impeller rather than compressed air blasting as far as possible. The metal-spraying of a zinc coating was done by a specially made machine which could be operated either manually or automatically. Finally, the painting which consisted of a four-coat treatment (etch primer, zinc chromate primer, and two weathering coats of micaceous iron oxide), was applied manually mostly by rollers; only the final coat was applied after erection. It is expected that this protective treatment will substantially reduce maintenance costs; it was the result of much research and development work, and already appears to be performing well.

J.C.P.