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CONTENTS

The Construction and Operation of the Military Ports in Gareloch and Loch Ryan	Brigadier Sir Bruce G. White	1
Logistic Flexibility for Our Land Forces	Major-General G. S. Hatton	28
Calpe Hole Power Station, Gibraltar	Major W. V. Sebire	47
The Hanningfield Reservoir	Lieut.-Colonel T. J. Wignall	55
Electricity from Hot Water	R. N. Hadden	64
Engineer Work in Julius Caesar's Army During the Gallic War	Major D. M. R. Esson	67
Service with the Federation Engineers in Malaya .	Lieut.-Colonel R. A. Blakeway	72
Why Not Teach?	Lieut.-Colonel W. E. C. Pettman	75
An Early Order of Battle	Colonel D. M. Eley	78
Memoirs, Book Reviews, Technical Notes, Correspondence		80

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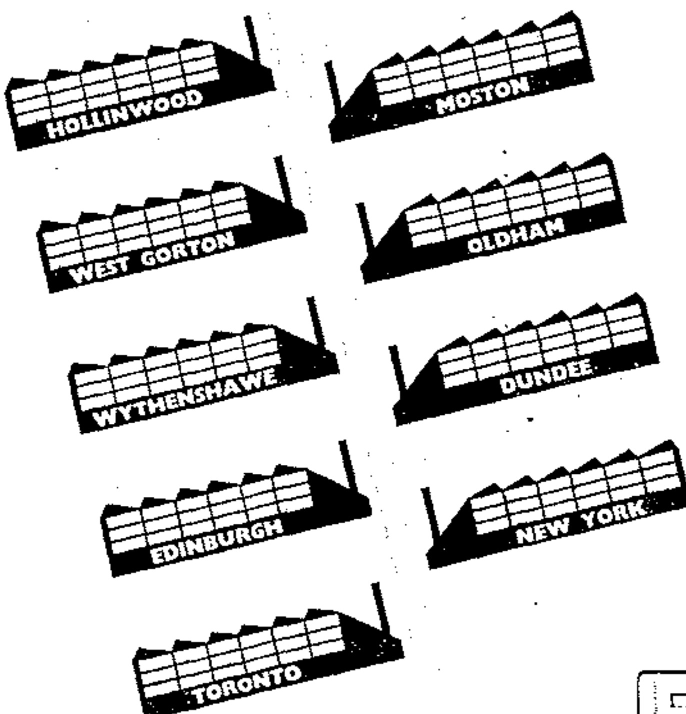

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VOL. LXXII

CONTENTS

MARCH, 1958

PAGE

1. The Construction and Operation of the Military Ports in Gareloch and Loch Ryan. By Brigadier Sir Bruce G. White, K.B.E., M.I.C.E., M.I.MECH.E. M.I.E.E., F.C.G.I. (*With Photographs and Sketches*) 1

2. Logistic Flexibility for Our Land Forces. By Major-General G. S. Hatton, C.B., D.S.O., O.B.E. 28

3. Calpe Hole Power Station, Gibraltar. By Major W. V. Sebire, M.I.PLANT.E., R.E. (*With Photographs and Sketches*) 47

4. The Hanningfield Reservoir. By Lieut.-Colonel T. J. Wignall, R.E. (T.A.) (*With Photographs and Sketch*) 55

5. Electricity from Hot Water. By R. N. Hadden (*With Photograph and Sketches*) 64

6. Engineer Work in Julius Caesar's Army During the Gallic War. By Major D. M. R. Esson, R.E. 67

7. Service with the Federation Engineers in Malaya. By Lieut.-Colonel R. A. Blakeway, O.B.E., R.E. 72

8. Why Not Teach? By Lieut.-Colonel W. E. C. Pettman, R.E. (retd.) . . 75

9. An Early Order of Battle. By Colonel D. M. Eley 78

10. Memoirs 80
    Colonel E. E. B. Mackintosh, D.S.O. (*With Photograph*)
    Lieut.-Colonel J. E. L. Carter, M.B.E., M.C., R.E. (*With Photograph*)
    M.C.A.H.

11. Book Reviews 87
    The Business of War . . . . B.T.W.
    The War Against Japan . . . . K.B.S.C.
    Before the Dawn . . . . W.G.F.J.
    U.S. Marine Operations in Korea . . . . B.T.W.
    Soldiers and Governments . . . . B.T.W.
    The War in the Mediterranean . . . . W.G.F.J.
    Rockets, Missiles and Space Travel . . . . . . J.E.
    Reinforced Concrete Designers Handbook and Explanatory Handbook on the B.S. Code of Practice for Reinforced Concrete C.R.S.
    Lagenscheidts Dictionary of Military Terms . . . . E.E.N.S.

12. Technical Notes 94
    Engineering Journal of Canada
    The Military Engineer
    Civil Engineering

13. Correspondence 102
    Armoured Engineers
    The Division in Nuclear War
    Strain Gauges for Bridges

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The Construction and Operation of the Military Ports in Gareloch and Loch Ryan

By Brigadier Sir Bruce G. White, K.B.E., M.I.C.E., M.I.Mech.E., M.I.E.E., F.C.G.I.
Director of Ports and Inland Water Transport, War Office, 1940–45

This paper was read to the Institution of Engineers and Shipbuilders in Scotland on 16th November, 1948, and is reproduced by their permission.

A paper on this same subject by C. W. Knight and S. G. Stork was also published by the Institution of Civil Engineers in The Civil Engineers at War Vol. II. *This Institution kindly loaned the original photographs and drawings for reproduction in the* R.E. Journal.

Introduction

In June, 1940, following the British withdrawal from the continent of Europe, all ports on the east and south coasts of the British Isles became virtually closed, thus throwing on the ports in South Wales and on Liverpool and Glasgow the great burden of coping with practically the whole of the ocean shipping traffic of the United Kingdom, including military cargoes in addition to commercial shipments. The Ministry of War Transport sensed that should any of these remaining ports, and especially those in South Wales, most of which were very vulnerable, be destroyed, the position, in view of the further growth of military traffic, might deteriorate until a dangerous situation had been reached. The use of the ports for the greatly enlarged service requirements was also wasteful, as military cargoes were being handled at berths equipped with shedding necessary for commercial cargoes but not for military shipments.

The Ministry of War Transport, therefore, suggested to the War Office that the position should be met by building additional deep-water berths for the express use of military shipments. Following acceptance of the suggestion a Committee to visit ports and select possible sites for new ports was formed of representatives of the War Office, the Ministry of War Transport and the London, Midland & Scottish Railway, under the chairmanship of the author. The terms of reference were:

(i) To investigate the use for W.D. traffic of ports not now being used to full capacity and to report on the improvements and additional facilities required.

(ii) To investigate the practicability of the construction of a new military port on the west coast of Scotland with the object of freeing existing port facilities, now in use by the War Office, for civil traffic.

The terms of reference being of a general nature, it was considered necessary to construe them before visiting existing ports and sites for new ones. The following considerations were taken into account and adopted by the committee as amplifying term of reference (i):

(*a*) Whilst the extent of the military shipments contemplated could not be stated, it was desirable to examine the problems in the light of urgent needs arising from the dispatch and maintenance overseas of large forces, whilst at the same time the existing ports remaining open might be heavily taxed in dealing with commercial requirements.

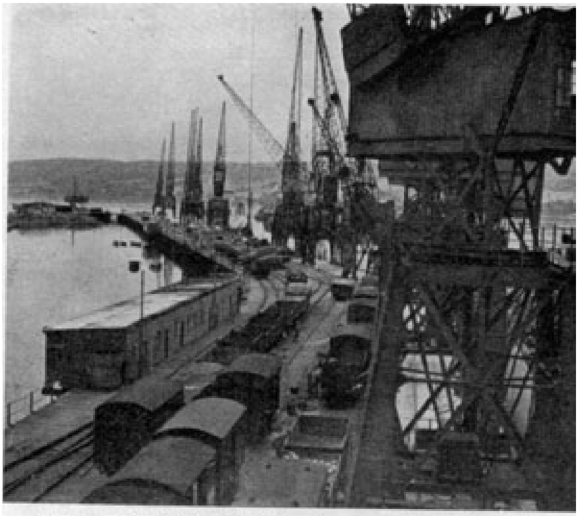


Photo 1.—No. 1 Military Port. The deep-water wharf, looking south.

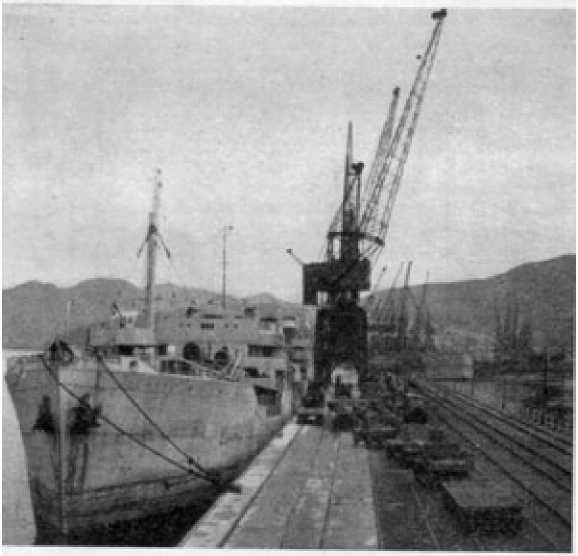


Photo 2.—The deep-water wharf at No. 1 Military Port, looking north.

The Construction And Operation Of The Military Ports In Gareloch and Loch Ryan

(*b*) As the fields of military operations were not known, it was desirable to consider the port facilities as being required both by small ships such as had been employed for traffic to certain of the French ports, and also by large ships for dispatch to more distant ports.

(*c*) Whilst W.D. shipments would be export, regard should be paid to the use of the port facilities for military or civil imports which might have to be dealt with under certain eventualities, although this was not to be a main consideration.

In connexion with the proposal to establish a new military port, it was desirable to recognize the following special factors:

(*d*) To avoid difficulties arising from military and civil labour working in proximity, the port to be established should be entirely separate from existing ports.

(*e*) A large military operating staff, special personnel, and the usual services, would have to be provided.

(*f*) Consideration to be given to the provision of anchorage for ships awaiting berths and of holding facilities for wagons awaiting ships.

(*g*) The possibility of the continued use of the port after the cessation of hostilities to be taken into account, but not so as to influence the selection of the site or the nature of the facilities provided.

(*h*) The facilities of the railway serving the port to be investigated thoroughly, together with the possibilities of their intensification and/or extension. These investigations to include the effects upon railway trunk services.

(*j*) Special regard to be paid to road access to the port.

(*k*) The time factor to be deemed all important.

It is not proposed here to deal with further proceedings of the committee in regard to term of reference (i).

In dealing with the terms of reference (ii)—after examining a number of sites, the committee found that it would be practicable to build military ports on the west coast of Scotland, the sites selected as being most suitable for the purpose being in Gareloch and Loch Ryan. They recommended that:

(1) Examination of the bottom and other physical features in these two lochs be undertaken immediately.

(2) The requirements for ten deep-water berths should be met by building taking place concurrently on two sites.

In connexion with the carrying out of the work, the committee made the following further recommendations, amongst others:

(3) Time being the all important factor and the War Office design staff not having been fully built up, a panel of consulting engineers be formed to supplement the work of such staff.

(4) The heavy and varied programme of construction work involved should be carried out by Army units having specialized training and experience in maritime engineering work, under the control of the War Office.

Needless to say such a great undertaking had to receive the sanction of the various Services, Ministries and the Cabinet. It is interesting to record that it was feared by all concerned that the chief objection would come from the Ministry of Labour on account of the proposal to employ military labour on construction and operation. The author was accordingly instructed to see the Minister of Labour and he accordingly called upon Mr. Ernest Bevin to explain the importance of the proposals and particularly those connected with the employment of military labour for the construction and eventual operation of the two ports. The agreement of the Minister, which was the only one outstanding, was obtained with a stipulation that "there shall be no admixture of civil and military labour." In the event, the whole of these works were carried out by military labour with only one civilian being employed, who was the Master of the 150-ton floating crane which had been brought from Southampton. The only difficulty which arose from the interview with Mr. Ernest Bevin was the enthusiasm which he had acquired for the proposal, resulting in his approval being subject to the military ports being made suitable for berthing the *Queen Mary* and *Queen Elizabeth*. The delay and expense involved were advanced as reasons for not proceeding with this proposal, which was then dropped.

Special Considerations which Governed the Selection of the Sites, Layout and Construction of the Military Ports

Under the war conditions prevailing, the more usual methods adopted by harbour engineers were departed from, and it may be of interest to state the special considerations which guided those responsible for the selection of sites and the layout and construction of the ports.

Siting. One of the conditions attaching was the building of the ports other than in existing port areas. There are many sites for deep-water berths in the sheltered waters of the Scottish lochs, but these were not found suitable for the purpose as rail and road connexions to many of them would be impracticable, and in other instances such connexions would involve exceptionally heavy and difficult works. A further reason which made certain sites unsuitable was the absence of areas of reasonably level ground adjoining the berths for the formation of extensive railway sidings, port installations and camps. Again, on certain sites not having the above disadvantages, the building of deep-water berths would be accompanied by heavy capital dredging programmes which it was desired to avoid. No sites having all the desiderata being available, compromise had to be adopted. The final selection of sites was made on the basis that the deep-water berths should be sited on approximately the 5-fathom lines to avoid heavy dredging and to enable the work of construction to be commenced at once, the best use being made of the land adjoining the berths, if necessary by levelling and filling, and the services to the port being met by construction of railways and roads.

The site of No. 1 Military Port in the Gareloch was an obvious choice as it gave the depth of water required, had the prospects of good ground to construct upon, and was within easy access of the West Highland line of the London & North-Eastern Railway. The land adjoining the site was not suitable without development, but that was to be accomplished by levelling at the back of Faslane Bay and with the spoil reclaiming a large area upon which the railway sidings serving the berths could be formed. Whilst Faslane Bay has long been recognized as a lay-up for ships, the site could not be considered completely sheltered due to north-westerly winds coming down over Whistlefield and making mooring conditions difficult.

The site of No. 2 Military Port in Loch Ryan was the second choice to Gareloch. In Loch Ryan two sites offered; one at the Wig, on the west side of the loch offering the most shelter, was abandoned in favour of a site at Cairnryan, as development at Wig would have entailed a very heavy capital and maintenance dredging programme. Both sites required the construction of approximately 7 miles of railway to form a connexion with the L.M.S. Railway in the neighbourhood of Stranraer. The site at Cairnryan enabled the deep-water berths to be built on the 5-fathom line without any appreciable dredging. Whilst the berths are subject to a certain amount of scend from the north-west, the loading of ships at the port was on no occasion interfered with from this cause.

Railway Connexions. As both ports were to be mainly served by railway and twenty-four-hour working carried out, one of the main considerations was suitable service by the serving railways. It was fortuitous that traffic at the ports being preponderantly export, it was possible to adopt heavier gradings for the rail connexions than would otherwise be desirable. Thus, in the case of the railway connexions, ruling gradients of 1 in 49 and 1 in 50 were adopted at Faslane and Cairnryan respectively. This was particularly useful in the case of Faslane as the West Highland line up-grades from Helensburgh to Whistlefield and the connecting line could be brought down to the port on a ruling gradient of 1 in 49 from a point only 2¾ miles south of the port. At Cairnryan the connecting railway 6½ miles long was mainly constructed on the level.

Possible Interference by Enemy Action. It was considered of considerable importance that the ports should be laid out so as to allow of their being operated, at least in part, should the works suffer damage by enemy action which might also affect the railways serving the ports. In the case of Faslane the berths were so planned that rail access could be obtained from either end and each group of three berths had separate access to it. The road system within the port gave access to the berths from both directions; an alternative to the main road approach from Dumbarton was formed by another route via Glen Fruin. Although never utilized, a reduced rail service could be obtained from the north via Crianlarich and Stirling.

At Cairnryan access to either end of the berths could not be provided, but in the case of this port a north berth with separate rail and road access was provided. The port could take traffic from the south via Carlisle or from the north via Girvan. Road services could be afforded from either north or south.

The provision made at both ports for lighterage to ships and moorings would have proved invaluable in the event of damage to the deep-water berths or to their rail services.

Design of Structures and Materials Used. In order to economize in the construction of the two ports, which had only to outlast hostilities, a number of departures from ordinary practice was made. Not much could be given away in design, stability being at least as important for these military ports as for those of which a long life is required. Some of the economies effected consisted of omission of the treatment of timber, of which large quantities were used, reduction of painting of ironwork, the extensive use of spiking instead of plating and strapping the timbers, and the use of bare copper electric cables under the wooden decking on the back parts of the berths to feed the electrical equipment on the berths. In view of the shortage, and therefore high cost, of timber and the great quantity to be employed on the works, it was decided that, as soon as pile casting yards could be established, composite piles 14 × 14 in., consisting of a lower portion of R.C. 40 to 50-ft. long spliced to a top portion of 24 ft. of timber by means of two ½-in. steel plates 8 ft. long, should be employed. By this arrangement the increased speed of construction obtainable with such operations as cutting off and attachment with timber was retained, but the handling of the long composite piles into the piling frame required care, slowed the work and added to the cost.

It was fortuitous that the author attended a meeting in Southampton to consider immobilization of the port as invasion was at that time imminent. Plans for destroying the cranes were discussed but these were not proceeded with on an offer being made to dismantle the cranes and remove them for storage until required at the No. 1. Military Port. The cranes in question were dismantled and re-erected at Faslane by Port Maintenance Company, R.E.

The cranes in question had a wide gauge of 18 ft. and 86 ft. radius required to work large liners, and each weighed 115 tons.

Equipment which could be Omitted. The ports were for handling "export" cargoes which, owing to operational and other requirements, were sent direct to ship's side by rail or road. With wharves of sufficient width to accommodate the crane tracks and a number of railway tracks, and road access, it was not necessary for large areas to abut on to the berths to accommodate transit and other shedding as in normal commercial ports. As it was agreed that the ships to load at the ports would be fully stored, watered and fuelled before arrival, no provision had to be made for these services, which normally form part of a port installation.

General Description of the Ports

The general layout of the ports is shown in Figs. 1 and 2, and it is only necessary to refer briefly to the provisions made.

No. 1 Military Port is situated on the eastern side of the north end of the Gareloch. The tidal range of springs is 11.6 ft. The berthing consists of:

	No. of berths	Total length ft.	Width ft. in.	Deep water at M.L.W.S. ft.	No. of rail tracks
Deep water wharf ..	6	3,000	76 4¾	33	5
Lighterage wharf ..	—	900	31 2	9	1
M.T. wharf ..	—	450	—	9	—
Heavy crane berth ..	—	400	—	9	—

In addition, two sets of M.T. ferry berths were provided, from which M.T. on pontoons could be taken to ship's side. Workshops, stores, D.S.T.O. gear stores, locomotive shed, electric generating station and sub-station, and headquarters offices and those for wharf superintendents and other officers working in the port, were provided. As large numbers of tanks and vehicles were loaded, the port had extensive parks with adequate road access from them to all berths. A trot of mooring buoys to take two ships was laid in Faslane Bay and extensively used in connexion with the operation of the port.

No. 2 Military Port is situated at Cairnryan, on the eastern side of the loch about six miles from Stranraer. The tidal range at springs is 9.3 ft. The berthing consists of:

	No. of berths	Total length ft.	Width ft. in.	Deep water at M.L.W.S. ft.	No. of rail tracks
Deep water wharf (south)	3 and approach	2,000	73 0	33	5
Deep water wharf (north)	1	750	72 10¾	33	5
Lighterage wharf ..	—	900	57 0	15 (west) 9 (east)	3
Lighterage wharf (south of basin)	—	460	—	9	—

Workshops are situated at Innermessan, where a slipway was provided for the repair of tugs and lighters. Sheds, D.S.T.O. gear stores, locomotive shed, electric sub-station, and headquarters offices and those for wharf superintendents and other officers working in the port, were provided. A trot of mooring buoys was laid to the south-east of the south wharf to take ships awaiting berths or loading from lighters.

Cranes

The berths at both ports were well provided with wharf cranes, the equipment being:

No. 1 Military Port

Location	No. of cranes	Capacity tons	Radius ft.	Track rail crs. ft.	in.	Acquired from
Lighterage Wharf ..	11	1½	45–35	10	0	Deptford
M.T. Wharf ..	1	3	60	14	0	Town Quay, Southampton Harbour Board
	1	15	42			
	1	5	35	29	6⅜	W.D. Std. Crane on wide gantry
Deep Water Wharf	9	5	86	18	0	Southern Rly., Southampton Docks
	11	2	86	18	0	
	1	1¾	80	18	0	Hays' Wharf Ltd.
	1	10	45	18	0	Fennings' Wharf.
	2	2	50	18	0	Hays' Wharf Ltd.

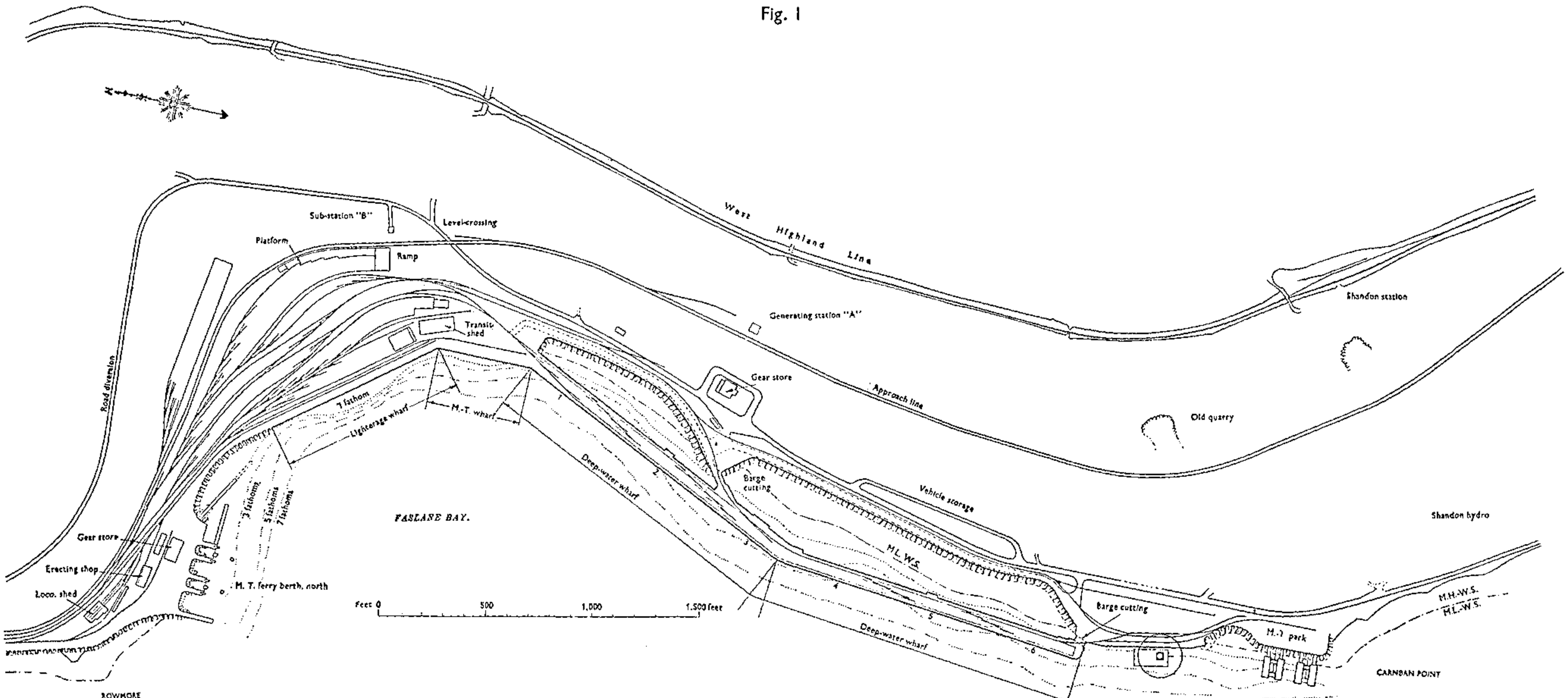
No. 2 Military Port

Location	No. of cranes	Capacity tons	Radius ft.	Track rail crs. ft.	in.	Acquired from
Lighterage Wharf ..	4	2	40	12	0	Boston Harbour Board
	2	1½	50	15	3	L.N.E.R. Parkeston Quay
	2	3	50	13	3¾	L.M.S. Rly., Garston Docks
South Quay Lighter Basin	2	5	35	29	6⅜	W.D. Std. Crane on wide gantry
North Wharf ..	2	6	65	13	6	M.O.S. contract
	3	3	65	13	6	P.L.A. Royal Docks
South Deep Water Wharf Heavy Crane Berth	2	6	65	15	0	M.O.S. contract
South Deep Water Wharf	7	6	65	15	0	M.O.S. contract
	3	3	65	13	6	P.L.A. Royal Docks
	4	3	65	15	0	M.O.S. contract

In addition, heavy lifts could be dealt with by 150- and 30-ton floating cranes at No. 1 Military Port, and by a 60-ton hammer-head crane, mounted on the approach to the south deep-water wharf, at No. 2 Military Port.

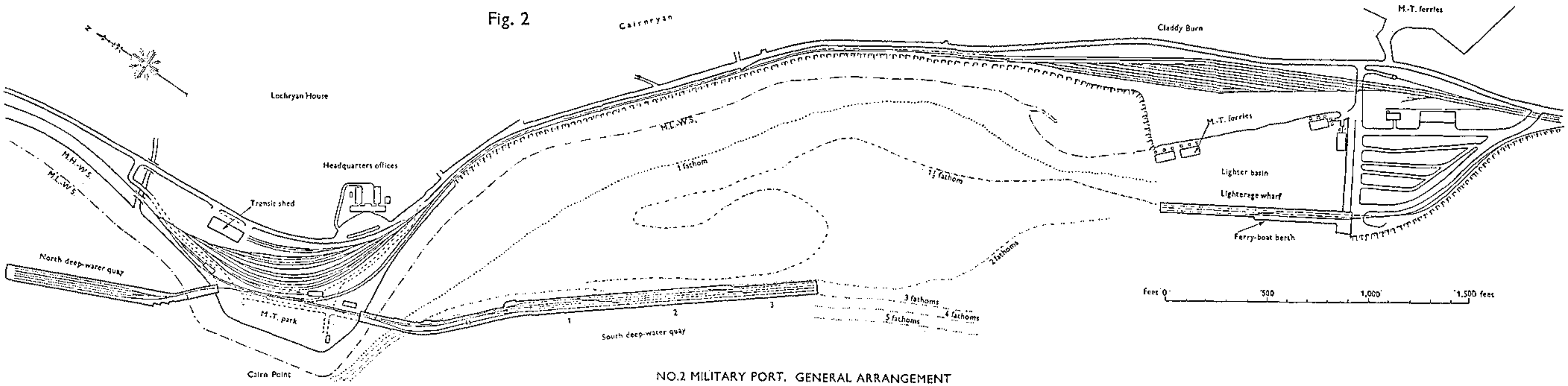
It was fortunate that, following the demobilization of Southampton Port and anxiety of the Authorities to move their 150-ton floating crane to safety, this useful equipment was obtained for service at No. 1 Military Port. The use of this crane was obtained conditional upon its being prepared for sea towage by stiffening and the lowering of the jib, and eventual return of the crane. The work of preparing the designs for the stiffening of the hull and the securing of the massive jib for the voyage to the north at an unfavourable time of the year was undertaken by the staff of the War Office, and the actual dismantling and lowering of the jib on to the trestles and re-erection in Scotland were carried out by the personnel of a Port Maintenance Company, R.E.

Fig. 1



No.1 MILITARY PORT. GENERAL ARRANGEMENT

Fig. 2



NO.2 MILITARY PORT. GENERAL ARRANGEMENT

In addition to handling numerous heavy lifts whilst the port was in operation, the 150-ton floating crane proved invaluable in connexion with the construction work and particularly in placing the units of precast concrete work up to 30 tons. With few exceptions, the cranes at the port were taken from ports which were not in full operation, and in all cases they were dismantled and re-erected by military labour. From the above Table it will be seen that the gauges of the cranes employed varied considerably, a matter which caused considerable work and inconvenience in providing the crane tracks on the wharves. In times of peace the whims of individual engineers for some special crane gauge and other requirements can be met without difficulty, but with higher manufacturing costs. It was only during the war, when it was required to move large numbers of cranes from point to point, that the evils of non-standardization came to light.

RAILWAYS

The considerable amount of railway construction required at each port was carried out by Railway Construction Companies, R.E., working under the Cs.R.E. in charge of port construction. In the case of No. 1 Military Port, the connecting line consisted of double track 2¾-miles long on a ruling gradient of 1 in 49 and joining the L.N.E. Railway (West Highland Line) about 1½ miles to the south of Shandon railway station. At the take-off point, exchange sidings were provided, from which point the port traffic was operated by military personnel. The main sidings, of which there were six sets serving the different sections of berths and one set for stabling, were laid out in the area to the east of the lighterage wharf and formed partly by levelling at the back of Faslane Bay and partly by reclamation. Considerable additional works were carried out by the L.N.E. Railway on the line between Helensburgh and the take-off point for the port, in order to increase the capacity of the line to handle the heavy traffic for the port. These works consisted of additional sections, lengthening of loops and provision of sidings.

At No. 2 Military Port, the connexion was made to the L.M.S. Railway about 1½ miles north of Stranraer, from whence the port was served by a line 6½ miles long, single as far as Leffnol sidings and thence in double track to Cairn Point. The construction of the line involved two major bridges over the main roads into Stranraer. Difficult works were experienced at Innermessan, where the line was carried on reclamation on the seashore formed with sheet steel piling and filling, and between Claddy Burn sidings and Cairn Point. This latter length in double track was laid on a formation on the seaward side of the main road and protected by rubble pitching. As there were no holding sidings on the main line within reasonable distance of the port, extensive exchange sidings were formed at the take-off point. In addition, a main shunting yard to accommodate 2,000 wagons was formed at Leffnol and a set of sidings at Claddy Burn, working in conjunction with Leffnol, to allow of the break-down of trains into small sections for wharf working. The immediate service to the berths was provided by a further set of sidings at Cairn Point.

As the L.M.S. Railway line from Carlisle, which is single track, was not considered to be capable of handling the heavy traffic to the port, the Railway Company put in hand a number of works between Stranraer and Dumfries to improve the capacity of the line.

Roads

At both ports a considerable amount of road construction and improvement was involved. Work on the existing or new roads used by the public was undertaken by the local authorities, that within the port areas being carried out in the main by the military.

Faslane. On selecting the site in Faslane Bay, it was clear that it would be necessary to divert the road between Helensburgh and Garelochhead from the position which it occupied on the edge of the loch, to the back of the port area. In the early stages of discussion the Ministry of War Transport, Roads Division, required the new road to be built to the full specification laid down for main roads. Subsequently they agreed, in view of the urgency, to accept a lower standard of construction which was less rigorous as regards footpaths, curbing, and in other directions. This departure was allowed on the understanding that if the road was retained after the war the standard could be raised. The road diversion involved construction of a road $1\frac{3}{4}$ miles in length, with a carriage-way 18 ft. wide, with two bridges, and a level crossing over the military railway connecting the port with the exchange sidings.

A considerable mileage of roads was constructed within the port area to connect the parks with the berths and to give an alternative exit at the north end. At the request of the War Office, the Roads Division undertook improvements to the road through Glen Fruin which afforded an alternative road connexion to the port.

Cairnryan. The local authorities carried out a widening of the road through Cairnryan village with a diversion at Cairn Point to allow of land being made available for the formation of sidings. Within the port area, roads were built to connect the parks with the berths.

Camps

No accommodation existing on the sites, early steps were taken to build camps. The earliest arrivals of troops at Faslane were accommodated in Shandon Hydro, which was retained throughout the use of the port by the military. Subsequently five camps were built in the vicinity. Great difficulty in providing accommodation was experienced when the port-operating personnel were drafted in to carry out loading at a time when the full construction force had still to be housed. At that time, 4,000 men had to be quartered.

At Cairnryan there was no equivalent to Shandon Hydro at Faslane, and the early arrivals were accommodated in tents. Subsequently, eight camps were constructed and, when the operating personnel were moved in for the earliest loadings, 4,000 men had to be accommodated.

The Organization Employed for the Control and Execution of the Work

Prior to 1939, under peace-time organization of the Army, the Corps of Royal Engineers did not make provision for carrying out the many branches of harbour engineering and operation, although a small number of Dock Operating Companies, R.E., existed. In May, 1940, following the fall of France, it was the author's responsibility as D.A.D.Tn., Tn. (4) (Ports), under the Director of Transportation for all matters connected with the construction and the operation of ports and subjects connected with the maritime activities of the Army; agreement between the Admiralty and War Office having been reached on this division of responsibility.

At that time there was very little activity, but nevertheless the responsibility extended to the provision for such organization and forces as might become necessary to deal with port construction and operation in all its branches. The first step taken towards fulfilment of this responsibility was the creation of a staff of expert technical officers at the War Office, experienced in all facets of port construction and operation and available to design and control any works to be carried out. As the War Office staff could not be built up in time to design the major works at the two Military Ports, it was recommended that a panel of three firms of consulting engineers be formed and entrusted with the designs to War Office requirements. This proved a wise step as the services of the panel, apart from being of the greatest value in connexion with the particular designs with which they were entrusted, were later available for furnishing general advice on many matters. The War Office staff when built up was responsible for the layout and design of many works, both at the Military Ports and at numerous places at home and overseas.

At the same time early steps were taken to raise and train a large force of Port Construction and Operation and Inland Water Troops, R.E., formed into special Companies and equipped and trained for their particular roles. In the main the officers were engineers drawn from civil life and qualified in the special branches with which they would be required to deal. In order that technical officers were enabled to devote the greater part of their time to technical duties, officers were seconded to the units from other directorates to undertake administrative duties.

In accordance with the directions of the Minister of Labour, the construction of the Military Ports was carried out by military labour, which was commanded and directed at each site by a C.R.E. who had an adequate staff under him to supervise the work. It was possible to employ eight-hour shift working for twenty-four hours a day and seven days a week, with accommodation and welfare facilities in the early days not such as would have been tolerated by civilian labour. At Cairnryan the conditions were particularly bad, and the preliminary work of pile driving and cylinder screwing had to be carried out from Thames lighters, converted for the purpose, under winter conditions and with seas which were rough for small craft. In addition to the control and construction of these difficult sea works, those in charge had to devote much time and labour to the preparation of camps for the military units. The improvement of the conditions of accommodation and welfare was the constant urge of those responsible, and it is pleasing to record that, soon after the early stages of construction, the troops were comfortably housed and provision made for their welfare. It can safely be said that, under the conditions prevailing, these great works could not have been carried out by an agency other than the military.

Whilst the main object of employing military labour for the construction was to allow of the work being completed in the shortest time, the author, with his responsibilities for building up a Port Construction, Repair and Operating force, took full advantage of the unique opportunity afforded in the construction of the ports to form and train the many specialized Companies which were raised. The personnel of which the Companies were formed was in general excellent, but it was only by having opportunities to work on heavy and difficult construction calling for every class of skill that they could become "teams" and the officers learn of the capabilities of the men under their command. The training thus afforded was invaluable, as was proved later when the numerous Companies trained and employed on the construction were drafted to military port work in all theatres of war, and also took part in the construction of the Mulberry invasion harbours. Even if the ports, on completion, had not been used, it might be said with truth that their construction was justified by the opportunities afforded to train the field force of Port Construction, Repair and Operation R.E. Troops.

It may be of interest to record the types of Companies, many of them in considerable number, which were employed on the construction of the ports.

Troops Lent to Director of Transportation—

General Construction Coy., R.E.	Quarrying Coy., R.E.
Artisan Works Coy., R.E.	Boring Section, R.E.
Electrical and Mechanical Coy., R.E.	Pioneer Companies.
Road Construction Coy., R.E.	Pack Transport Coy.

Troops under Director of Transportation—

Port Construction & Repair Coy., R.E.	Railway Operating Coy., R.E.
Port Maintenance Coy., R.E.	Railway Survey Coy., R.E.
Port Artisan Coy., R.E.	Railway Mobile Workshops, R.E.
Mechanical Equipment Coy., R.E.	Crane Operating Coy., R.E.
Port Repair Floating Workshops, R.E. (Repair ship)	I.W.T. Operating Coy., R.E.
Railway Construction Coy., R.E.	I.W.T. Workshop Coy., R.E.

In addition, large numbers of A.T.S. were employed on clerical, cooking, driving and other duties, and thus saved manpower.

Diving is not included as one of the trades in the Royal Engineers but as it was felt that divers would be required in large numbers, this trade was established, special rates of pay approved, and arrangements made for the Admiralty to take selected officers and men for training. The great variety of work calling for diving in connexion with the construction of the military ports and in all theatres of war afforded immense opportunities for divers to gain experience, and there can be no question that the number of skilled divers available in this country today is in part due to the provision made. At times there were as many as twenty divers under water at the same time. On the author's instructions those officers in charge of the construction work were sent to a diving course as he held that anyone who is driving piles should know what is happening at the bottom of the sea.

Design of the Main Items of the Works

In view of the heavy loadings to be experienced on the front sections of the main wharves from cranes and rail and road traffic, it was decided to adopt a design of R.C. construction for these, with the back portions, which had to be suitable for rail loadings only, of piled construction (Fig. 3). For the sake of expedition it was decided that the 14 × 14-in. piles driven in the early stages of construction should be of timber and later, when the necessary casting yards had been established, use should be made of composite piles with R.C. bottom portions, the top portions and also the caps, bearers and decking being of timber.

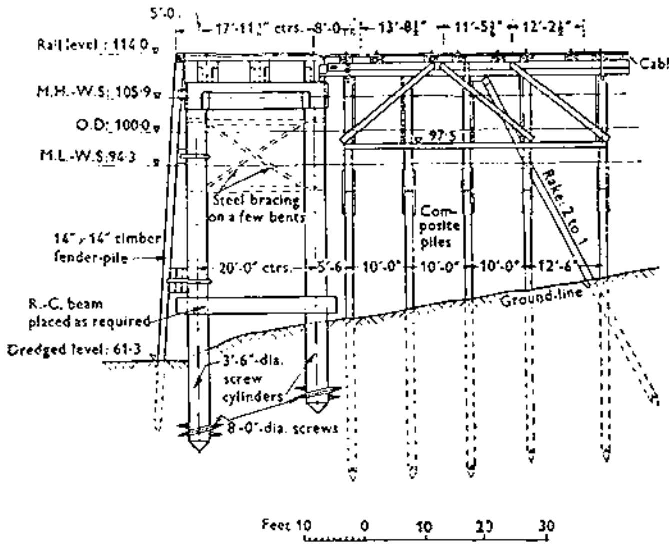


Fig. 3.—No. 1 Military Port. Cross-section of deep-water wharf.

For the support of the R.C. decks, it was decided to employ screw cylinders with wide spacing and without underwater bracing, as it was thought that the construction would proceed at the highest possible speed by this means. Whilst works employing screw piles had been carried out in this country, it is believed that the works of the nature being described were the first on which screw cylinders of large diameter, 3 ft. 6 in. and 3 ft., were employed. That this decision was reached was due to the fact that the author and those responsible for the design and works had had extensive experience with this type of construction overseas.

In order to economize in the use of steel, it was further decided to employ "Screwcrete" in place of steel or cast-iron screw cylinders. This form of cylinder consists of a thin corrugated sheet 12-gauge and of the desired diameter and in lengths of about 12 ft. The bottom length is attached to the cast-iron screw, 8 or 7 ft. diam. in these cases. As the screwing proceeds, an additional length of shell is welded to that already in position so as to maintain watertightness. As the necessary torque from the electric screwing capstan cannot be transmitted to the screw by the thin casing of the cylinder, a mandrel is temporarily employed and withdrawn when the cylinder has been screwed to the required depth. The cylinder, when screwed, is virtually the form for a reinforced concrete cylinder built up on the screw when in position. After de-watering and removing all material from the cylinder, there is inserted into it a cage built up of reinforcement steel. Thereafter the cylinder is filled with concrete. A disadvantage of this type of cylinder in soft ground is its greater weight than with cylinders of steel or cast iron, which are not normally filled.

A further aim in the designs selected was that the construction could be speeded up. By the time the screwing plant and material were likely to be available, the back portion of the wharves, which were to be piled, could be completed and act as the stagings from which the screwing of the cylinders could be carried out other than by the "end over" method. Once the special screwing plant and materials had been assembled, the comparatively few cylinders to be screwed, owing to the open spacing adopted, could proceed rapidly. During currency of the above operations, the large yards for precasting the elements of the decking could be prepared and the R.C. units be cast by the time the cylinders were ready to receive them.

The designs for the R.C. decks for the two works were very similar, but the spacing of the cylinders differed as follows:

	Lateral spacing	Longitudinal spacing
Faslane	20 ft.	30 ft.
Cairnryan	16 ft.	20 ft.

The design consisted of heavy transverse R.C. beams which were not continuous, to allow of uneven settlement of the cylinders, carrying longitudinal beams of two types, one for crane and the other for rail loadings. On the beams were laid heavy R.C. deck slabs on which the rails were laid.

The beams were cast in two parts, each part being limited to 10 tons, the capacity of the derricks employed. So as to ensure that the two parts of the beams fitted snugly, the second half of each beam was cast up against the first half, cast previously, with paper in between them. When in position the halves of the beams were bolted together. At Faslane when the loading programme required cranes of greater capacity than the 5-ton cranes provided, a section of the wharf was equipped to take 10-ton cranes. This alteration in loading was met by spacing the standard longitudinal beams 12 in. apart and, after inserting a reinforcing cage and placing shuttering beneath, concreting the space *in situ*.

In order to provide an additional berth at Cairnryan, and one which could be brought into use earlier than the berths on the south wharf, it was decided to construct a deep-water berth on the north side of Cairn Point. In the case of this construction, the face line was kept on approximately the 3-fathom line, to be eventually dredged to give 5½ fathoms at M.L.W.S. Test piles

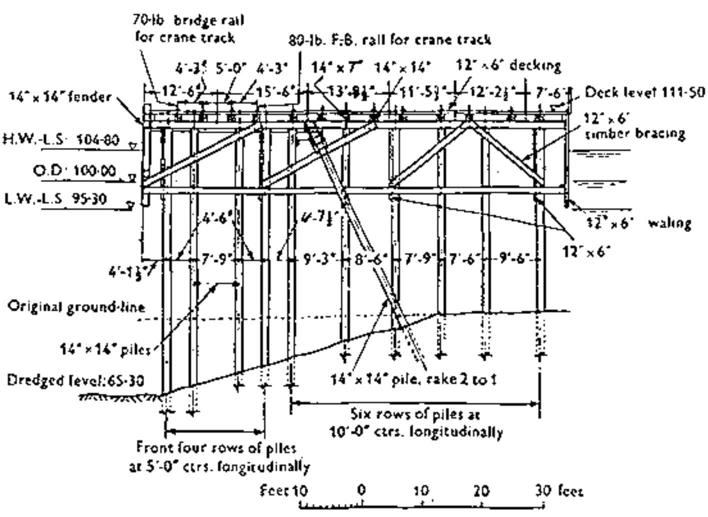


Fig. 4.—No. 2 Military Port. Cross-section of north deep-water wharf.

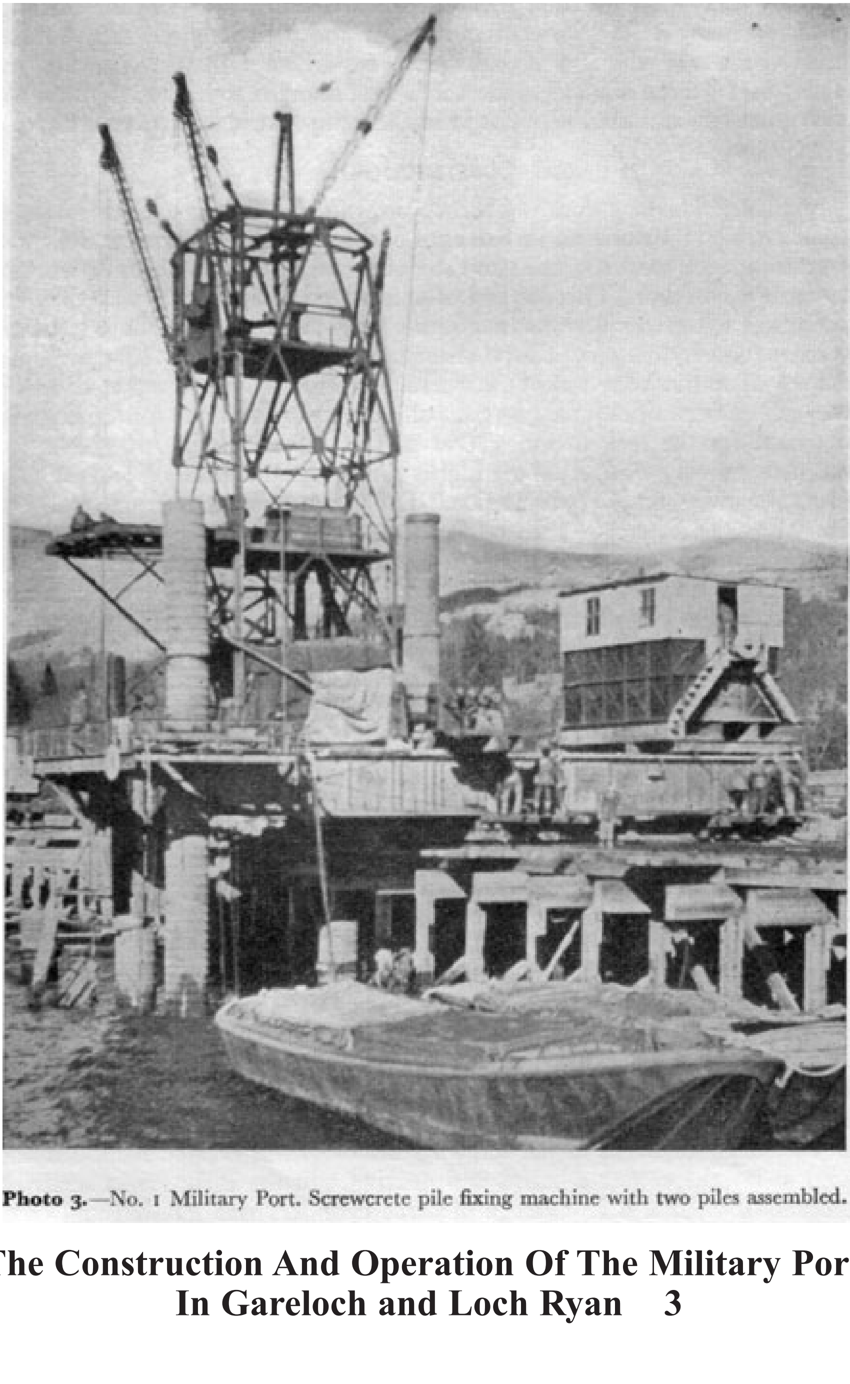


Photo 3.—No. 1 Military Port. Screwcrete pile fixing machine with two piles assembled.

having shown that the bottom was better than that on the south side, where the use of piling had to be abandoned, it was decided to construct the wharf of 14 × 14-in. composite piles, with timber top sections, and caps, bearers and decking. Fig. 4 shows a section of the wharf. The desired loadings for crane and rail tracks were obtained by driving the piles at varying centres, laterally and longitudinally, those in the front row where crane loadings occurred being 4 ft. 6 in. centres laterally and 5 ft. longitudinally. Raker piles with a rake of 2 to 1 at each bent were driven with a special raker rig. The wharf is more exposed to the north-west than the south wharf, but it was in regular use and no difficulties in loading ships were experienced there.

Some Construction Details

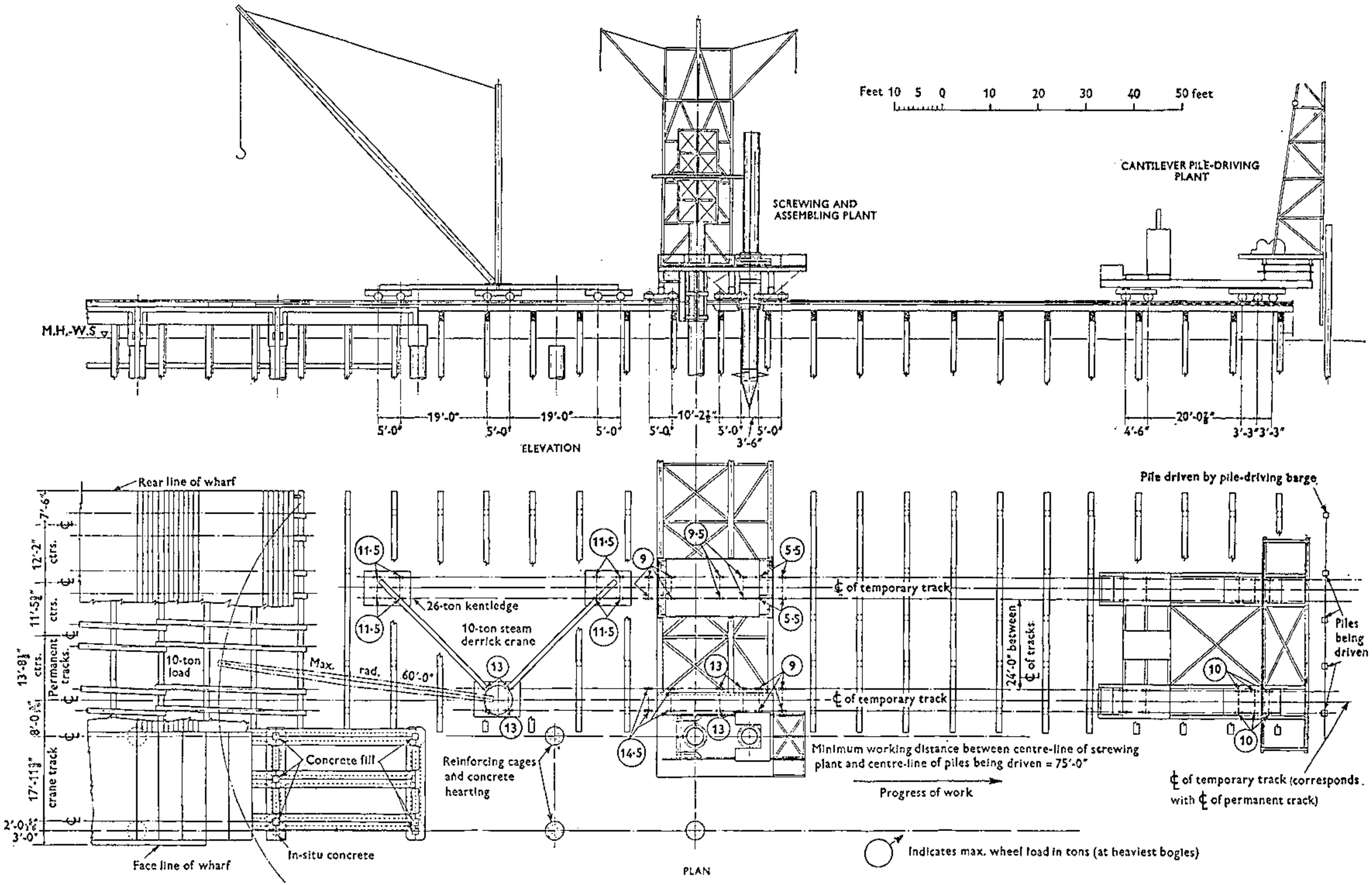
Faslane. The first work was the tipping of rubble banks to enable work to commence on the north and south ends of the lighterage wharf. Derricks were erected at each working point and the piles were driven with these working towards each other. This method of opening out the work at more than one point was followed wherever practicable, as it was thus possible to speed up construction by creating a keen sense of rivalry between the sapper teams employed on those sections of the works. As the wharf was completed, rubble was tipped from side-tipping wagons on the landward side to form the retaining bank for the reclamation of that part of Faslane Bay. A large fleet of scrapers, moving earth from the higher ground at the back of Faslane Bay, provided filling for the reclamation. The two burns which discharged into the Bay were carried in culverts formed of concrete pipes. The area thus prepared, and partly reclaimed, was required for sidings and also for the formation of a large yard for the preparation of the pre-cast reinforced concrete units and composite piles, and this section of the work was therefore pressed on with at high speed.

Work commenced early on the north end of the piled structure forming the back part of the deep-water wharf, the approach being formed of piles driven by a floating pile driver. A special piling frame to drive four of each bent of piles was erected on the approach, the fifth pile in the bent being driven ahead by a floating pile driver; by this arrangement the capping beams could be fixed immediately behind the pile frame, and the decking laid. To speed up construction of the first section of the wharf, the total length of which was 1,500 ft., a pile frame was also erected at the south end and worked to meet the other frame.

As soon as a sufficient length of piled structure at the north end had been completed, preparations were made for the erection of the special screwing machine, Fig. 5. This machine, with which all operations of assembly of cylinders, pitching, screwing and finally concreting were done, was of great weight and developed heavier momentary loads than the normal operating loads, and special precautions had to be taken. When the screwing machine had been set to work and had been moved forward, a 10-ton derrick, running on the same rail tracks as the screwing machine, was erected behind it and used to lay the concrete beams and decking. In the early stages screwing progressed well, and an average of three cylinders was screwed and completed every two days.

Before the first section of the wharf comprising three berths had been completed, it was decided, in view of the urgency for additional berths, to construct the second section of the wharf, 1,500 ft. long and comprising Nos.

Fig. 5



NO.1 MILITARY PORT. DEEP-WATER WHARF. CONSTRUCTION PLANT.

4, 5 and 6 berths. The line of these additional berths followed the 5-fathom line and this resulted in it being at an angle of 160 deg 25 min. with berths Nos. 1, 2 and 3. For this work an island of piles was driven by the floating pile-driver at the south end of the wharf extension, upon which a four-pile frame was erected. A further island was formed in the centre of the work upon which two more four-pile frames were erected, to work south and north. With all piling frames working simultaneously, a length of 40 ft. of the piled structure of the wharf was constructed each twenty-four hours.

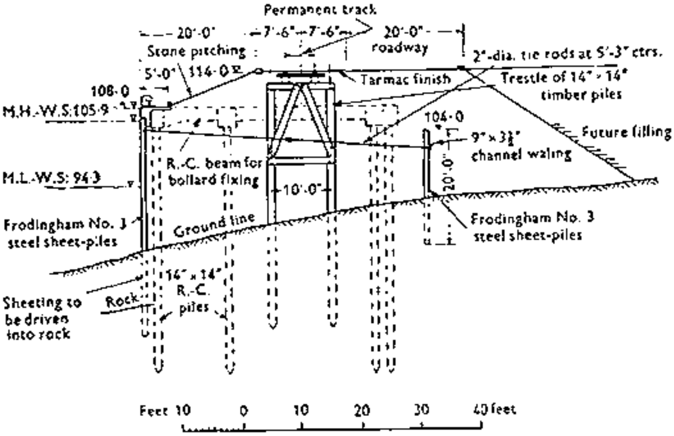


Fig. 6.—No. 1 Military Port. Cross-section of Floating Crane berth.

An interesting example of rapid construction was that carried out in connexion with the berth to accommodate the 150-ton floating crane, Fig. 6, from which heavy lifts were transported by this crane for loading direct on to ships. As this berth, built at the south end of the port, had to be constructed in the water and required a large amount of reclamation, it was decided that the quickest form of construction would be to drive a trestle of 14 × 14-in. piles throughout the length, at a distance of 27 ft. 6 in. east of the face-line of the berth, to carry a track at the general rail level of the port. This structure, which was driven from either end, was completed very rapidly. Thereafter 5-ton steam cranes were moved on to the trestle and employed to drive the sheet steel piling forming the front face of the berth. Similarly the cranes were employed to drive short lengths of steel piling to act as anchors for the front sheeting. Rubble was side-tipped from the trestle on the seaward side of the anchor piling, with the object of giving sufficient initial support to it before surcharge on the face piling could result. The filling was gradually brought up to the general rail level for a width of 27 ft. 6 in. on the landward side of the trestle. Again with the object or reducing surcharge, the coping was left at the lower level 108.00, the space between it and the trestle being sloped and pitched to the general rail level of 114.00. This proved an eminently satisfactory arrangement and suitable for the particular application which did not require to be worked as an ordinary berth. Subsequently the extensive pond formed between the works described above and the high-water line was filled in, mainly from material dredged from the entrance to the loch. The pile structures shown dotted in Fig. 6 relate to the

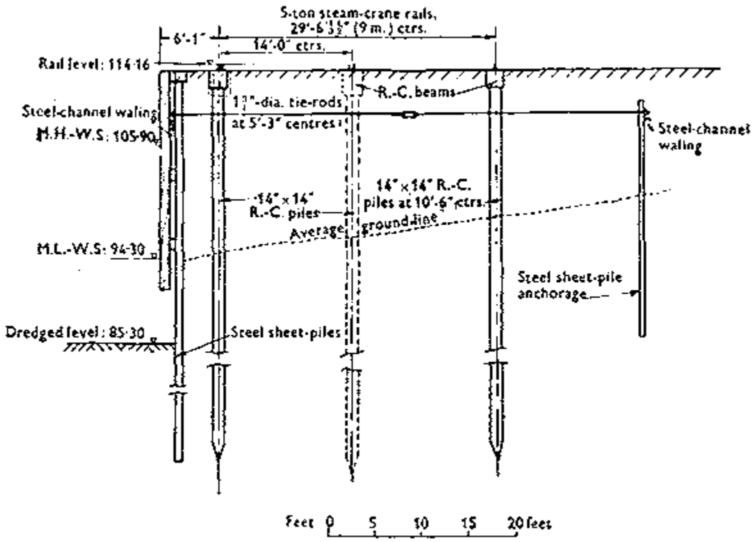


Fig. 7.—No. 1 Military Port. Cross-section of M.T. wharf.

heavy bollards and anchorages necessary for mooring the floating crane under the wind conditions which prevailed.

In the case of the M.T. wharf (Fig. 7), which was formed between the lighterage wharf and the deep-water wharf, the construction was of sheet steel piling for the face and anchorage, with the area behind filled with spoil from the back of Faslane Bay. On completion of filling, the area behind the wharf was covered with a tarmac surface and employed for parking tanks and vehicles awaiting shipment. Concurrently with the driving of the sheet piling, two lines of 14 × 14-in. R.C. composite piles were driven to carry R.C. beams which in turn carried the crane tracks which were at 29 ft. 6⅜ in. centres at one end, and 14 ft. centres at the other end of the wharf. This arrangement of supporting the crane rails independently of the structure was adopted so as to reduce the surcharge on the face piling.

Cairnryan. The first work was the tipping of a rubble bank out to the southern end of the line of lighterage wharf (Fig. 8). The rubble was obtained from a quarry a short distance away to the south on the main road to Girvan. On the end of the rubble bank a travelling derrick was erected which drove the piles, in this case all timber, forming the structure of the wharf. A second derrick followed up and laid caps, bearers and decking.

The south side of the lighterage wharf (Fig. 9) was constructed of sheet steel piling driven by a pile frame working off the rubble bank. The anchorage for the face piling was formed in the heart of the rubble bank by means of concrete blocks 2 ft. 6 in. × 4 ft. × 10 ft. long from which the tie rods to the sheet piling were carried. The space between the rubble bank and the sheet piling was filled. The large quantity of filling required for the lighterage wharf and adjoining area was obtained from an excavation opened out on the high ground immediately east of the main road. The spoil was worked from the excavation across the main road by a large fleet of scrapers working twenty-four hours a day. The excavation served the dual purpose of provid-

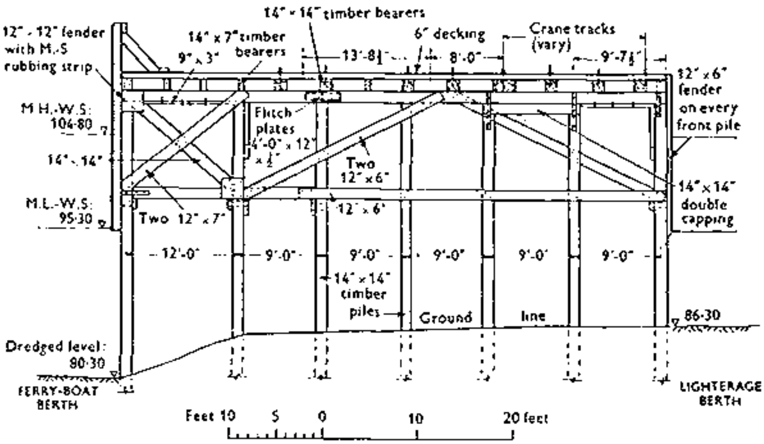


Fig. 8.—No. 2 Military Port. Cross-section of Lighterage wharf.

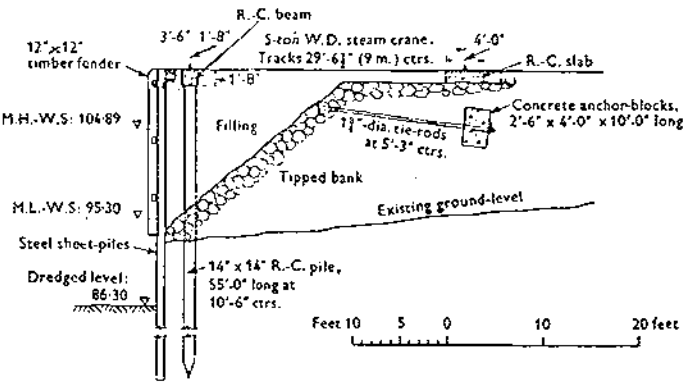


Fig. 9.—No. 2 Military Port. Cross-section of South Quay, Lighter Basin.

ing a vehicle park and furnishing the fill. Next, a rubble bank was tipped from the end of the lighterage wharf in a southerly direction to a point adjoining the main road and to enclose a large triangular area which was filled from the excavation and also with dredged material pumped into it. This area, which was subsequently top-dressed and given a surface of tar macadam, was employed as a tank and vehicle park.

The work on the lighterage wharf was pressed on at high speed, so as to allow of early loading by lighterage and also to form a haven for the large fleet of Thames lighters, tugs and other craft employed on the construction.

The first work in connexion with the construction of the deep-water berths was the driving of test piles from lighters equipped with pile drivers and derricks. A considerable amount of work was involved in this as, the results of early driving being unsatisfactory, it was necessary to make further trials of sets of four piles and also with various types and designs of piles, and to apply numerous test loads. The work was of a somewhat hazardous nature, as it was carried out in the winter of 1940 and seas rough for small craft had to be contended with.

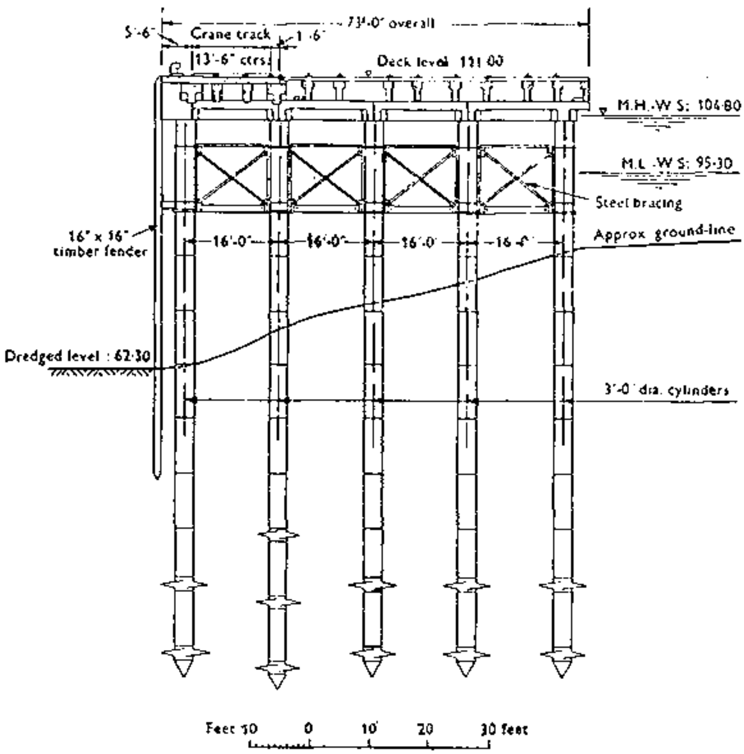


Fig. 10.—No. 2 Military Port. Cross-section of south deep-water wharf.

When the line of the wharf had been decided, early steps were taken to open up the work by tipping a small rubble bank and driving piles to form the approach to the south wharf from Cairn Point, a small promontory formed of a shingle bank. No difficulty was experienced in forming the approach, but, as piling proceeded, the unsatisfactory nature of the bottom, which was later to provide difficulties in constructing the south wharf, was discovered. On the decision being reached to employ screw cylinders throughout for the south wharf (Fig. 10), a number of lighters were equipped with plant required to screw the cylinders, and this floating equipment was employed until sufficient of the structure had been completed to allow of the screwing machines, specially designed for the purpose, being assembled. Portable electrically driven screwing machines, which were placed by a floating derrick on the cylinders to be screwed, formed part of the floating equipment. The derricks were each mounted on two lighters. Other lighters were employed for transferring the units of the cylinders and screws to the site and providing platforms on which these could be assembled. Anti-rotational devices for the capstans took the form of an elaborate system of anchors requiring constant attention and repositioning.

As the work opened out the two screwing machines were erected on the cylinders already screwed. As there were five cylinders in a bent, one machine was equipped to screw two cylinders in a bent and move forward, the other following and screwing the remaining three cylinders. In practice the

Photo 4.—No. 1 Military Port. Front of Screwcrete Wharf.

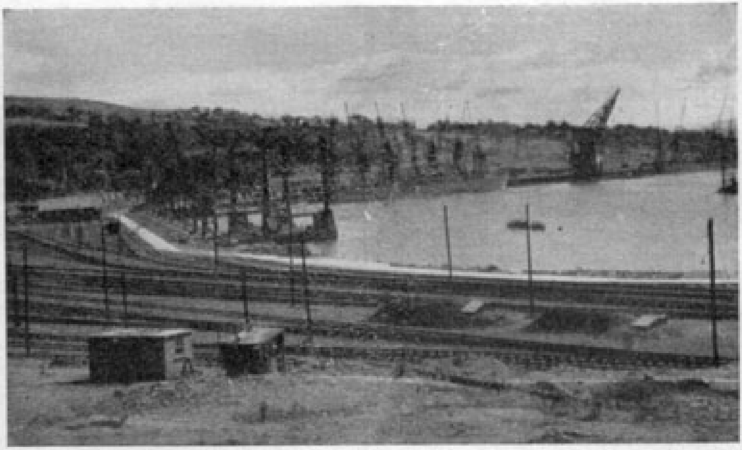


Photo 5.—No. 1 Military Port. Lighterage wharf and rail sidings. Deep-water wharf in background, and 150-ton floating crane alongside.

The Construction And Operation Of The Military Ports In Gareloch and Loch Ryan 4 , 5

Photo 6.—No. 2 Military Port. The deep-water wharf south, viewed from the heavy-crane berth.

Photo 7.—No. 2 Military Port. The shunting sidings at Leffnol, looking north.

The Construction And Operation Of The Military Ports In Gareloch and Loch Ryan 6 , 7

machine for two cylinders was too heavy and caused undue settlement of the cylinders on which it was mounted. It was eventually altered by fitting it with Samson posts and other equipment to allow of screwing being carried out by the portable electric capstan. The other machine, by the greater spread of loading on three cylinders, was successful. In all, about 540 cylinders were screwed, some 500 of these between March, 1942, and March, 1943; the best performance was twenty-two cylinders screwed in three consecutive eight-hour shifts. The fact that the cylinders had at least two, and some three, screws added greatly to the work, as did also the fact that the cylinders had to be made watertight for purposes of buoyancy in pitching.

Early steps were taken to establish at Old House Point, just north of Cairn Point, a large and well-equipped casting yard in which the composite piles and the large numbers of pre-cast R.C. units to form the decking of the south wharf could be prepared in advance of requirements. The yard, which was well laid out, was equipped with crushing and batching plants, and also with cranes and derricks to handle the units which weighed up to 10 tons each. It is thought that the programme for the R.C. units for the south wharf may constitute the biggest programme of heavy pre-cast work so far carried out. The wooden moulds employed were of excellent design and construction and, with the careful handling received, enabled many casts from each to be obtained without replacement.

In view of the unsatisfactory nature of the ground, it was decided to employ steel bracing between the cylinders. This bracing, which was designed to be placed with a minimum of diver's work, was only employed in certain parts of the wharf.

The decision to employ R.C. pre-cast units for the deck of the wharf was fully justified in practice. The units, prepared in advance, were brought up by rail from the casting yard to the wharf, where they were placed in position by the derricks following the screwing machines, and the rate at which the deck was constructed was remarkable, and could not have been approached by any system of *in situ* R.C. work.

At Cairnryan the construction was far more difficult than at Faslane, as the bottom conditions caused trouble, and it was only possible to build the south wharf by end-on methods, whereas at Faslane it was possible, once the back or timber portions had been built, to open out the work along the length of the wharf.

Dredging

Whilst the deep-water wharves were purposely sited about the 5-fathom contour line so as to avoid heavy dredging programmes, nevertheless considerable dredging was necessary at both ports. In the Gareloch, although a certain amount of clean-up dredging was done on the line of the deep-water and M.T. berths before construction commenced, the main dredging was begun at Rhu Point at the entrance to the loch, which, whilst sufficient to pass the type of vessels to be loaded, would have imposed restrictions and consequent delays due to tidal working. As large vessels, such as the P. & O. liners used as troopships, would use the port, it was decided to dredge the entrance to 30 ft. below chart datum for a width of 400 ft. and treat this as forming part of the work of building the port. This improvement to the entrance proved of the greatest benefit as, following its completion, many large ships, including battleships, used the Gareloch and berthed at the port.

Apart from serving a useful purpose in the war, the improved entrance is likely to prove a lasting benefit. In all, about 200,000 cu. yds. of dredging, including 150,000 cu. yds. from the entrance, was carried out by dredgers controlled by the War Office. Wherever suitable, the material dredged was used for reclamation work at the port, self-controlled pumping units being employed for placing the material.

At Cairnryan a more extensive dredging programme was required as, in addition to dredging alongside the berths and particularly the north berth which was sited on about the 3-fathom line, it was necessary to provide a turning circle and berths at buoys for large ships. In all, the dredging of about 550,000 cu. yds. was carried out, the material being largely employed for reclamation. It was also necessary to widen the entrance channel to Loch Ryan to 500 ft. with a depth of 24 ft. at M.L.W.S. Whilst this dredging, as well as that referred to above, was carried out by the modern diesel-electric drag suction dredger *Victor Guilloux* manned by the Free French, certain hard spots in the channel were removed by the heavily built dredger *Humber*. Opportunities were afforded by the dredging at the ports to train military personnel who manned the dredgers. The personnel thus trained were ultimately embodied in the Dredging Companies, R.E., which did good service throughout the world.

Some of the Difficulties Encountered

It is desirable in a paper on an engineering subject to record the difficulties experienced and the methods adopted to overcome them. It was to be expected that difficulties would be experienced in these large and varied works, and particularly so as the urgency precluded the following of the more prudent method of procedure normally adopted, whereby complete surveys are carried out and plans in full detail prepared before the work is commenced.

In all marine work the nature of the sea bed on which the work is to be founded is of the greatest importance if the method of construction and the plant provided are to be suitable. Important as this may be generally, experience on these works showed that it is of paramount importance in connexion with works carried out in the Scottish lochs, where foundation conditions may vary considerably on a site.

Borings were taken on both sites at the outset, but these proved of little value, partly owing to the conditions not being fully revealed by the borings and also due to the fact that dependence had to be placed upon the few borings which it was possible to take, whereas the nature of the sea beds eventually showed that true determination could only have been obtained by a series of close-pitched borings. Incidentally, the urgency for taking borings showed how ill-equipped harbour engineers are in general so far as sea-boring plant is concerned, for whilst land-boring equipment exists in plenty, when there is a request for sea-borings, improvisation results in mounting land rigs on craft generally unsuitable for the purpose. Subsequent events showed that the borings taken on the sites were of little value.

At Faslane it was found that the sea bed consisted of loch mud over broken rock, stones and sand, and it was accepted that it would be possible to screw the cylinders well into the bed. At the north end of the deep-water wharf this proved correct, as no difficulty was experienced in obtaining the desired penetration of 14 ft. As the work over the remainder of the site pro-

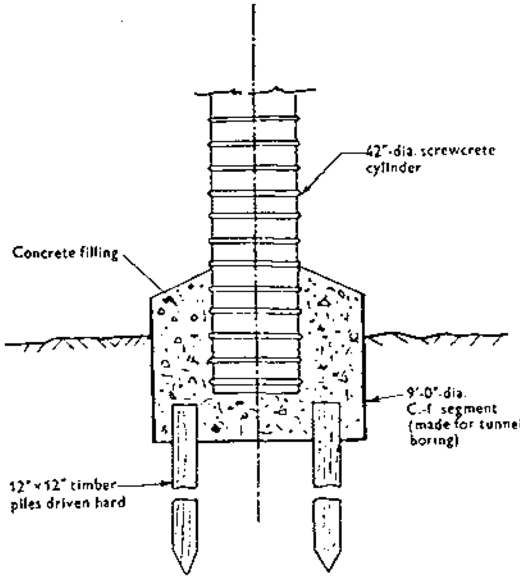


Fig. 11.—No. 1 Military Port. Footing for cylinders which refused to screw.

ceeded, however, screwing became harder until a point was reached when no more than 6 ft. of penetration could be obtained, this in spite of trials of a number of designs of nose caps, and the original intention of screwing had to be abandoned in favour of a system of founding the cylinders on piled footings (Fig. 11).

At Cairnryan the reverse of these hard sea bed conditions was met. In this case it was proposed to follow the same design as at Faslane, whereby the front portion of the wharf would be supported on screw cylinders and the back portion on piles. Test piles on the first section of the wharf were driven to a penetration of 90 ft. without set and, following trial of every known method of increasing the holding qualities of the piles, the scheme for the back portion of the wharf was abandoned in favour of one employing screw cylinders throughout the whole structure.

It is of interest that on one site the difficulties experienced were with the sea bed being too hard to allow of screwing the cylinders, and on the other site the difficulties arose through the sea bed being too soft for driving piles. At Cairnryan the conditions encountered caused a further change of design in the cylinders in that, in place of the screwcrete filled cylinders which were used at Faslane, hollow cylinders of cast iron, and later, to increase production, of steel, were employed, so as to reduce the deadweight of the cylinders. Even so, undue settlement of the cylinders occurred, but was successfully overcome by employing cylinders with two screws, and three screws under the heaviest loaded parts of the wharf. The use of additional screws, however, brought with it further difficulties in that the plant available for handling and pitching the cylinder with one screw was designed for 10 tons. With three screws the weight of the cylinder and screws on pitching was as much as 15 tons, but this was partially overcome by relying upon the buoyancy of the cylinders, which again required the provision of watertight joints between the lengths of cylinder.

Omission to cut a level bench on which to pitch the cylinders resulted in much work to prevent the cylinders from slipping down the bank. Some of the methods employed were to back screw the cylinders several revolutions before screwing, and thus level off the mud, pitching out of position to counteract the slip, and the use of underwater bridles to act as a check to slipping.

When the initial difficulties with screwing had been overcome and rapid progress was being made, it was reported that at bent 56 a cylinder refused to penetrate beyond 5 ft., and, after a great many ineffective revolutions, it was brought up and the point found to be highly burnished. Two 14 × 14-in. timber piles were then pitched and driven by a floating pile driver but "bounced" upon reaching the obstruction; on withdrawal scraps of oak were found adhering to the piles. Use was then made of the echo sounder equipment and, using the double echo of the mud and the obstruction, a fairly accurate plot of the latter was made, which showed some object, about 100 ft. long, shaped like a dish. Inquiry at Lloyd's elicited the information that in 1876 a sailing ship, the *Falcon*, had sunk in the Bay after a fire. She was of 135 tons register, carried a cargo of coal ex Glasgow, and was unattended when fire broke out, the crew being ashore. To remove the obstruction it was necessary to obtain the use of a heavy dredger from Ireland and dig out the hull, coal, etc. Following removal of the obstruction, the great hole left was filled in by dumping from bottom door hoppers, and screwing was renewed after a delay of five weeks. It was unfortunate that the obstruction should have been met, but the lesson to be learnt is that an echo sounder should be used to make a close survey of a site in advance of the work, to locate obstructions; and this was the practice thereafter.

The necessity for speed accounted for two instances of failure on the works, both connected with the use of rubble banks. At Faslane the lighterage wharf was a piled structure (Fig. 12), and from the deck, when completed,

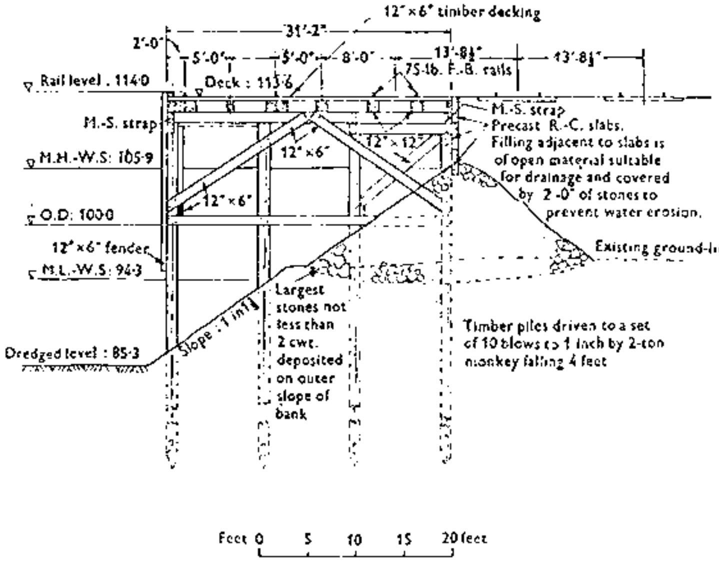


Fig. 12.—No. 1 Military Port. Cross-section of Lighterage wharf.

a rubble bank was tipped on the landward side to act as the retainer for the large amount of reclamation which was to follow. The rubble bank as formed allowed of water acting on the soft fill behind, and loss of fill occurred, with subsequent subsidence at the back of the wharf. This was remedied, but only partially, by dumping in the holes formed by the subsidence. At Cairnryan where the double railway track was laid on a formation on the sea side of the main road and protected by a rubble bank, the bank suffered heavy damage during a storm in the winter of 1942–43 when, for the same reason, the back fill was sucked out through the rubble. The reconstruction in this case consisted of forming the core of the bank of sand and gravel which was covered with an 18-in. layer of 6 to 8-in. stone. A concrete toe was formed well down in the beach at the foot of the slope and the face of the bank was finished with hand-placed stone with open joints. The bank withstood subsequent storms satisfactorily.

In the early days of construction at Cairnryan, difficulty was experienced with cracking and spalling of the piles when driven. The arrangements for casting the piles in the casting yard and the method and mixes employed were exhaustively examined, but no reason for the difficulty experienced was discovered. The slinging and handling of the piles on the driving site were found to be satisfactory. The method of transporting the piles between the casting yard and the site was next examined. This consisted of carrying the piles on bolsters on flat unsprung wagons, the wagons being hauled over the railway track connecting the yard with the site, a distance of ¼-mile. Although this method of carrying the piles over the short lead was not suspected, the cracking was eventually traced to vibration set up by the unsprung wagons passing over the rough rail joints of the contractor's type of track which was used. Alteration to the method of supporting resulted in no further failures.

Another instance of failure was in connexion with the M.T. wharf at Faslane. At the south end the ground falls away sharply and, owing to failure to employ a test pile, the 40-ft. sheet piles employed, after filling had commenced, kicked out at the toe for a length of 50 ft. The only course was to withdraw this length of piling and replace it with piles 50 ft. long.

Although the difficulties were great and caused disappointment to those controlling and carrying out the works, the vital importance of bringing the ports into use at the earliest possible time acted as a spur to all concerned. Throughout, the great drive and originality of thought and action of those on the sites overcame the difficulties and enabled the ports to be completed in what may be considered very creditable times.

Period of Construction

Following sanction in November, work at the two sites commenced in December, 1940, when the Cs.R.E. were appointed and the first troops moved in.

At Faslane the lighterage wharf was completed for use by the middle of 1941. The deep-water wharf was sufficiently completed and equipped with cranes to allow of H.M.S. *Fosbeck* to load a complete cargo of boom defence gear in early May, 1942, seventeen months after commencement of the works. The works were completed by December, 1942, twenty-three months after commencement, but loading had been continuously carried out, with increasing intensity, from May, 1942.

At Cairnryan the progress was not so good, due to the difficulties encountered, but the south wharf was completed by January, 1943, and the works as a whole were completed in July, 1943, thirty months after commencement. Here also the berths were taken into use as they became available and had been equipped with cranes.

Financial

In the author's view, no paper on an engineering subject should be considered complete without particulars of the costs of the works. Under war conditions, accurate costs of works carried out by the Army are not normally ascertained. As the works described, however, were of a heavy civil engineering character and carried out to all intents and purposes by civilian methods within the framework of the Army the author deemed it desirable to institute, from the commencement of the works, an approximate set of accounts.

General approximate estimates of the cost of the works were prepared and received Treasury sanction. A control account was initiated at each site to record all liabilities and expenditure on materials. At the same time complete records of labour in the form of man-hours for the individual portions of the work were maintained. The accounts were regularly audited by the appropriate Service accountants. The system of accounts adopted, whilst enabling the War Office branches to exercise control, also assisted the Cs.R.E. in charge to exercise economies. Apart from these advantages, the fact that accounts were kept served a useful purpose when a party of M.P.s of the Select Committee on National Expenditure, having heard rumours of large sums of money being wasted at Gareloch and Cairnryan, visited the works. It is gratifying to record that, following these visits, they were able to report that they had found the works being conducted in a most efficient manner and full accounts kept which, in their experience, it was unusual to find in such cases.

On the works being completed and it being desirable to close the accounts and ascertain the final cost, difficulty arose in determining the cost of a military man-hour, which had to include the heavy overheads in the form of supervision, housing, messing, clothing, leave, etc. On being pressed, and after the fullest consideration, the Finance Branch of the War Office advised that the over-all cost of a military man-hour should be taken as 1s. 10½d. After including the labour element, the accounts were finalized and showed that the cost of the work on the two ports was approximately £4½ million.

Operation of the Ports

It can be said with assurance that both ports, by relieving the civil ports of much heavy military tactical and stores-loading, fulfilled the purpose for which they had been built. The useful facilities provided within the ports, which were enclosed as military areas, and the opportunities afforded for working continuously without fear of labour troubles, were appreciated and made full use of by the Services.

The operation of the ports was carried out by Port Operating Stevedore, Port Maintenance, Crane, I.W.T., Railway Construction, Railway Operating Companies, R.E. The Port Commandants and the officers under them on the berths had all carried out ship loading duties in civilian life. The Ministry of War Transport exercised their responsibility in connexion with loading military cargoes by officers of the D.S.T.O. stationed at the ports.

Military cargoes, consisting as they do of a great variety of items including tanks, vehicles, plant and stores, call for the highest skill in loading. Tactical loading, comprising the vehicles and stores of a unit so as to ensure that all the equipment is stowed to allow of discharge in a correct order to suit military operations, particularly calls for skill. This type of loading was employed in connexion with the North African landings, a large part of the loadings for which was carried out at Faslane.

In many cases where secrecy had to be maintained, the ports were of great value, for instance the putting into the sea at night of the first midget submarine, which arrived at Faslane heavily camouflaged, and thereafter all craft of this type; the embarkation at Faslane of Mr. Churchill and party in the cross-Channel steamer which took them to the *Queen Mary* lying at the Tail of the Bank for the passage to Canada for the Quebec Conference; and the embarkation at Cairnryan in 1942 of T.M. The King and Queen in a cruiser which took them on their secret visit to Northern Ireland.

H.M. Navy made numerous requests to be allowed to utilize the berths, and these were readily agreed to so long as the usage was of short duration and did not interfere with the main object for which the berths had been provided. In all, the Navy found the ports of great value, as there were numerous instances of assistance to ships in cases of urgency, storing or de-storing, and gun mounting; for example the regunning of H.M.S. *Malaya* prior to the Normandy invasion, for which purpose the 150-ton crane was employed.

Faslane had almost continuous demands on it for heavy lifts, which in war are far more frequent than in peace-time. These consisted of the discharge of locomotives, and other heavy lifts, from the decks of commercial vessels which then proceeded to their normal ports of discharge. In the latter stages of the war, most tankers from U.S.A. carried anything up to thirty aircraft on special trestles prepared on their decks. All these tankers came to the Faslane wharf where the aircraft were discharged. The tankers then proceeded to their oil berths and the aircraft were reloaded on to small power vessels for discharge at Renfrew. The normal time for clearing a tanker of aircraft was one and a half to two hours, and on one occasion six tankers were discharged in the course of one day.

The ports had also to deal with cargo involving risks which could not be accepted by other ports. An example was the clearance of a number of store ships in which, owing to the petrol being consigned to North Africa in "flimsies" and stowed under the instructions of the D.S.T.O. despite the advice of the officers of the port, loose petrol to the depth of 3 ft. was found in the lower holds. These ships, on return from North Africa, were sent to Faslane, fires drawn, the crews taken off, and the military given the task of cleaning them. This most unpleasant and hazardous work, carried out in shifts of five months, was accomplished without accident, but only due to the skill and high standard of discipline maintained.

Throughout, those in charge of the ports, their skilled staffs, and the military personnel showed general keenness and a full appreciation of the importance of the work upon which they were engaged.

Logistic Flexibility for Our Land Forces

By Major-General G. S. Hatton, C.B., D.S.O., O.B.E.

(The views expressed are the author's own and do not in any way reflect official opinion)

Subject

"If our Land Forces are to have battle mobility it is essential that they should have administrative flexibility. At the same time, the destructive power of nuclear weapons complicates the logistic pattern. Discuss the ways in which administrative flexibility might be achieved."

(This article was the runner-up for the Bertrand Stewart Prize Essay for 1957. The winning article was written by Colonel R. A. Barron, R.E., and was published in the Army Quarterly, *January 1958.)*

Introduction

British strategy, tactics and the logistic support on which they are dependent for success must take account of both "hot" and "cold" war problems, as, to quote Field-Marshal Lord Montgomery, "The true object of all military thinking today must be how to combine most economically the military measures needed for success in the 'cold war', with the development of the military strength needed to convince our enemies that a 'hot war' would result in their own destruction." [1]

The logistic pattern of our Land Forces should, therefore, be capable of satisfying a three-fold range of warfare:—

"Cold War"	Operations, either in concert with our allies or independently, as for example: those we have had against the communist guerillas in Malaya and the Mau Mau in Kenya; lesser terrorist activities and normal duties in aid of the civil power.
Limited "Hot War"	Peripheral operations, probably with allies, like those in Korea and at Suez; where the limitations were firstly geographical and secondly of weapons.
Global Nuclear War	The only unlimited war in this nuclear age would be nuclear, waged in co-operation with our NATO and other allies. "The trend is towards the creation of integrated allied forces."[2]

It should, moreover, be accepted that the effort to avert and, if necessary, to survive the greatest danger, global nuclear war, must be the dominant consideration.

There is no obvious distinction between nuclear and atomic weapons. The writer, therefore, proposes for simplicity to use the word "nuclear" in relation to war and "atomic" in relation to weapons; both in the general sense covering: fission, fusion and fission fusion reactions; and also to refer to missiles producing no radioactive "fall-out" as "clean" and those producing "fall-out" as "dirty."

[1] *A Look Through a Window at World War III*, page 1.
[2] Defence White Paper 1957, para. 11.

As one contemplates the almost imponderable struggle for survival produced by even a few days nuclear attack and tries to evaluate the resulting command, logistical, physical and physiological problems, military and civil, there is a frightening vista of: widespread devastation, millions dead and dying, disrupted communications and other public services, and impotent administration with public morale at breaking point. One of the most challenging of these many difficult problems will be provision of logistic support for our Land Forces.

There is no evidence to suggest that the advent of atomic missiles will produce any changes in the principles of war, but there will be fundamental changes in the application of those principles; especially in the application of those logistic principles which should guide us in determining the logistic pattern of our Land Forces.

To avoid ambiguity the writer does not use the word administration but uses the term logistics[1] to cover: mobilization, movement and maintenance.

To confine this paper within permissible limits, it is assumed that:—

The global commitments of our Land Forces will be somewhat reduced and the means of meeting them will change, including the elimination of the commitment to provide two reserve divisions as NATO reinforcements.[2]

The present financial burden of Defence must be greatly reduced and our Land Force's share of any available defence funds will probably get smaller.

Our active forces will be mainly regular but National Service, in some form or other, will continue as long as it is essential to our manpower requirements for defence, including Home Defence.[3]

In any future global war we must be prepared for nuclear attack from the outset with little, if any, warning.

This paper will examine: the nature and effect of nuclear war, the commitments and organization of our Land Forces, the principle of flexibility in relation to other logistic principles and finally the ways in which logistic flexibility for our Land Forces may be achieved. It will, therefore, continue in three parts:

1. Nuclear warfare and our Land Forces,
2. Flexibility and other logistic principles,
3. Ways of achieving logistic flexibility for our Land Forces.

PART I

Nuclear War and Our Land Forces

Global Nuclear War

Both the NATO forces and those of our potential enemies possess or will possess atomic weapons and the means for delivering them almost anywhere. In future, no area will be safe from attack.

It can be accepted that the enemy's strategic aim will be to destroy the morale of our people and our allies; and consequently our will to win or to continue the war. At the same time, they will attempt to assure their own

[1]U.S. Army Definition of Logistics: "Logistics is that branch of administration which embraces the management and provisions of supply, evacuation and hospitalization, transportation and service. It envisages getting the right people and appropriate supplies to the right place at the right time and in proper condition."

[2]See Defence White Paper, para. 57.

[3]See Defence White Paper, paras. 42, 48 and 51.

ability to continue the war. It follows, therefore, that their primary strategic targets are probably our own and our allies' strategic air bases and any inter-continental ballistic missile launching sites; those next in pirority would be large centres of our own and allied population. These latter centres are also important industrial areas and focal points of communication, many of them ports, which react on the logistic support of our military forces.

The enemy's tactical aim we can also safely assume will be to destroy, neutralize or by-pass the NATO land forces in the Combat Zone and to destroy or immobilize their reserves and their logistic support in the Communications Zone. It follows that the immediate tactical aim of the NATO land forces, and consequently of ours, will be defensive—an active mobile defence—i.e., to protect: our people, our airfields, our bases and to aid Civil Defence to sustain public morale.

There is likely to be a wide range in the yield and targets of atomic missiles. For simplicity it is convenient to divide both into two categories: strategic and tactical. The yield of strategic missiles may be assumed to be in the low megaton range delivered either by piloted aircraft or rockets and the yield of tactical missiles in the low kiloton range delivered either by rocket or cannon. The difficulty in forecasting the enemy's choice of Ground Zero and the inaccuracy of delivery of strategic missiles makes their precise yield relatively immaterial. Similarly the enemy's difficulty in locating tactical targets together with consequential inaccuracies in aim and delivery make the precise yield of their tactical missiles unimportant.

Typical damage figures from the tables published by Mr. Swain of *Power Magazine*, August, 1954, are:—

Warhead	Radius of damage in miles				Area of damage—square miles				Total area affected sq. m.
	Complete	Severe	Moderate	Partial	Complete	Severe	Moderate	Partial	
1 Kiloton	0.18	0.37	0.59	0.74	0.11	0.33	0.66	0.63	1.72
5 Kiloton	0.3	0.6	1.0	1.25	0.30	0.90	1.95	1.80	4.95
5 Megaton	3.1	6.3	10.1	12.6	30.2	94.8	195.0	179.0	499.0
10 Megaton	4.0	7.9	12.7	15.9	50.0	146.0	311.0	287.0	794.0

Complete destruction is self-explanatory. Severe damage translated into military terms means that neither personnel, stores nor equipment, other than tanks and other armoured vehicles, are likely to survive unless in high-grade shelter, preferably underground—all bulk petrol storage should be below ground. Moderate damage would normally not affect personnel or stores protected by trenches or traverses, although some dislocation would result in the latter case. Partial damage would only affect personnel in the open and destroy inflammable material.

All damage areas are, moreover, likely to be affected by radioactivity initially as will other areas in a cucumber-shaped "fall-out" pattern down-wind, of the burst of a "dirty" missile. The area affected by lethal radioactive "fall-out" from a "dirty" missile is about sixteen times its damage area, e.g., for the five megaton bomb, 8,000 sq. miles. Some areas will be unapproachable for a long time and delay in the use of stores, vehicles and equipment over a large area must be expected. Protection against radioactivity is achieved by placing either distance or a mass of material (shielding) between the soldier and the radioactive substance, e.g., mobility or armour, or a compromise of both. The slit trench with some head cover has gained rather than lost value.

The Geneva Convention has become nearly meaningless as the Red Cross can no longer be respected and food and water may be poisoned by radioactivity. Contamination of water by "fall-out" is unlikely to present serious problems, but this must be considered as must the protection of food.

It is important to note, therefore, the very marked difference in the yield and effect of air-burst and ground-burst missiles.

It would seem that, normally, missiles used against strategic targets will be "dirty" that is "ground-burst" either: on a target, to cause destruction and deny reoccupation of a large area by "fall-out", or upwind to deny occupation or use of a target while avoiding its destruction, e.g., a city or a bridge. "Clean" missiles, that is, air-bursts, are only likely to be used against targets to cause maximum destruction over a large area which it is intended to occupy immediately.

Missiles used against tactical targets, on the other hand, we may assume by the same process of reasoning, will normally be "clean": that is air-burst (or of so small yield, that there is no significance in their being ground-burst) causing maximum destruction without any significant "fall-out."

To sum up, the strategic missile will normally be a large "dirty" one and the tactical missile a small "clean" one.

There is likely to be a less clear distinction between strategic and tactical targets than between the yield of these missiles. The means of delivery of tactical missiles, now rocket or cannon with ranges from 8 to 100 miles exist and will soon replace or offer alternative missiles for the conventional weapons of the division—divisional weapons are likely to have missiles with a smaller yield than 1 kiloton. Strategic targets have been indicated; the targets for tactical atomic missiles may be expected to be:—

Major concentration of forces,
Major concentrations of logistic units and support,
Vital communication centres.

Geographic or natural obstacles augmented by demolitions, including atomic demolitions,[1] have increased in importance as they canalize movement causing vulnerable concentrations of forces or logistic support—targets for atomic weapons. The military importance of meteorological conditions and consequently of meteorological information as affecting "fall-out" patterns must be noted. In this connexion, the prevailing winds which are from west to east offer great advantage to the NATO forces in Europe as do atomic strategic demolitions; both these advantages are, however, discounted by the presence of Allied civilians in the combat zone.

The inevitable devastation caused by atomic weapons and the consequential destruction of: land line communications, road and rail movement may be augmented by the presence of civilian refugees. The total effect may considerably restrict tactical mobility and the effectiveness of command. The

[1]For the first time we have an obstacle automatically covered by fire, i.e., radiation.

difficulty of moving reserve forces and logistic support in nuclear warfare, therefore, places a premium on their correct initial positioning and dispersal.

The availability to our Land Forces of atomic tactical missiles delivered by rocket and cannon will largely replace the need for tactical air forces except for reconnaissance, surveillance and intercommunication.

Certain deductions concerning the organization of our Land Forces for global nuclear war may now be made:—

Our active peacetime forces must be up to strength and at all times ready to fight; all mobilization arrangements should be streamlined and local to the theatre of operations.

Our reserve forces, including those with a Home Defence role, should be: equipped, mobilized and positioned for their specific task, taking due account of enemy's probable targets.

The range and area effect of our tactical atomic missiles, especially the effect of the "dirty" missile, is such that control of atomic weapons should be centralized in the highest formation that can exercise such control effectively. Therefore, except for atomic warheads for conventional support weapons, most atomic weapons are unlikely to be organic to the division.

In the battle area there will be atomic, possibly "dirty", and non-atomic, certainly "clean", fire zones. Thus our divisions will tend to operate dispersed on wide fronts covering vital ground and centres of communication, as in the Western Desert from '40 to '42. Continuous surveillance of the atomic fire zone is necessary, including periods of darkness and poor visibility. Much of this surveillance can be done by radar and infra-red rays, but patrols will still be necessary.

Even before the provision of atomic warheads for divisional weapons, there can be a reduction in the volume of conventional fire support per gun due to the support available from Corps rocket regiments.

The division should no longer remain either the largest or smallest formation of all arms in peace. We already have a Corps in peace. We have had independent brigade groups and the most recent armoured divisional organization is but an independent brigade group with a divisional headquarters capable of commanding additional formations.

To quote Field-Marshal Lord Montgomery, "Powerful, compact fighting divisions of all arms are what we need for unlimited nuclear war, capable of sustained fighting without reinforcement. The system of control within the Corps must be simple and, should it break down, the divisions must still be able to fight. The Corps will contain three or four of these powerful divisions. A Corps must be able to fight without the interlocking support of other corps."[1]

Limited War

Since World War II our Land Forces have been engaged in two limited or peripheral hot wars: Korea and Suez. Neither campaign involved the use of atomic missiles; in both we had air superiority and employed World War II tactics and techniques and used approximately one division. Otherwise there was little similarity between the two campaigns.

Korea was far the "bloodier" of the two yet it did not reveal the weakness in the mobilization and movement capacity of our Land Forces that Suez did. Korea developed relatively slowly for us and in a favourable political

[1] *The Panorama of Warfare in a Nuclear Age*, page 7.

atmosphere. Suez, from the original Egyptian annexation of the Canal to the cease fire, was the most severe test of the mobility of our Land Forces since World War II and was conducted against a most unfavourable political background.

The danger in the Suez crisis was not the Egyptian Forces, but the danger of external intervention. It was essential for success to present our potential enemies and well-meaning, if misguided, friends with a military *fait accompli* before international political pressure could call a halt to operations.

The best time for military action was unquestionably when the Egyptians first created a breach of their international obligations by forcibly seizing the Canal; but our forces were unprepared for immediate action. By the time mobilization and concentration of adequate forces had been achieved, the opportunity for action in a favourable political atmosphere had passed.

At the second opportunity there was again a delay, this time more difficult to understand, between the initial ultimatum to Egypt and Israel and the employment of our Land Forces. In consequence, military operations were overtaken by political events before more than one-third of the military objective had been seized. In addition, the Canal was blocked for months and we lost considerable military prestige and what little remained of our Middle East base.

The new lessons from Korea were: the more than creditable performance of the National Service Soldier; co-operation and integration with allied and Commonwealth forces and logistic lessons related to terrain, climate and length of communications, notably the size and extent of the "pipe line."

In the Suez crisis there was, in the military sphere, a lesson of major importance: the tempo of modern war and its logistic consequence. It would appear that our Land Forces lack the battle mobility essential for initial success in peripheral or global war. This lack of battle mobility would appear to be chiefly due to lack of logistic flexibility especially in the sphere of mobilization and movement. The latter probably due to shortages in air lift and landing craft.

While recognizing that the need to ensure success, avoid civilian casualties and curtail our own military casualties complicated the Suez operations, it would appear that either: our aim exceeded the logistic possibilities; or there was a reluctance to accept calculated risks—risks which were justifiable.

There are, therefore, certain questions that should be asked, not in carping criticism, but as generally applicable to the achievement of logistic flexibility in the future. How much was sent to the Middle East that was not wanted and why? How much was wanted that was not sent in time and why? How can we expedite our mobilization and movement facilities?

In any future peripheral war we cannot be sure that the limitations will extend to weapons. Both sides may have to disperse their forces as if for nuclear war in case it should happen; as it nearly did in Korea. Large concentrations of troops on the scale of World War II are becoming less likely. We cannot, however, depend on atomic weapons alone. We have to have conventional Land Forces with a weapon family capable of firing either atomic or conventional missiles.

In peripheral war the division needs to be more self-supporting even than in global nuclear war, but its composition and the nature of its self-support will vary with the climate, topography and length of "pipe line" from the nearest advanced base.

"Cold War" Period

In considering the "cold war" period, it is unnecessary here, even if it were possible, to make an appreciation of the size and distribution of the Land Forces we require. It is convenient, however, to consider the operations or tasks of these forces in four general areas:—

The Far East
The Middle East
Europe (excluding the U.K.)
Elsewhere

The Far East commitment necessitates the existence of a theatre headquarters and Land Forces, say one or more divisional formations, including the Commonwealth Strategic Reserve, with little armour and augmented by locally-raised forces.

The Middle East[1] commitment necessitates the existence of a theatre headquarters and Land Forces; including one or more divisional formations, with some armour; and also certain small garrisons like Gibraltar. These garrisons should again be reduced by the use of locally-raised forces.

Our commitments to NATO in Central Europe necessitate providing, during the "cold war" phase, a theatre headquarters and a Corps of several divisions. The organization of these forces is dictated by the requirements of global nuclear war and has already been discussed.

Elsewhere the problems are local and do not require a theatre headquarters nor the presence of any divisional formations. It is a limited commitment to provide certain units and other garrison troops, which should be still further reduced or replaced by locally-raised forces.

In the "cold war" the requirement is much more for men than for "fire power" or machines; the type of mobility required also differs from nuclear war.

Land Forces in United Kingdom

The requirement in the United Kingdom is for a command structure, and the necessary reserve forces and training organization to enable us to meet our commitments for: the "cold war", peripheral "hot war" and global nuclear war. The reserve forces should, therefore, comprise an active central mobile reserve (at least one division) and certain non-active divisions for Home Defence. The initial Home Defence role is aid to Civil Defence.

Our non-active reserve formations, due to lack of equipment and training and to other difficulties, have got more and more out of step with their active counterparts. Their ability to mobilize and their rate of mobilization is archaic even for a Civil Defence role.

Our Land Forces Divisional Organization

There is, therefore, need for a divisional organization suitable for our active forces: in Central Europe, the Middle East, the Far East and as our Central Reserve; and also for the non-active reserve force in the United Kingdom. The divisional requirements for these five commitments vary. There is a conflict between the "cold war" and limited "hot war" need for manpower within the division and the nuclear war requirement for more "fire power", more machines and a smaller ratio of manpower to "fire-power" and machines.

[1]"Apart from its own importance the Middle East guards the right flank of NATO." *Defence White Paper*, 1957, para. 26.

Therefore, the divisional organization should be flexible, consisting of certain "basic elements" common to all divisions: active or non-active. To the basic elements the necessary additions can be made as required. The simplest type of division with the lowest common denominator of units is obviously the non-active reserve type division with its initial Home Defence role. To this basic division, "bricks" can be added according to the role and theatre conditions to produce:—

A "nuclear war" division—(Central Europe)
or
A "light" division—(Central Reserve)
or
A "peripheral war" division—(Far East or Mid-East type).

Just as battle mobility depends on logistic flexibility, so the ways of achieving logistic flexibility, within the division, depend on the nature, size, number and organization of the "teeth" arm components of the division. At the present time, our Land Forces are about to be reorganized and the divisional organization is uncertain. It is, therefore, proposed to assume: first a tripartite organization as basic for all formations and units within the division, and secondly, to enable the division to operate over wide areas in different theatres and different wars, brigades easily made into self-sufficient brigade groups.

Let us, for simplicity of discussion, assume a basic infantry division of three infantry brigades to which units of armour, artillery, engineers and signals can be added as required by the role of the division. Each brigade to consist of the following basic elements: headquarters and signals with three battalions of infantry to which armour and artillery units, each tripartitely organized, can be attached as required. Each battalion to comprise three companies, each selfcontained with support weapons and comprising three rifle platoons of three sections of seven to ten men.

For nuclear war our active divisions in Europe will normally be part of a corps, should have a great defensive capacity with, or supported by, atomic weapons; this type of division should have extra artillery and armoured units. For cold wars and limited hot wars our active divisions need an offensive capability and light equipment. These requirements should determine what extra types of units are required.

For simplicity, economy and flexibility all divisional weapons designed to fire atomic missiles in global nuclear warfare should also be capable of firing conventional-type missiles. Units with other types of atomic weapons should be corps troops.

To obtain some idea of the changing nature of logistic support, we require to examine the extent of the changes in the manpower, vehicles, equipment and ammunition requirements of "teeth arm" units that should result from the substitution of tactical atomic weapons, mainly in artillery and armoured units, for conventional weapons and ammunition.

It appears reasonable to assume that, after allowing for "over-killing", the ratio of yield to weight of atomic missiles will show a hundred-fold increase over conventional missiles fired from the same or equivalent type of weapon. Therefore, in theory, the number of such weapons that is required in a division could, by the use of atomic warheads, be reduced to one-tenth and still need only one-tenth of the ammunition supply for the reduced number of weapons to produce the equivalent fire support for the division. If, for organization efficiency and other reasons, we only assume a reduction of one-fifth in the number of weapons and one-fifth in the scale of divisional ammunition reserves, we have still doubled our fire-power and doubled our potential divisional ammunition reserve.

For nuclear war and possibly peripheral war, the infantry and engineers of a division require armoured personnel carriers for battle mobility, say enough for one brigade group; but in other roles the division only requires a training scale of armoured personnel carriers. We shall require more not less engineer units, but their transport and equipment require to be modernized.

A general idea of the elements of the basic division and the "teeth arm" bricks to be added for nuclear war has been given. It is suggested that the "teeth arm" bricks, for the Far and Middle East theatres, might be provided by the addition of a fourth rifle company in each battalion plus artillery, and armoured units, e.g., armoured cars, as required in the division or brigade by local conditions.

The "bricks" for the Middle East division or divisions present difficulties; since in addition to their "cold war" and "peripheral war" tasks, they may be involved in global nuclear war to protect the right flank of NATO. It would be presumptuous to suggest here what type of organization best meets these conflicting requirements; in fact, the organization may have to be changed at different times in accordance with the emphasis of the period. It is, however, maintained that the addition of "theatre bricks" to the basic divisional organization would provide the flexibility on which this decision or any later change can most readily be made.

The major difficulty will be to provide suitable "bricks" for the strategic reserve. The "Light Division" must have air-portable equipment and vehicles and each battalion should have a fourth company, or each brigade a fourth battalion, to provide parachute units. The present system of training and organization of paratroop units might be simplified by following the practice in the Canadian Army for their airborne forces.

Remembering that we have still to add the logistic element at each echelon of command, we see that the manpower and vehicles of the infantry units and formations of the basic division are of the following order: the basic battalion 400/600 fighting men[1] and some sixteen vehicles[2]; the basic brigade 1,500/2,100 fighting men[1] and some sixty vehicles of only two types.

We now have a rough estimate of the requirements of the divisional "teeth" arm units in: manpower, weapons, vehicles and equipment on which to plan changes in the nature and extent of logistic support.

PART II

Flexibility of other Logistic Principles

General

The application of one principle to a situation frequently involves the partial breach of another. As flexibility is but one of several logistic principles it must, for our purpose, be considered in relation to simplicity and economy.

Flexibility is defined as "pliancy; adaptability; freedom from stiffness or

[1]Depending on the size (seven or ten men) of the infantry section decided upon.

[2]One jeep and three armoured personnel carriers per company, the A.P.C.'s normally used for support weapons and ammunition.

rigidity."[1] In the operational sense it means the ability to move formations rapidly from one area to another. The logistical corollary is the ability to support such changes by "holding" stocks and transportation facilities where they can be rapidly diverted to meet operational needs. The first essential of any form of flexibility is mental flexibility.

"It takes little skill or imagination to see *where* you would like your army to be and *when*; it takes much knowledge and hard work to know where you can place your forces and whether you can maintain them there."[2]

A good logistical plan is almost always a simple plan, yet the subject of logistics is in itself complex. These complexities increase with the variety of weapons, ammunition and equipment of modern war, intensified by the presence of allied troops and, now, atomic warheads! Moreover, a simple logistic plan for the Land Forces may well conflict with the essential functioning of the other services, e.g., use of ports or air lift.

Economy in all branches of logistics is essential. Manpower wasted in handling unnecessary material or staffing non-essential units is lost to fighting units and increases the logistical overheads. The need for dispersion tends to conflict with the principle of economy, but is essential provided there is not over-insurance.

Inter-Service Implications

The sum of all three principles, flexibility, simplicity and economy, indicates the increasing need for Joint Service concepts; especially for logistic support and the associated technical services which should be co-ordinated and developed on a Joint Service basis. "Theoretically, the ideal would be to combine all military functions into a single Service"[3]—a beginning might be made with a single logistic Service. In the meantime, some amalgamation of services in our Land Forces should be examined. The increased powers of the new Minister of Defence seem to indicate that there is to be a new approach to these vital problems.

In nuclear war tri-service logistic flexibility is essential; embracing as it frequently must: the switch of formations; the switch of ports; a careful balance of dispersed stocks, in both forward and rear areas; alternative means of communication by land, sea and air; and the availability of reserves, particularly of transport and labour to meet conflicting demands.

There are other fields for common endeavour; tri-service holdings of common-user stores would facilitate economy and dispersal, by utilizing the depots of the three services for common holdings—unfortunately, many of these depots are located in urban target areas and should be replaced to reduce vulnerability and increase flexibility.

Replacement v. Repair

In view of the relatively short time the first phase of nuclear war may be expected to last, it is logical that replacement and not repair of vehicles and equipment should be the order of the day. Except for the simplest and quickest repairs on the spot, there will be little opportunity for evacuation to workshops and less time for repairs. This change of policy would greatly reduce our holdings of spare parts. In peace, repair must continue on present scale, but this is mainly done by civilians.

[1] *Oxford Dictionary.*
[2] Field-Marshal Lord Wavell.
[3] Field-Marshal Lord Montgomery in *The Panorama of Warfare in a Nuclear Age*, page 14.

Standardization

The difficulties of achieving any very marked degree of standardization, except for food and fuels and the frequent conflict of standardization with international and national economy, are very real; but the obvious flexibility which cross-servicing with allies can produce makes it essential to increase standardization. The four main categories to which standardization should be applied: ammunition, weapons, vehicles and equipment, are now considered.

Ammunition is not only the most important component of logistic support but shows the best progress towards standardization and is the easiest category in which to achieve standardization. There is little conflict in this field with either national or international economic effort. Weapons again show some progress towards standardization, e.g., the F.N. .300 rifle. Production rights can be obtained and home production organized. The fact that all the NATO forces are tending to adopt atomic weapons at the same time should greatly facilitate standardization. Military vehicles present much greater difficulties as their production conflicts with both national and international economy. The standardization of vehicles, however, is less important except within each formation, if we accept the idea of replacement instead of repair as part of our short-term logistic policy for nuclear war. The standardization of equipment, except for vital electronic equipment, which must be treated as weapons, is not as important as the other categories.

Standardization on a tri-service basis is also most important where practical; but again there is a possible field of conflict—tri-service standardization or Allied Land Forces standardization. Which is to have preference?

Personnel Problems

There are sure to be heavier casualties in nuclear war than ever before, but fewer casualties are likely to be evacuated from the division or corps area if, in fact, they have any better chance of living by being evacuated. It would seem reasonable to deduce that only very serious casualties, especially surgical cases, would be evacuated; radiological cases would be retained with the formation and the medical units of a division will have to care for larger numbers of casualties. Any casualties evacuated should go direct to hospital.

Remembering that the Geneva Convention is meaningless in nuclear war, the problem of siting hospitals and other medical units to give the maximum chance of survival to casualties is difficult; large cities will be targets, tented hospitals offer no protection against "fall-out" and hospitals and other suitable buildings in small cities and towns will be at a premium due to civil requirements. To offset these difficulties there is, however, one asset: the transport used for evacuation need no longer return empty; it can transport reinforcements or stores on the return trip.

The previous practice of leaving certain key personnel out of battle (l.o.b.) now appears meaningless. First reinforcements must be in the theatre and the best place to hold them would appear to be with their units. Other reinforcements would, it appears, be better held in the U.K. base, where presumably any who are available will be located and, when possible, sent direct to formations for units. The Far and Middle East theatres would probably have "to live on their own fat" in nuclear war, i.e., use up the resources of their fourth company, etc. The inflexibility of the regimental system in the infantry and armoured regiments is again emphasized by a study of this problem of reinforcements. Reinforcements will be by arms but not by cap badges!

Divisional Implications

The efficiency of our tactical atomic missiles should, as has been shown, enable us to make very considerable reductions in the number of support weapons and the scale of first-line ammunition holdings within the division. These reductions and the consequential economics in manpower, vehicles and equipment in the "teeth arms" will permit corresponding reductions in the second-line holdings of food, petrol and ammunition; and therefore in the manpower, vehicles and equipment of the division's logistic "tail."

Two other logistic economies which are possible within the division are: first a reduction in workshops' facilities and scale of spares due to a policy, in the initial phase, of replacement rather than repair; and secondly further reductions in second-line transport due to an army air lift.

Second-line transport normally goes back to fetch replenishments and often lives outside the divisional area. Would it not be better policy for each echelon of transport, commencing with Unit "B" echelon transport, to be controlled by the next higher formation than at present; thus replenishment would then be sent up rather than brought up. This new concept becomes particularly important with an army air lift replacing part of the second-line road transport, both of which should be under unified control.

The yield and destructive power of the enemies' weapons should discourage any major reductions in medical units; but these units require to be modernized, especially as regards transport and equipment.

Our peace and war establishments and equipment tables require overhaul to facilitate and expedite mobilization and to eliminate non-essentials—more peace equipment might well be "barrack stores". Too many units are, like the White Knight, overburdened by their war equipment tables with everything they might need. There is considerable scope here for economy, simplicity, standardization and consequent flexibility by having "basic elements of war equipment" with the addition of "theatre bricks". This concept also enables the maximum use to be made of local resources. We must also remember that in nuclear warfare we shall be fighting defensively. The implications of "cold war" and limited "hot war" equipment are covered by the concepts by "barrack stores", "basic elements" and "theatre bricks" of war equipment.

To achieve economy in manpower, especially staffs, and to free commanders for their proper functions of command, commanders at all levels, and especially the regimental commander, should be freed from some of the present peacetime administrative burden by greater decentralization of financial powers.

Logistical Philosophy

The previous steady progress of most items of replenishment from Base via Advanced Base to Army Maintenance Areas and/or Corps Maintenance Areas and then to divisional and other meeting points is now: too rigid, too extravagant in labour (handling) and transport, especially if second-line transport were allowed to remain organic to the division. For example, at any one time, due to enemy action, one formation might have to be maintained by air delivery; another by air drop and a third by road transport.

We require a more flexible system of maintenance so that items may go forward to fighting formations by whichever of several means is most suitable and direct from whichever maintenance area or base depot is most suitable, be it: C.M.A.; A.M.A.; Advanced Base or Base. Both a flexible replenishment system and a flexible transportation network of road, rail, water, air and fuel pipe-line systems is essential to ensure the maintenance of our Land Forces under sustained nuclear attack.

Our military philosophy in the field of logistics requires some modernizing, but there are two basic concepts that remain sound: our concept of general and local administration and the concept that all commanders are responsible for the logistic control, as well as operational command, of their forces. On the other hand, as has been shown, our system of maintenance is too rigid and our previous concept of a Line of Communications is too linear and inflexible. The concept that transport should be centrally controlled for economic use requires, as has been indicated above, to be carried further than at present.

Theatre Logistic Support

It is axiomatic that the ground line of communication for our forces should be as short as possible. We must, therefore, continue to make the maximum use of our maritime resources. Ships at sea present unfavourable nuclear targets and are little affected by "fall-out". Ships will, however, be in danger from enemy submarines and mines.

At least some of the U.K. depots are unsuitably sited and items are not adequately dispersed. Some of the unsuitably sited depots should become mixed (floating) depots in order to achieve a mobile base, either tri-service, or anyway for our Land Forces, on the lines of the Mobile Marine Base. We have also lost our Middle East Base, and the vulnerability of the Suez Canal, even before the fall of bombs, has been clearly demonstrated. Our Middle East Base might be replaced by Mobile Advanced Bases east and west of Suez.

Admittedly, this concept of a series of mixed depots in store ships would tie up a certain number of ships, but not shipping in the normally accepted sense; they would be store ships, similar to the fleet auxiliaries now used by the Royal Navy, to be replenished by shipping or other means. The advantages which these mobile mixed depots would provide for: loading, holding and issuing stores as well as for dispersal or movement to a threatened theatre of operation either direct or by "stepping up" would, it is suggested, more than counterbalance the disadvantages. The initial capital "outlay" could be met, at least in part, by disposal of the existing depots in vulnerable urban sites. The replacement of existing depots by this means can also be more easily and rapidly achieved than by constructing new depots on land. Other land force depots, if they are not already adjacent to airfields, should be provided with air strips.

On land, in nuclear war, aircraft seem likely to offer the best vehicle for producing flexible logistic support, but aircraft are unlikely completely to replace road transport. As vertical take-off aircraft and helicopters come into general use, the present vulnerability of airfields will disappear and the problems of air supply become easier. Already the "flying truck", of 2½-tons lift, only requires a little over 200 yards of natural surface take-off and helicopters little more than a tennis court. The small pay load of these aircraft, compared with heavy lorries and trains, is compensated for by their more rapid "turn-round".

Fuel pipe-line systems, which are coming more and more into commercial use, are also relatively invulnerable to atomic attack and can provide a considerable aid to logistic flexibility.

Technical stores (signal, engineer stores, plus chemical and mechanical spares) require technical skill to hold and issue. It is suggested that: all common-user items, stores and supplies, including ammunition and explosives, should be held and issued by one service; while the holding and issue of technical stores and spares should be the responsibility of the technical corps, the only users concerned. With the exception of heavy engineer equipment and local emergency requirements, technical stores can normally be issued direct from Base or Advanced Base to formations.

In peace-time, economy is measured in terms of money and manpower, while in war it is measured in terms of time and manpower. With the vast tonnages to be handled and the vulnerability of communications, especially sea and airports, essential priorities can only be met by rigid economy. It will be a case of hard living and hard rations including possibly a ration of water. The "jerry can" will be required again for both petrol and water. The civilian standard will be bare survival; the Armed Services can expect little better. We shall be faced with deficiencies and must make the maximum use of local resources, including manpower.

When considering the reductions in manpower and in ratio of "teeth" to "tail", that can be affected by our possession of tactical atomic weapons and an army air lift, it must be stressed that whatever "tail" is needed in war must be there in peace; there will be no time in war to grow a tail.

The opportunity for reductions in numbers and the ratio of "tail" to "teeth" should be great even for the "divisional slice"[1] since we can now see considerable reductions in the daily maintenance tonnages; but the dependence of Land Forces on their theatre base and the related problem of developing a time-saving and less vulnerable "pipe line" remains with us.

We must win the first phase of any global nuclear war or we shall not have any control over subsequent phases. Yet if we are not to "over-insure" we must make a correct appreciation of the duration of each phase, especially the first phase. Our Land Forces will very largely have to exist on their own resources for x days; but what is x? The answer to x together with a correct appreciation of the vulnerability and length of our communications must determine the extent and dispersal of our stockpile; and our policy and consequent organization for repair and replacement.

In the Communications Zone our logistic support has increasingly been dependent on the continuing functioning of civilian resources, especially in the transportation and labour fields, normally foreign. Our new logistic concept should aim to reduce this considerably as regards transportation, but we shall not be able to eliminate our need for labour. The morale of this civilian labour, our own or foreign, will vary directly with the effectiveness of the Civil Defence organization.

A flexible logistic system must, therefore, also be a simple and economic organization that can be properly dispersed. The logistic organization of our Land Forces should also: be suitable for cross-servicing by Commonwealth

[1]It must be remembered that in a theatre with less than ten divisions, reductions in the number of divisions does not produce a corresponding reduction in the other elements of the "divisional slice". If you cut from four to three divisions you only get about 10 per cent reduction in the rest of the "divisional slice" not 25 per cent.

and Allied logistic support; take cognizance of the enemy's attack potential and the variations of terrain, climate and communications.

PART III

Ways of Achieving Logistic Flexibility

It follows from our earlier reasoning that some of the more important ways of achieving logistic flexibility for our Land Forces which will now be further examined are: a new concept of mobilization; the organization of joint or tri-service logistics; streamlining the basic divisional logistic organization augmented, as necessary, by theatre logistic bricks; modernizing theatre logistic support; increased dispersal of the U.K. Base and an overall increase in the flexibility of our system of maintenance.

After all or any of the above changes have been accepted, it will be necessary to make a fresh appreciation of theatre stocks required for the initial phase of nuclear war, including an appraisal of its duration, and the layout and units for the advanced base and maintenance "pipe line". Such an appreciation should show considerable reductions in the size of the division, the "divisional slice" and the ratio of "tail" to "teeth".

Mobilization

If mobilization of both our active and reserve forces is to be effective, it must be completed in hours rather than in days. We need the Swiss concept of home mobilization: men and their personal equipment always together (at home) and unit equipment located at tactically-selected war stations, outside strategic target areas, where all members of the unit should be able to join in a few hours.

All the reserve formations, other than the Central Reserve, would, it is assumed be T.A. divisions located much as at present; but distributed in the manner most suited to carrying out their initial Home Defence role—aid to Civil Defence. The personnel of these divisions would require to have some limited initial training and a liability for annual "call up". This would not require the vast training organization now required for National Service. Responsibility for mobilization should be decentralized.

The mobilization of all other divisions, except the Central Reserve (Light Division), must be capable of being completed rapidly in the overseas theatre on theatre resources. The Light Division must comprise active units equipped and ready to leave by air at a few hours' notice. Once our Central Reserve is committed overseas, it will be necessary to create a new reserve, which could be done by calling up reservists and building up a new formation of regular units.

Joint Service Logistics

A Joint Services logistic system would involve the fusion of certain existing separate logistic services into a number of tri-service logistic bodies; say one for each of the following functions: medical, works, chaplains, pay, education, legal and for holding supplies and common-user stores. Two other common tri-service services are possible: one for repair of aircraft and one for repair of road transport.

Space does not permit, nor is it profitable, to argue the details of which of the Armed Services should take over what responsibility and why. The Army has always been the housekeeper and handmaiden to the other services. In overseas theatres the Armed Services have nearly always accepted the principle of the predominant partner; now these ideas should be applied world-wide with a good measure of "give and take". Perhaps the solution may lie in a Joint Logistic Service, owing no special allegiance to "brown jobs" or "blue jobs"; but this does not seem very practical at present. In the meantime, we should start with putting our own house in order. All common-user items for our Land Forces: stores, supplies, ammunition and explosives, should be held and issued by one corps on one system. This would involve the amalgamation of the R.A.S.C. and the R.A.O.C. after the latter had divested itself of responsibility for technical stores to the corps concerned.

Divisional Logistic Units

Conforming to the basic divisional organization discussed earlier, we should now examine the basic logistic elements of: units, the infantry brigade and the basic division as well as the logistic bricks to be added to form the other type divisions. All logistic units should have a tripartite organization for flexibility and decentralization.

There must be a basic logistic element in all fighting units, but this should be kept small by making all practical reductions in equipment, manpower and transport. Moreover, the type of vehicles used for logistic support in a unit should be identical with those otherwise in use in the unit, e.g. for the infantry battalion jeeps and A.P.Cs.; thus providing for replacement of casualties. A modern three-day iron ration and the light modern equivalent of the blanket and great coat can easily be carried on the men. "B" echelon transport and the unit light aid detachments (other than armoured regiments) should be withdrawn from units to more centralized control.

The infantry brigade should have only one logistic unit; the combined unit L.A.Ds. reinforced to provide a new concept of recovery and first echelon repairs.

The basic division should have two logistic units: a medical battalion and a maintenance battalion. The medical battalion to incorporate the functions of the present divisional medical units with increased facilities for holding casualties and operating. The maintenance battalion should replace the "B" echelon transport withdrawn from units and combine the three-fold functions of: replenishing units daily; receiving, holding and issuing all common-user items, including ammunition and any divisional reserves, e.g. dumped stocks, and carrying out first echelon repairs for non-brigaded divisional units. Pay, postal and any canteen service might be incorporated in the maintenance battalion.

The above concept of a maintenance battalion would make the following redundant as divisional units: second-line transport; second-echelon workshops and all divisional ordnance units. Another unit no longer required is the divisional reinforcement unit and battle school. There will be no requirement for ambulances; but all vehicles should be fitted for carrying stretchers and all divisional vehicles should have a good cross-country performance.

The addition of armoured regiments, artillery regiments and an armoured personnel carrier battalion to bring a "basic division" up to the required nuclear divisional organization would also mean the addition of "bricks" for: the first-echelon repairs to their vehicles and equipment; transport and store-holding "bricks" for the maintenance battalion and a medical "brick" for the medical battalion.

The theatre "logistic bricks" for: transport, supply, stores, medical and repairs, etc., should augment the medical battalion and the maintenance battalion of the basic division to meet the requirements of each of the Far and Middle East-type divisions, by additional units suitably organized and equipped, again allowing for full use of local resources and the dictates of climate and terrain.

Theatre Logistic Support

Corps or Army Maintenance areas require both overall dispersion to two or three points as well as increased dispersion within their own area. They should, as far as possible, be so sited and developed that they are each served by air, rail and water transport as well as by roads. The extent to which their depots can be mixed requires careful examination. A maintenance battalion should be in charge of each maintenance area—not necessarily having the same organization as the maintenance battalion of the division. The overall control of maintenance areas can then be alternated between Corps and Army as required.

The maintenance and medical care of non-divisional units will require: maintenance battalions and medical battalions in the Corps and Army area and general hospitals located as local facilities dictate.

The modernization of movement facilities must include: more reliance on air transport, the use of fuel pipe-line systems, beach craft and other small craft capable of loading and unloading in small ports and on beaches. The air lift must be both long-range, for the movement of forces and daily maintenance into the theatre, and an army air lift, forward of the advance base in partial replacement of road transport. The complete second-line transport for the strategic reserve should be "air lift".

The road transport maintaining formations from C.M.A. (or A.M.A. if no C.M.A. exists) would normally be controlled by Corps. All transport facilities in rear of C.M.A. should normally be controlled by the theatre headquarters.

Only the flexibility of movement thus achieved, together with the dispersal of stocks in and forward of the advanced base, in such a manner that one atomic weapon can only destroy one depot, can provide logistic support in the atomic age.

The Advanced Base, therefore, requires to be dispersed by groups of depots to three or at least two points, depending on local facilities. One of the groups might, with advantage, be mobile consisting of depot ships and tankers. The depots should be mixed depots with the necessary dispersal to minimize the effect of an atomic missile. The extent to which depots hold mixed stocks must be influenced by the commodity, e.g. petrol and ammunition and not as at present according to the service responsible for holding. Workshops should be on a reduced scale to World War II, in view of the proposed policy of replacement rather than repair. The concept of a Mobile Advance Base comprising groups which can be dispersed, for example, East and West of the Suez Canal is particularly applicable to the Far and Middle East theatres. The mobile groups of an Advanced Base could be stepped up to reinforce any threatened theatre, or to provide initial logistic support in a new area.

These depot ships would require to be organized for receipt and issue like a normal depot with different types of items in different hatches or bays. They should not be held in large harbours liable to attack but could be dispersed to the type of anchorage used for ships in "moth ball". They would have the ability to concentrate as, where and when required or to put to sea in face of threatened attack. The store ships and tankers should have the necessary facilities for loading and unloading including a complement of landing craft and fuel pipe-line facilities. The ships would also be interchangeable between the Advanced Bases and the U.K. Base.

Adjusting the U.K. Base

The U.K. Base is reasonably well dispersed geographically, but not as regards the holding of commodities; all items should have at least a three-point dispersal. All depots should be made more accessible to all forms of transport by, for example, the addition of air strips, and the availability of air-dropping equipment. Some depots in urban target areas should be abandoned and replaced by mobile mixed depots in store ships and tankers.

Increased Flexibility for Maintenance

It is unlikely that we shall have both C.M.A. and A.M.A. functioning one in support of the other, but it may be necessary to have the same maintenance area controlled first by army and then by corps. Except in Europe the opportunity to draw both from advanced base and base is unlikely to arise; but nevertheless, our maintenance system should be so flexible that items urgently required by fighting formations are provided by whatever of several means of transport is available from whichever maintenance area or base depot is most suitable. There must be complete flexibility of control, transportation and choice of depot with the minimum of procedural paper work.

Additional flexibility can also be achieved by "cross-servicing" between Commonwealth and Allied forces, but a much greater degree of simplicity, i.e. standardization, must be achieved before this form of flexibility is really practical except for fuels and food. At present standardization seems an elusive ideal; it becomes less so on a more careful preview of the trend in future developments. Standardization must be increased.

A Re-Appreciation of Theatre Requirements

With the above outline of the battle mobility and logistic flexibility of our Land Forces taking shape the next step is a theatre appreciation of the phase or phases of war which the logistic organization of the theatre must be organized to support. An appreciation which in each theatre must take into account the length and vulnerability of its "pipe line" and the local resources available. From this appreciation the nature and extent of holdings and the numbers and shape of logistic units required for the theatre will become clear.

The overall reduction in the size and ratio of the "tail" to the "teeth" should be considerable, although not proportionate to the reduction within the division.

Conclusion

The impossibility of preventing the enemy's nuclear attack from penetrating our defences and inflicting wide-spread devastation with megaton bombs or other atomic missiles makes it clear that our overriding consideration must be to prevent war. It is, however, the weakness of the victim that invites aggression. The deterrent of our own and allied nuclear air power alone is not enough to stop aggression and our land frontiers, beyond the Rhine, must be defended.

Scientific advances have fundamentally altered the whole basis of military planning and the time is ripe to reshape our Land Forces. "I find it quite impossible to visualize a war of the future being supported by our present logistic system."[1]

In planning, as in war, our own difficulties always loom large, the enemy's difficulties are, however, usually as great or greater if we only knew. The Russian logistic system is probably inferior to ours and, despite their ability to live hard, they would have greater difficulties to overcome in an advance across Europe, while subject to nuclear attack, than we would have on the defensive. For this reason a reduction in the strength of the Land Forces in Central Europe is less serious than would at first appear.

Against this background our aims must be to provide well-equipped Land Forces capable of meeting our world commitments for: the cold war, limited peripheral wars and, ultimately, if global war cannot be prevented, global nuclear war.

For all three types of wars, our Land Forces require battle mobility and its essential complement of logistic flexibility. In the face of the destructive power of nuclear weapons, it is not so much a matter of increasing battle mobility or logistic flexibility, but of retaining our existing standards in an infinitely more complicated situation.

By applying the accepted principles of war, including logistic principles, and utilizing certain other scientific advances that have accompanied the development of the atomic bomb and the rocket, we should be able to achieve the necessary logistic flexibility.

Some of the more effective means suggested for achieving the logistic flexibility essential for our Land Forces are: more rapid mobilization; Joint Service logistics; increased standardization and replacement rather than repair of equipment; the concept of a basic divisional organization with theatre "bricks" added as required; reductions in manpower, vehicles and equipment organic to the division and of "holdings" in rear; the modernization of movement facilities including an army air lift; most important of all, a much more flexible maintenance system embracing changes in the U.K. Base, theatre logistic installations and the transportation service; and finally a fresh appreciation of the theatre stocks and logistic units required for the various phases of war in each theatre.

[1] *The Panorama of Warfare in a Nuclear Age*, page 12.

Calpe Hole Power Station, Gibraltar

By Major W. V. Sebire, M.I.Plant. E., R.E.

Calpe Hole Power Station is unique as it is thought to be the largest underground station operated by the R.E. The power station, many of the substations, and the greater part of the high tension distribution system are installed in tunnels in the Rock and as a result many unusual problems were encountered during the installation and many more have since arisen.

Since many people have been involved in the construction and installation and the supply of stores and equipment for the scheme, it has been considered worth while to record its history and lessons which have been learnt.

At the end of the 1939–45 war the W.D. electricity requirements were supplied from four stations inside the Rock, each with an installed capacity of 200–250 kW. They fed into a 2.2 kV system which was interconnected with the Dockyard power station and were operated by military personnel.

With the return to peace-time conditions and the increase in the use of electrical appliances it quickly became apparent that a considerable increase in generating capacity would be necessary to meet even the foreseeable demand. A supply from the City Council, Gibraltar power station was considered, but its position was little better than our own. As a temporary measure the Dockyard agreed to take over part of the W.D. load, but they could not supply it indefinitely. The R.A.F. was constructing new accommodation and obtaining their supply from the City Council for the time being, but both departments had to take action to organize their own power stations.

In 1948 an inter-services committee met under the chairmanship of Colonel J. H. D. Bennett, O.B.E., C.E. Gibraltar, to investigate and report on the possibility of an inter-services generating station. The need was plain, and it was recommended that a station be constructed at sea level on the east side of the Rock to generate at 6.6 kV. This was basically an Admiralty scheme and a long-term proposal. The W.D. and R.A.F. required a more rapid solution.

Interim Measures

As an interim measure it was decided to enlarge "Calpe Hole", and centralize the existing generating sets.

Further consultations took place and by the latter part of 1949 the W.D. and R.A.F. had decided on Calpe Hole as the final answer. By December of that year further excavation had been carried out in anticipation of a large installation. A large chamber had previously been excavated in 1943 for use as a ration store.

Since Calpe Hole Power Station was a joint W.D./R.A.F. scheme and both were to take part in its execution a clear division of responsibility was necessary. It was decided that the W.D. would be responsible for all the excavation for the station whilst the R.A.F. would design and build the station. The sets would also be supplied by the R.A.F. as they had three Fullagar/English Electric sets available, ex-Burtonwood airfield in U.K. Each service would be responsible for installing its own distribution system.

Photo 1.—General view of Power Station showing three General Electric 1,000 kW. sets and the gas turbine under construction.

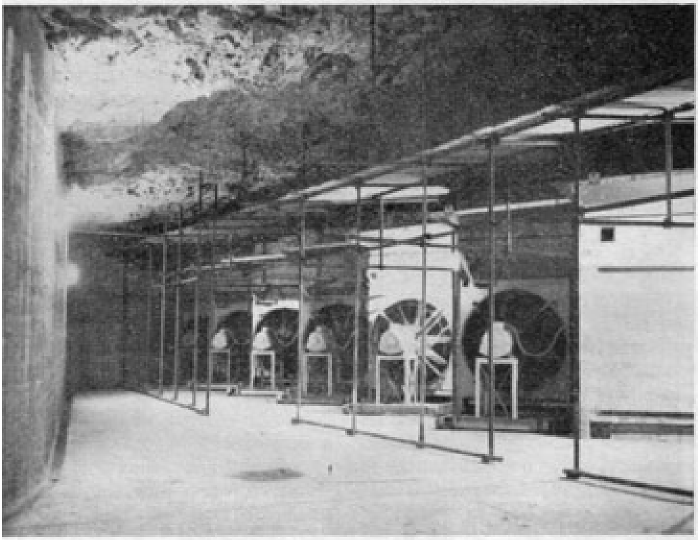


Photo 2.—One bank of 6 Radiators and Cooling fans.

Calpe Hole Power Station,Gibraltar 1 , 2

On completion of the station the W.D. were to take it over, together with the R.A.F. 6.6 kV ring main and H.T. sub-stations, and operate it.

This division of responsibility would have worked out better and achieved better results had the experience of the engineers at the large W.D. diesel station at Tidworth, also operating similar sets, been utilized at the design stage to represent W.D. interests. In addition a full time W.D. representative with a permanent interest in the station, such as the Station Superintendent, should have been available. In a large engineering project of this type taking approximately seven years to complete, the constant change of personnel, both A.M.D.G.W. and W.D., did nothing to aid the continuity of knowledge so essential to good results, in spite of the willingness with which the two Services co-operated.

The Station

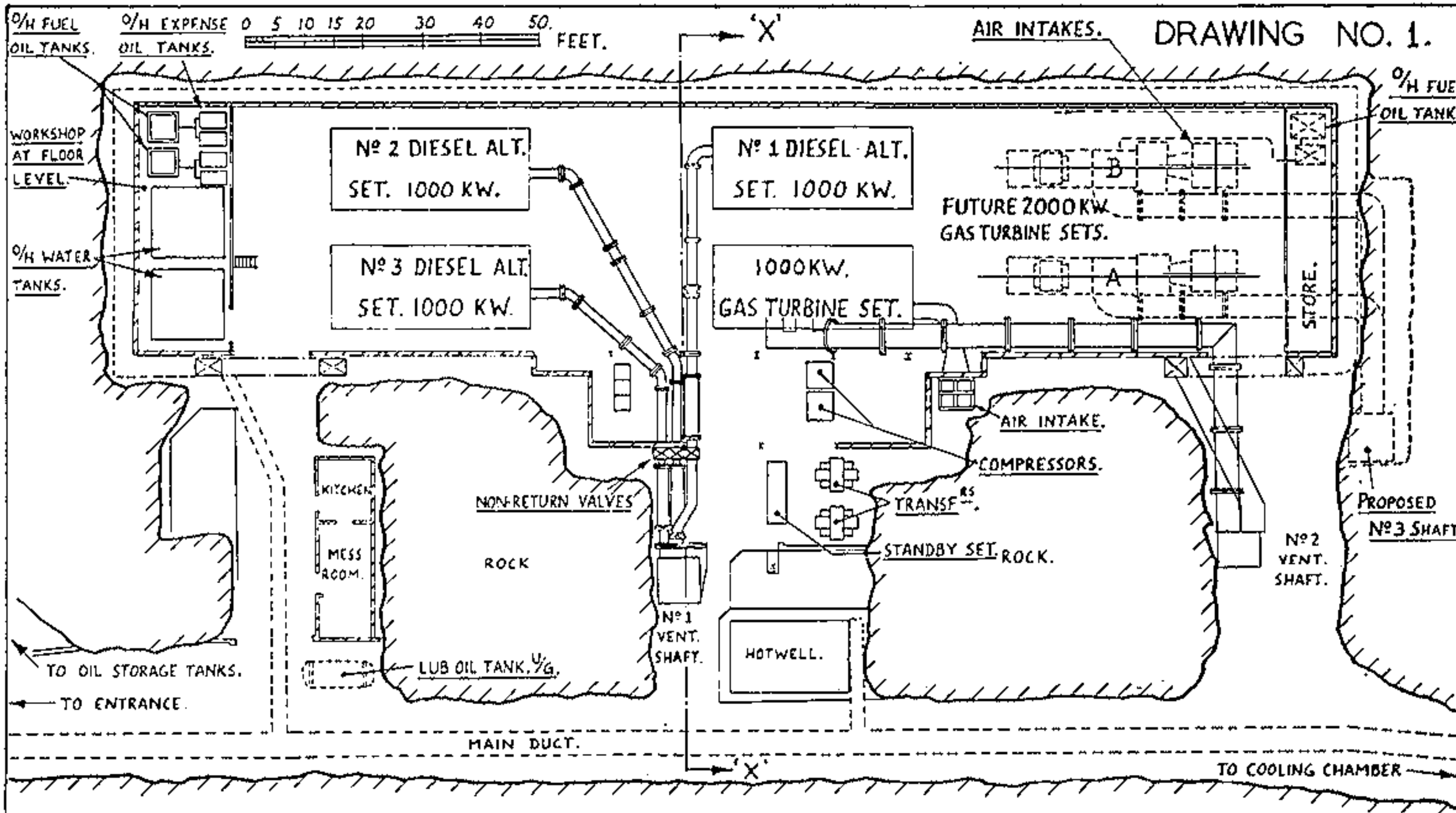
The location of the site was determined solely by the military considerations and thus the station cannot be compared economically with normally sited stations. The cost per unit supplied is about 3¼d.

The initial design included the installation of three English Electric-Fullagar (opposed piston) diesel engine driven, 1,000 kW sets, generating at 6.6 kV. The engines are direct coupled to English Electric salient pole alternators and rotate at 300 r.p.m. (Photo 1). They are similar to the sets installed in Tidworth power station. The sets are cooled by two banks of six Serck radiators, each radiator cooled by a fan driven by a 10 b.h.p. motor (Photo 2). The three exhausts are taken out to atmosphere through a common shaft. The station is fully ventilated by two 36 h.p. centrifugal fans exhausting into two shafts. The main switchboard is by Ferguson Pailin and is arranged in two halves connected by a busbar coupler. Earth leakage and overload protection are provided on the feeder panels and overload and reverse power together with Merz Price protection on the alternators. The voltage regulators are of the Brown Boveri rotating segment type.

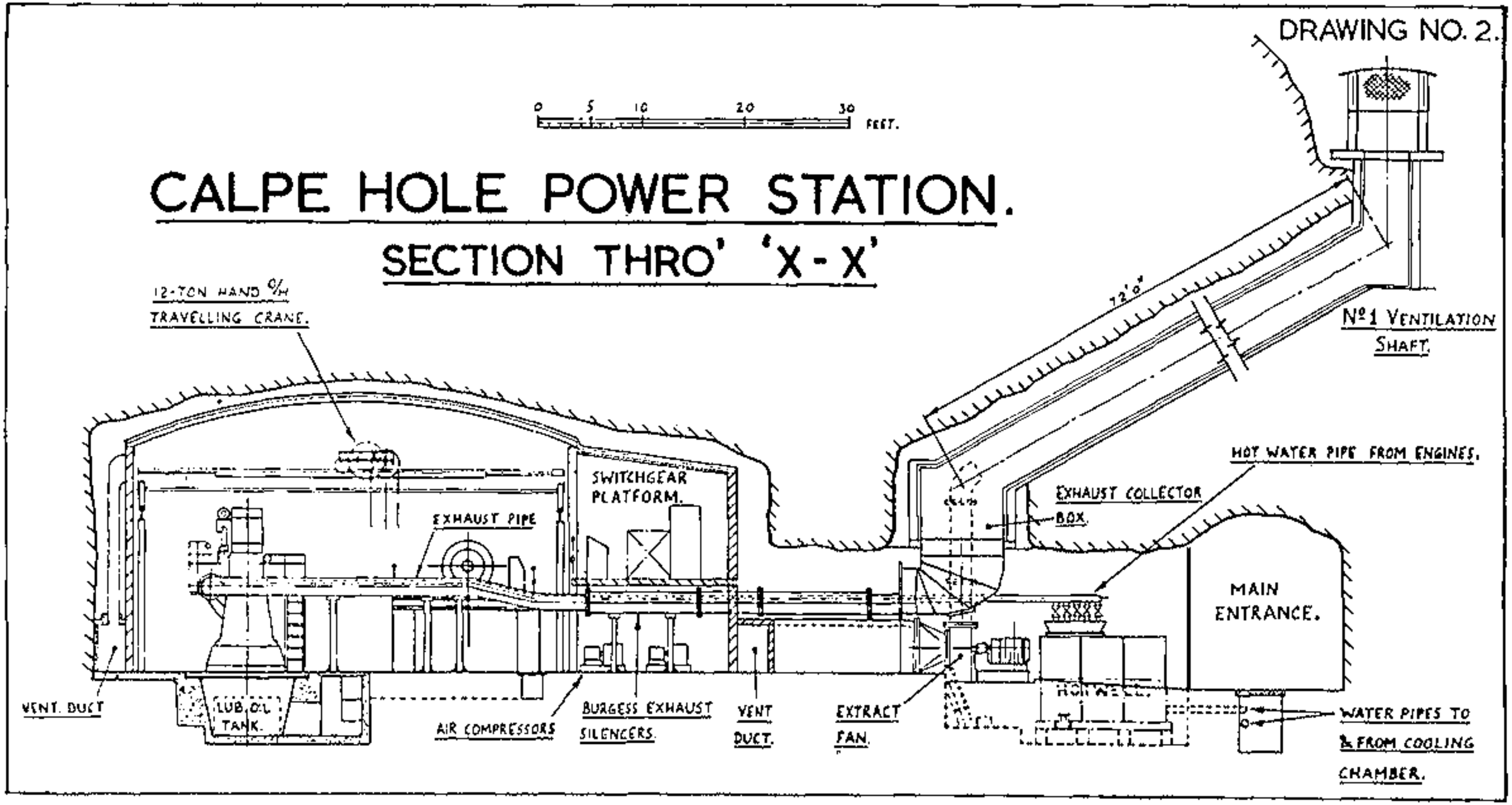
Diesel fuel is obtained from Admiralty storage at sea level, pumped up by Mirrless I.M.O. screw pumps through a 1,600 yard pipeline. The fuel is pumped to a 60.000 gallon storage tank and then through filters and centrifuges to the daily use tanks.

The lubricating oil system consists of a 5,000 gallon underground tank feeding direct to the engines. The engine circuits include centrifuges, and originally Streamline filters which have now been removed, as although the sets (second-hand and manufactured in 1938) operated originally on straight mineral oil, the W.D. uses a detergent oil. This necessitated a thorough flushing and cleaning of the lubricating oil system. The oil is cooled by heat exchangers, there being one to each set.

The sets are mounted on 5 ft. of concrete with the holding-down bolts keyed into solid rock for an additional 5 ft. It was decided that no useful purpose would be served by anti-vibration mounting as the sets were below 400 r.p.m. The lack of vibration in the mounting is confirmed by the fact that a Stationery Office issue 2H pencil will stand upright quite easily by a set on full load. Earthing in the rock is extremely difficult as the rock itself has a resistivity in the region of $p=10^6$ mΩ/in. cube. Consequently the main station earth is obtained by means of a cable down to sea level. No resistance or reactance is included in this connexion. Drawings 1 and 2 show the layout of the station.



DRAWING NO. 1.
O/H FUEL OIL TANKS.
O/H EXPENSE OIL TANKS.
0 5 10 15 20 30 40 50. FEET.
'X'
AIR INTAKES.
WORKSHOP AT FLOOR LEVEL.
O/H WATER TANKS.
Nº 2 DIESEL ALT. SET. 1000 KW.
Nº 3 DIESEL ALT. SET. 1000 KW.
Nº 1 DIESEL ALT. SET. 1000 KW.
1000KW. GAS TURBINE SET.
B
A
FUTURE 2000 KW. GAS TURBINE SETS.
STORE.
O/H FUEL OIL TANKS.
AIR INTAKE.
COMPRESSORS.
TRANSF^RS.
STANDBY SET.
ROCK.
PROPOSED Nº 3 SHAFT.
Nº 2 VENT. SHAFT.
KITCHEN
MESS ROOM.
ROCK
NON-RETURN VALVES
Nº 1 VENT. SHAFT.
HOTWELL.
LUB OIL TANK. U/G.
TO OIL STORAGE TANKS.
TO ENTRANCE.
MAIN DUCT.
'X'
TO COOLING CHAMBER


DRAWING NO. 2.
CALPE HOLE POWER STATION.
SECTION THRO' 'X - X'
0 5 10 20 30 FEET.
12-TON HAND O/H TRAVELLING CRANE.
SWITCHGEAR PLATFORM.
EXHAUST PIPE
72'0"
Nº1 VENTILATION SHAFT.
HOT WATER PIPE FROM ENGINES.
EXHAUST COLLECTOR BOX.
MAIN ENTRANCE.
VENT. DUCT
LUB. OIL TANK.
AIR COMPRESSORS
BURGESS EXHAUST SILENCERS.
VENT DUCT.
EXTRACT FAN.
HOT WELL
WATER PIPES TO & FROM COOLING CHAMBER.

Two distinct systems, R.A.F. and W.D. exist, the main difference being in the choice of gear. The R.A.F. is all outdoor gear, whereas the W.D. is of the indoor type. The humidity in the tunnels and the amount of percolating water makes the R.A.F. system the better of the two. So much trouble has been experienced to date due to the indoor type gear being used by the W.D. that it is recommended, in future, that outdoor type gear be specified for use in tunnels. Apart from this discrepancy there is a lack of standardization regarding switchgear on the part of the W.D. which makes the stocking of spares a difficult task. The bulk of the W.D. sub-stations, and the R.A.F. sub-stations have Cowen switchgear, but other sub-stations built as parts of Part I Services have switchgear by South Wales Switchgear, and Ferguson Pailin. Also some of the old 2.2 kV ring main switchgear by Crompton Parkinson was dual voltage type (6.6/2.2) and was used again on the 6.6 kV system. All equipment of the network should be standardized, especially for stations overseas.

The W.D. cables were ordered on 10-ton (longest possible length) drums, with a view to reducing the number of joints, but in fact this had the opposite effect. The drums could not be handled in the tunnels and the cable had to be wound on to smaller ones, which gave rise to a muddle in phase sequence and core numbers, etc., due to lengths of cables being reversed on drums.

No metering was supplied on R.A.F. H.T. feeders and this together with the fact that the W.D. require the project to be costed makes life extremely complicated. The R.A.F. installed their own H.T. mains and did not allow for the station being costed. They had meters on their L.T. system.

Although the system appears to be ring main on paper, it is in fact not so as the feeders run for considerable distances on the same hangars and are thereby actually parallel feeders. This was unavoidable as cables had to be taken through tunnels for long distances. The station supplies consumers through twenty-nine sub-stations.

High voltage tests were carried out for the services by the C.C.G. Electrical Department and various disturbing results were obtained. All the indoor type switchgear had to have heaters installed to maintain their insulation resistance. Some current transformers broke down completely. The alternators' insulation resistance was zero and a week's run on short circuit was required to bring them up to a satisfactory value. Even now when a set is shut down it is necessary to switch on heaters to maintain the insulation resistance. The conditions under which the switchgear would have to operate were included in the W.D. specification, but outdoor type gear was not called for; had it been, these troubles would have been obviated, to a great extent. Phasing tests on the complete ring main were not possible due to the fact that part of it had dual voltage gear, which was in use on 2.2 kV.

The sets were tested to 110 per cent full load on an artificial load using half of the hot well containing salt water. Difficulty was experienced in obtaining a sufficient flow to take the heat away.

Recruiting difficulties both in the United Kingdom and Gibraltar resulted in a very slow build up of staff. Suitable tradesmen are hardly to be found at all in Gibraltar outside other generating stations, and for security reasons Spanish labour cannot be employed. However, with the assistance mainly of the R.A.F. and the D.C's.R.E. and other services, suitable raw material was finally obtained. Some of the most difficult positions to fill were those of switchboard operators, but the Fortress Engineer Regiment helped out by supplying some excellent personnel of higher national-graduate class who operated the board and trained the civilians.

Taking over Load

There seemed to be so many snags and difficulties that it looked extremely doubtful if Calpe Hole Power Station would ever run, even though we had now obtained sufficient staff for two-shift working. A major hold-up occurred through our link-up to the 2.2 kV system via 2 × 200 kVA transformers. On the morning of the changeover it was found that when the Calpe Hole board was energized that they were actually 11 kV transformers, notwithstanding the fact that the name plates said 6.6 kV. This was overcome by juggling of existing transformers. The eventual starting was finally precipitated by a requirement for an electric cooker.

It was then decided that the station would commence two-shift working while the Fortress Engineer Regiment supplied the night load from the small tunnel power stations, and that gradually the fourteen sub-stations on the W.D. portion of the network would be changed from the 2.2 kV to the 6.6 kV system. This was necessary because the Dockyard Power Station refused to operate in parallel with Calpe Hole through such a small link (400 kVA)

At 0600 hrs on 1st November, 1955, the Fortress Engineer Regiment took the load from the Dockyard Power Station, who were then isolated. Then Calpe Hole took over the load from the Fortress Engineer Regiment. The other feeders from the Dockyard at Europa and Windmill Hill were taken later and finally the Military Hospital and R.A.F. (part only) from the City Council system. The remainder of the R.A.F. load was taken over during 1957.

This changeover was accomplished smoothly with no violent disturbances or interruptions to supply. In fact, all essential supplies such as to the salt water pumps were maintained throughout.

During the changeover overheating of transformers occurred frequently and when load was transferred from small stations to Calpe a reduction of kW was noticed. This was due to all neutrals of small generating sets being connected together resulting in large currents circulating between the sets. When running one set only the neutral should be closed, but when two or more are connected in parallel neutrals should be open.

Additional Capacity

Early in 1957 a 1,000 kW (nominal) Ruston and Hornsby Gas Turbine Alternator Set was installed and taken into commission. It was installed without a heat exchanger and consequently has a high fuel consumption. Owing to the fact that cooling water has to be cooled and recirculated it was not thought possible to use normal C.I. diesel engines as prime movers for new plant as this would have meant new major excavations for additional cooling chambers. A heat exchanger was not available when the Gas Turbine was ordered and although one will be available within a few years it is doubtful whether this will be required as although it would improve the fuel consumption figures it would mean that the set would have to be stripped down to install the heat exchanger, apart from its own high cost.

The Gas Turbine is thus only used for peak loads, training and as an emergency set. No excessive difficulties were met during its installation and it runs well in parallel with the piston driven sets.

The demand for electricity is still growing and will not reach its peak until after 1960. To meet this a proposal has been submitted to install a 2,000 kW gas turbine with heat exchanger.

An interconnector between Calpe Hole and the City Council power station will be completed by June 1958 and this will allow for an exchange, either way, of up to 2,000 kW. This will be to the advantage of both the W.D. and the City Council, and the cost of the interconnector is therefore being shared equally.

Unusual Difficulties

An occupational hazard in the tunnels exists in the form of rock falls, and whilst it is considered that there is no danger of a major collapse, constant vigilance and scaling of rock faces are required. A service for lining part of the tunnel with reinforced concrete has been approved and work has commenced.

It is therefore essential to have an effective standby scheme in readiness. This is necessarily fairly complex, but provides a limited supply to all important installations rapidly and a curtailed supply to all other consumers within a reasonable time, in the event of a breakdown.

The effect of ducting the exhaust gases into a vertical concrete-lined shaft is to amplify them and produce an extremely objectionable noise at the outlet which can be heard some considerable distance away. As a building development area exists in the immediate vicinity steps are being taken to eliminate this nuisance. The problem is difficult as all three piston sets exhaust into a common shaft and the station is in continuous operation. It is now thought, however, that the addition of extra silencers in the lines will provide a solution.

The opportunity of completing such a task does not present itself very often and this factor aroused the interest and enthusiasm of all concerned. So many different authorities were involved that the supervising officer seemed to spend the greater part of his time on Public Relations. The main conclusion is that Royal Engineers must be adaptable and not expect work to proceed as per book.

Acknowledgement is made to Colonel D. M. Eley for editing, Major J. C. Court, R.E. for photos and W.O.I. R. J. Baker, R.E., for ploughing through all the necessary files.

The Hanningfield Reservoir

By LIEUT.-COLONEL T. J. WIGNALL, R.E. (T.A.)

READERS of this journal will inevitably at some time in their careers have faced the many problems associated with the expansion of existing or development of new establishments and will readily appreciate the need for water supply. Thus the very considerable post-war industrial and domestic development in Essex created a need for expansion of existing water supplies as a basic service.

The concerned authorities in the area are the Southend Waterworks Company and the South Essex Waterworks Company. Together, they serve a combined population today of close on one million. The New Town at Basildon is proceeding towards its planned population of 80,000 and considerable development takes place concurrently in a number of other towns nearby. Industrial water consumption is an important consideration too. The Barking Power Station, the Ford Motor Works and the two oil refineries at Thames Haven are examples of large-scale consumers. Another power station twice the size of that at Barking is under construction and two more are projected.

To anticipate the expected growth in demand, these two authorities wisely decided some eight years ago to tackle the problem jointly. They constituted a Joint Management Committee from the members of their companies and a panel of Consulting Engineers and Joint Engineers was appointed.

The object was to augment existing water supplies to the extent of 21½ million gallons per day.

The many other obvious considerations apart, there were a number of important technical factors to be taken into account because of the comparatively small availability of raw water. For example, whereas almost the whole requirements of Birmingham are met from a total drainage area of 71 square miles in Wales, offering a safe yield of 102 million gallons per day, a drainage area of five times that size in Essex offers no more than a safe yield of 25 million gallons per day. Clearly therefore to overcome drought periods, large-scale storage of the winter flow was essential. That being so, any storage reservoir would have to be located not only having due regard for the geology, topography and population density, but sited too as near as possible to the available raw water, which in due time would require purification and ultimate transmission into the supply of either company. Before such a project can be embarked upon in this country, a Parliamentary Order is necessary. This requires an appreciable amount of preliminary technical investigation and considerable administrative consultation and inquiry with all likely concerned parties and bodies. This was pressed forward with all possible speed and eventually the Hanningfield Water Order of 1950 was piloted through. Thus was authorized the Hanningfield Reservoir Scheme which was designed, constructed and finally inaugurated last autumn at a cost of something over £5 millions, although it was in operation more than a year before this.

The Scheme

The broad principles adopted were that the Rivers Chelmer and Blackwater were both to be tapped in the vicinity of the existing Southend Water Company's Works at Langford and the water pumped for 8.9 miles through an aqueduct to the reservoir located in a shallow valley between Ramsden Heath and South Hanningfield. (See drawing facing page 62.)

Reservoir No. 1, the main storage area, covers approximately 1,000 acres. On the eastern side the natural contours of the valley form the banks, but on the west marginal embankment construction was necessary, including the building of two small dams to isolate defiles, ideal for sludge storage. The southern end of the valley was enclosed by a dam to avoid a large expanse of shallow water and the flooding of valuable land upstream of this was overcome by the provision of the small reservoir No. 2, from which the natural flow is pumped over into the main storage. The northern extremity of the reservoir is formed by the main dam, 6,750 ft. long, of maximum depth of 64 ft., creating a top water level of 181 O.D.

This considerable storage area has an approximate capacity of 6,000 million gallons and it is anticipated that once the reservoir is filled and the correct aquatic conditions established, it will in itself effect an appreciable improvement in the bacteriological condition of the water.

Control of the stored water is effected at a valve house and tower located on the upstream side of the main dam. It is on the line of the old Sandon Brook which formerly passed through the valley. Incorporated with this structure is the statutory overflow chamber and a tunnel underneath the main dam. The primary function here is, of course, the drawing off of stored raw water for ultimate consumption. This is effected through a gravity main to a pumping station which lifts it to the supply chamber of the treatment works. There is also a low-level draw off through a scour pipe to enable less desirable raw water to be discharged through the tunnel to waste when required. It is not anticipated this will often, if ever, be necessary as the incoming water is pumped and the incidence of scour should thus be negligible. Facility too exists for the drawing off of compensating water which again can be passed through the tunnel and into the line of the Sandon Brook to compensate for the natural flow cut off by the reservoir. Finally, there exists the obligatory safety valve in the form of a weir at top water level over which surplus water can pass down the swallow hole and through the tunnel and discharge channel to waste. Again, since the inlet is a pumped supply and the catchment area draining directly into the reservoir is only 5 square miles, it is not anticipated this precautionary measure will often be utilized.

The inlet to the reservoir is also located on the northern main dam near its eastern extremity and the possibility of raw water substantially short circuiting the main storage area by being drawn off through the valve tower before having had the natural advantages of storage for a period, has been considered and provision made to counteract it. It takes the form of an outlet tower located about midway along the west side of the reservoir. This is in effect a subsidiary valve tower from which water can be drawn off at any one of three different levels and delivered through an aqueduct running along the reservoir bottom to the valve tower. Yet another emergency feature exists, should it ever be required, in that raw water pumped from the intakes at Langford can be passed direct to the supply chamber of the treatment works without entry into the reservoir at all. Clearly not a desirable measure in the ordinary way, but a useful facility should ever an occasion demand it.

The treatment works are conveniently located near the main dam and the adjoining underground filtered water reservoir is adjacent to the main pumping station which directs the processed water through mains to either the Southend or South Essex systems.

The Main Dam

Work was put in hand under a series of contracts, the first, quite a small one concerned primarily with the establishment of access. The project was begun in earnest in July, 1952, with the placing of the major contract for the construction of the main dam with its attendant inlet works, valve control and outlet works, the diversion culvert under the main dam and the subsidiary outlet works. It was scheduled for completion in February, 1958; for all practical purposes it was substantially complete by the end of 1955 and was finally finished off during the summer of 1956.

Geologically speaking, the main dam was sited on ground typical of that part, indeed the greater part, of Essex. Some twenty to thirty feet below ground level exists the London blue clay, an ideal strata into which to establish a watertight cut off. Overlying this is drift material composed in the main of local brown clay, but containing as it often does, pockets of silt or silty gravel. A clay puddle core was specified as the watertight membrane. It is 6 ft. wide, extending throughout the centre of the main dam at least five feet down into the blue London clay and up to a little above top water level. It is flanked by a marginal zone of approximately equal width on either side above ground. This is composed of selected clay fill found from within the reservoir area, placed and rolled in. The main body of the dam was constructed, not of arisings from within the reservoir area as is often customary, but with local as raised gravel extracted from nearby dry pits. This was something of a major decision since about 1¼ million cubic yards were used in the construction. After careful consideration of expert opinion on soils, however, it was deemed imprudent to utilize the drift for such comparatively rapid construction. On the upstream face the slopes are 4 : 1 on the lower levels, rising to 3 : 1 and on the downstream side 2½ : 1 with a substantial berm. This berm carries a new county road, replacing one submerged in the water area. The downstream slopes are soiled and sown with grass, whilst the upstream face is covered with 6 ft. square concrete slabs, cast *in situ*.

Work was begun progressively from the west side with the sinking of the cut-off trench. This was taken down to the exact overall width of 6 ft. and was close boarded. The horizontal method of timbering was utilized. This permits a constant width to be maintained indefinitely and further allows gradual withdrawal ahead of the rising puddle clay. The sheeting was of 9×3 in. timbers, the soldiers of 12×6 in. and the struts 10×8 in. Half frames were pitched 6 ft. 6 in. long, 4 ft. 6 in. deep, allowing clear openings of approximately 5 ft. square through which to pass the excavations up and the puddle down. Some 250 standards of timber were consumed in this timbering. Mechanical excavation was found to be possible for the first 14 ft. A specially adapted Allen Parsons trencher was used but lower down it was all hand

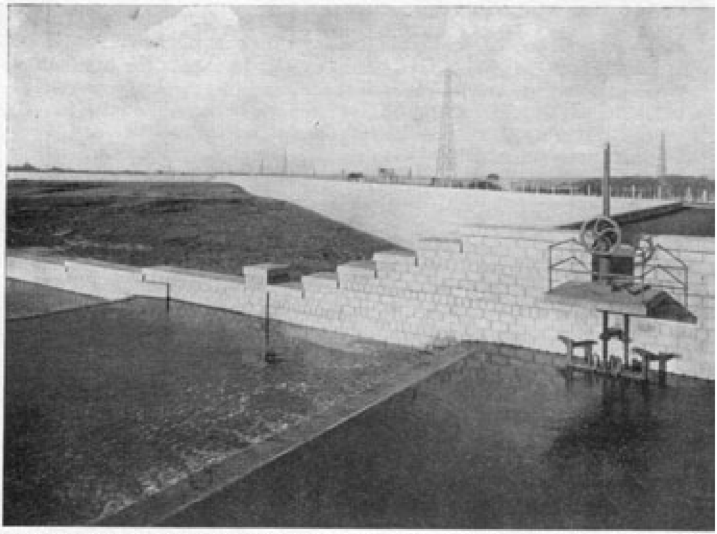


Photo 1.—The Reservoir Inlet. Showing also the eastern extremity of the main dam running into the natural contours.

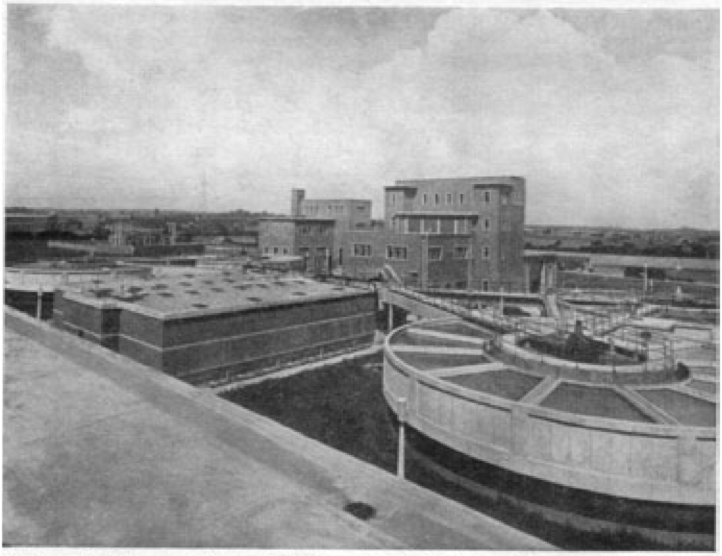


Photo 2.—The Treatment Works. A view from the roof of the Filter House showing the circular Accelators, the Contact tank in the foreground and the Chemical and Boiler houses. The electricity sub-station can also be seen.

The Hanningfield Reservoir 1 , 2

work with cranes and skips. There was a continuous pumping problem, but never more than was anticipated. The prepared puddle was placed in the trench with small grabs, diced out and heeled in. The trench averaged 22 ft. in depth, reaching a maximum of 32 ft.; 30,000 cu. yds. of puddle were placed below ground and a further 50,000 cu. yds. were used in the core above. It was all prepared from the local clay extracted from a selected site within the reservoir area and processed through two large conventional pugmills. Production and placing of puddle was abandoned during the winter months, but when operating, up to 300 cu. yds. were dealt with in a day. Raw clay for the puddle was dug with a small multi-bucket excavator which cut the material into very desirable small particles. Conveyors were used to transport it to the processing plant, and subsequently it was transported by 4-wheel drive vehicles to its place in the dam.

Simultaneously a start was made on the diversion culvert or tunnel under the dam, with its attendant forebay, discharge channel and tailbay. Since it was in the clay and not of excessive depth, it was not driven as a tunnel but taken out in open cut and the concrete placed by derrick into a travelling shutter. It was essential to push this construction work ahead to allow the valve tower and attendant structures rising above top water level, to proceed ahead of the main dam construction.

The winning, hauling in and placing of the bulk filling to the dam produced no difficult engineering problems. It did, however, call for fairly thorough organization. During all but winter months some 200 trucks were constantly engaged on this work. They travelled through the narrow lanes of the Essex countryside, over distances of between seven and twenty miles, from a dozen or more pits, nearly all specially opened up for this purpose. That some of the lanes, without the expenditure of any other effort whatsoever, became nearly doubled in width in the process, was not to be wondered at. What was remarkable, was the fact that the whole operation was achieved without a single fatality. The long suffering members of the villages, the concerned local authorities and the police, are indeed to be congratulated for their efforts throughout what were at times mildly hectic days. This gravel was all led on to and placed in the dam to a minimum dry density of 130 lb. per cu. ft. It is an interesting fact that could full coverage have been assured by the passage of the vehicles themselves, this density would have been comfortably attainable without further compaction, the material having been dozed out in loose layers of 9 to 12 in. in thickness. Additional rolling was of course necessary and was effected in the main by rubber-tyred wobble-wheeled rollers. Number of passes varied from two over well trafficked areas, to eight over areas not thus pre-treated.

The Marginal Works and Subsidiary Dams

The second major contract was for the construction of the marginal banks around the west side of the reservoir, the two sludge lagoon dams and the upstream dam to the reservoir, together with certain ancillaries. The three small dams were all constructed in selected rolled clay and keyed in by means of a central cut off trench. Their main feature was that for all practical purposes they were built entirely with mechanical equipment. They were therefore comparatively inexpensive, and rapidly constructed. The clay was dug from selected areas nearby with motor scraper units, placed and rolled in by the same machines. Some care was taken to ensure that the material was handled at or about its natural moisture content. To aid this, borrow pits were carefully worked in narrow stepped strips and the banks raised in short sections at a time. During dry spells no effective and practical means were found to maintain the moisture content on the surfaces of either the pits or bank overnight. The quick answer was to strip two or three inches off both first thing in the morning and cast to waste. Standard field control tests were carried out to check dry density and moisture contents, and during the course of construction, cells were placed in the fill to record pore water pressure. These cells were allowed to remain in the banks and are connected to the recording apparatus which has been conveniently set up in the nearby pumping station.

The seats of all embankments, including that of the main dam, were stripped down to a good foundation in all cases. An allowance of 2½ per cent was also made throughout for settlement of both banks and foundations, a quite common practice in construction of this kind.

The lagoon dams were concrete lined on both faces, as was the inside face of the upstream dam. The reverse slopes of the latter were soiled and sown. It carries a new road on its crest, replacing another inundated by the scheme.

The marginal banks were constructed of the local clay on a cut and fill basis, and the toe is at all times at least 10 ft. below top water level. This is because the whole of the reservoir bottom was left in its natural state after the removal of all trees, shrubs, hedges, buildings and other undesirable impedimenta and growth. There is, therefore, the danger that unless adequate water coverage is given, further growth may re-appear and all areas within the reservoir which projected above this level were reduced as part of the work.

The marginal banks extend for 2¼ miles along the west side of the reservoir and a small service road, linking those crossing the upstream and downstream dams, is carried on the crest just below the wave wall. Again, the inside slopes are concrete lined, in fact the slabbing is quite a feature of the whole project. With the four dams and the marginal works it totals 40 acres in area, and until the water in the reservoir approaches its top level, as it is unlikely to do much before 1960, it remains a rather striking sight. Some of this slabbing of the slopes was laid during the autumn of 1954 on an exploratory basis, and a little outstanding was finished off in the spring of 1956. Some 32 acres were, however, laid between May and September of 1955. That on the dams was mixed and placed by traditional means, leading from a conveniently sited central batching plant. On the whole of the marginal slopes, use was made of a 1¼ yd. travelling mixer with a purpose made inclined boom. This allowed the mixed concrete to be spotted direct from the machine. The cement and aggregates were premixed dry at a batching plant and led to the machine where water was introduced. Keeping up the latter supply was quite a task; there was plenty of water about of course, but not of the right quality in a convenient place at the right time.

This second large contract was begun early in 1954 and was scheduled for completion in two years. It fell somewhat behind programme during the bad summer of 1954. Full advantage was however taken of the corresponding excellent weather during 1955, and substantial completion was effected by the autumn of that year. It phased in quite well therefore with the anticipated early completion of the main dam, as was hoped.

The Treatment Works

A third sizeable contract was placed shortly after that for the marginal works, for the construction of the treatment works.

It was begun in May, 1954, and in order to be able to take fullest advantage of the expected early completion of the reservoir, unusual haste in its construction was desired. An enforceable penalty/bonus clause was incorporated in the contract, a fairly uncommon feature for work of this kind. Substantial completion was called for in eighteen months and in the event was effected nineteen weeks earlier.

The works are located on the east side of the reservoir, just downstream of the main dam on the higher ground, a few feet below top water level. The principal units comprising the works are:—

The Supply Chamber.
The Four Accelators.
The Contact Tank.
The Filter House.
The Filtered Water Reservoir.
The Chemical House.
The Pumping Station.
The Boiler House.

There are additionally quite a number of smaller units, an intricate network of pipelines and the external services including the roads. Looking at it all now, with its neatly trimmed lawns, tastefully arranged flower beds, trees and shrubs, it is a little difficult to recall the general picture of apparent chaos which persisted throughout the greater part of the period of construction, on what was in fact a somewhat difficult site.

The works operate by means of specially designed plant which in turn necessitated some quite intricate reinforced concrete construction. The object is to reduce the raw water to a total hardness not exceeding 150 parts per million, and the plant installed provides for softening mainly by lime and alumina. The softening process is supplemented by coagulation. The necessary chemicals for these processes are all stored, mixed and introduced in the four storey chemical house building, which contains also the necessary laboratories and apparatus for controlling all of the processes.

Raw water gravitates from the supply chamber which is by way of being a balancing tank. It is metered through a venturi to a butterfly valve chamber from whence it is directed to one of the four accelators. These are of the upward flow, sludge blanket type and herein the lime, alumina and other chemicals are added. Impurities adhere to the chemicals which by design suspend themselves at predetermined levels. They are then drawn off in a sludge main for ultimate disposal in a lagoon. The water passes on to the contact tank where carbon dioxide is added to turn the excess lime now in the water into chalk. This latter settles out in the bottom and again is drawn off and passed into sludge. The processed water is delivered into the filter house and passes through one of eight rapid gravity filters where the media removes the remaining suspended solids. After leaving the filters, the water is chlorinated and stored in the underground filtered water reservoir. It is delivered on demand by the pumps installed in the pumping station to either the small high level storage reservoir at Downham, constructed by the Southend Company as a convenient means of gravitating the water into their existing supply system, or by means of an aqueduct to the South Essex Company's main leading from Abberton.

The primary function of the boiler house is to produce the carbon dioxide needed in this treatment. It is achieved by the combustion of coke and the heat produced is used to warm both the chemical and filter house buildings.

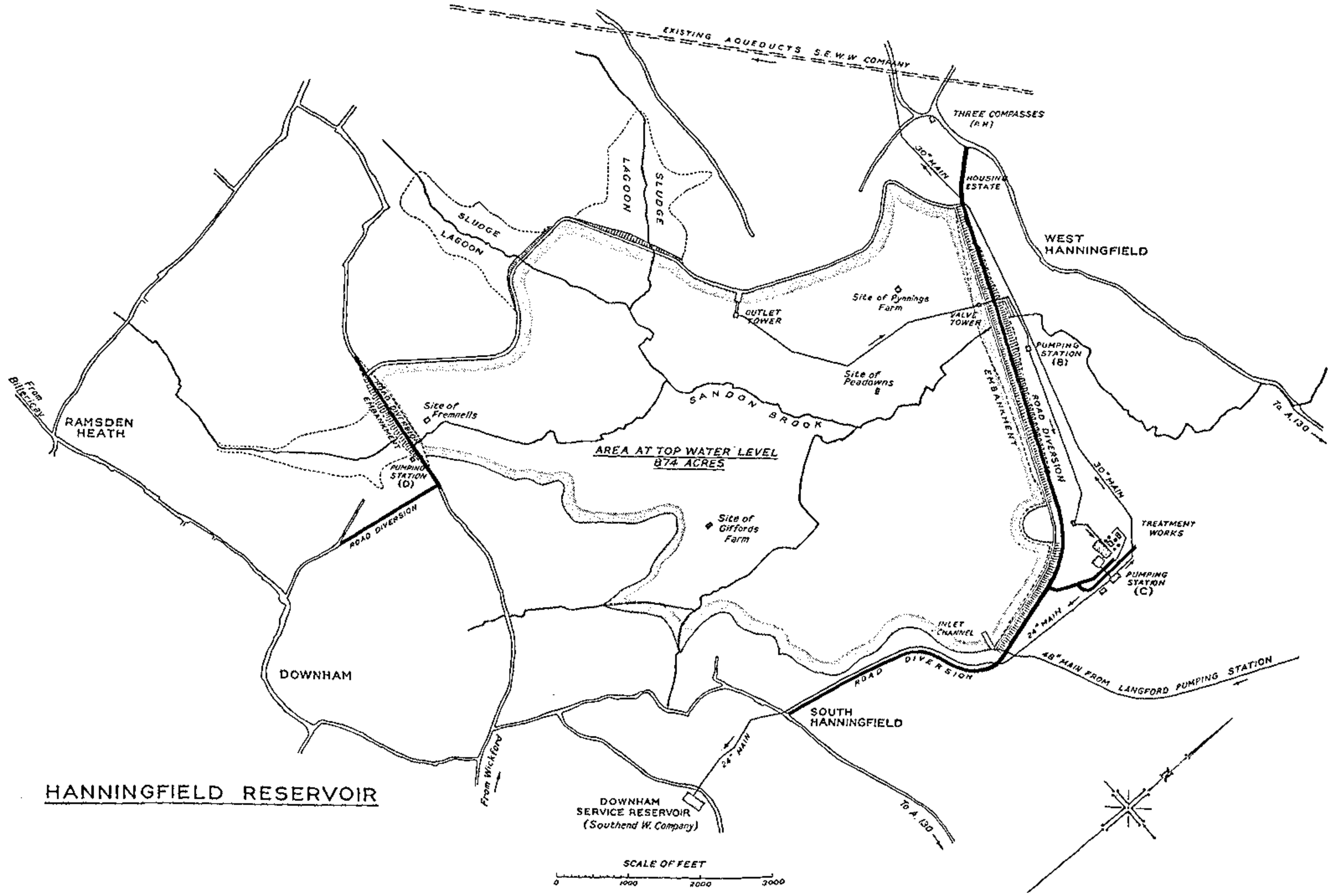
The construction of the works had all the normal problems common to most reinforced concrete structures, slightly aggravated by the extremely stickly clay site and the fact that very little time was allowed for building. There is some 10 ft. of fall across the site. Since it was desirable to have the units comprising the heart of the works all on the same level, provision was made to use the arisings from the excavations to make up these levels. Time did not permit the excavations to be removed and afterwards returned and placed to achieve this, particularly since the roads and other services were to be laid on the fill within the stipulated time. The clay had to be spread, levelled and compacted in its final position as taken out. This otherwise economic procedure did make the site very difficult to operate on. It was therefore decided that all handling of construction materials would be done by two mobile tower cranes built up on track laid out initially to what were to be finished levels. Again, time did not permit systematic construction unit by unit. A simultaneous start had to be made on approximately half of the units and a central batching plant was established incorporating a concrete pump. This was used to place the majority of the concrete. In many cases it was not pumped directly into the shutters, wall widths generally making this impracticable, but pumped to hoppers strategically spotted round the site. It was drawn off from these into placing skips and craned into position. Thus again, the problem of mobility on site was overcome and work was able to proceed comparatively unabated throughout the year.

Steel for reinforcement was dealt with in the conventional manner, delivery to site being effected in long random lengths which were cut, bent and fixed on site as the work proceeded.

The formwork was similarly dealt with entirely on site. A workshop was established to fabricate, alter and repair forms which were all out of timber, ply faced. The design was based on standard panels of predetermined sizes, 4×2 ft. and 8×4 ft. in the main, although some were made up as large as 24×18 ft.

The four accelators were unquestionably the most difficult units of all to build and are indeed the very crux of the whole works. They are circular in plan, 65 ft. in diameter, with sloping sides. They stand substantially above ground level, but it is the nature and extent of their intricate insides that called for most careful thought. Ultimately, it was decided to precast the majority of internal supports, partitions and platforms in units not exceeding two tons in weight. These were positioned and erected by crane and finally bonded into the main structure by casting other members to them *in situ*. The existing precast works on site, established initially to form the many thousands of precast units required around the reservoir generally, was therefore expanded to meet this new requirement quickly. The operation was on the whole quite successful. An unusual degree of accuracy was essential, but the innumerable odd shaped bits were eventually cast, cured, handled and secured in their precise positions in the tanks.

All the structures other than the supply chamber, accelators and filtered water reservoir were brick clad, and since little could be done of this work



HANNINGFIELD RESERVOIR

in the early stages, squads of up to seventy bricklayers were ultimately operating seven days a week. The amount of scaffolding necessary to keep things moving as units reached their top levels and inside work began, was quite disproportionate. To all this was added eternal trenches. Trenches for the pipelines, drains, water mains, electricity ducts, heating ducts and telephone cables, all in the clay and often in the most inconvenient of places.

However, the work was finally completed as desired and in August, 1956, the first trickle of processed water left the Hanningfield Works.

Ancillaries

In addition to the foregoing projects, running right throughout the scheme was a contract embracing all the cast iron and steel main laying. This included the 48-in. diameter aqueduct from Langford to the reservoir inlet. The aqueduct, which passes through the bed of a river among many other obstacles *en route*, was in welded steel tubes, as indeed were many of the mains. Because the area is notoriously bad from the point of view of cathodic action, the tubes were bitumen lined inside and out. Anodes were also introduced in an effort to counteract this most undesirable feature.

A further contract extending through the year 1955 was the erection of the Langford Pumping Station, including the Blackwater intake. Progress was initially slow because of difficult ground conditions, but improved considerably and was substantially completed to phase in with the over all scheme.

Still further contracts embraced the administrative building and houses for the permanent staff on the works. There were additionally many others largely concerned with the manufacture and erection of the plant and machinery.

Small additions in and around are still proceeding and the Joint Management Committee are going to quite considerable lengths to blend the whole area into the existing countryside.

As with all such undertakings the project inevitably uprooted a few and temporarily disturbed the peace of many others. Today, it not only serves an obviously pressing need, but by common consent has added a distinctive feature to one of the more attractive parts of the Essex countryside.

Electricity from Hot Water

THE MAIN DETAILS OF A UNIQUE POWER GENERATING SYSTEM

By R. N. HADDEN

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IT is an everyday occurrence to make hot water using electric current, as is done in electric kettles and immersion heaters, but it is quite another thing to try to use hot water to make electricity. Yet this can actually be done, and there is at least one generating station running today on water that would not be hot enough to boil an egg. This power plant belongs to a mining firm operating in the Belgian Congo. The plant itself was built and designed by an English firm, Messrs. Belliss and Morcom, and is shown in Fig. 1.

The problem that faced the mining company was how to get power to operate their plant, which was situated in a district that had no natural source of fuel, and where the cost of transport of oil or coal was exceptionally high. In fact, the only natural asset that might possibly be used to produce power were two fresh water springs, one hot the other cold. The Belgian mining engineers calculated that there was sufficient difference of potential energy between the hot water in one spring and the cold water in the other, to supply their power needs. The only question was how could it be done? How could the process be reversed, instead of heating water by electricity, to make electricity by cooling water?

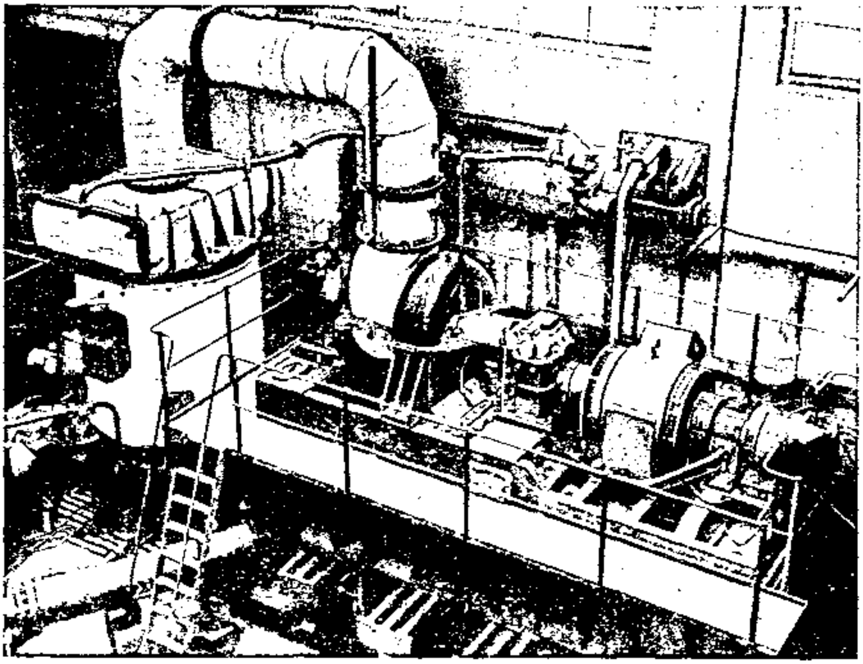


Fig. 1. Plant designed by Bellis and Morcom.

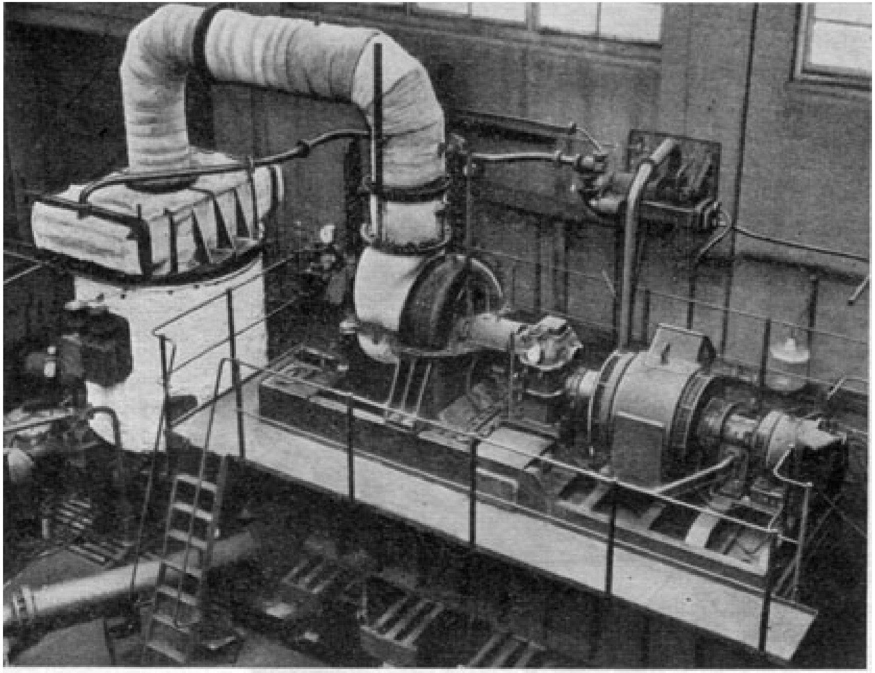


Fig. 1. Plant designed by Bellis and Morcom.

After approaching many firms in many different countries to try to find a solution to the problem, it was eventually Belliss and Morcom who agreed to tackle the problem. Their solution was not only very ingenious but was also very successful in practice. They relied on the fact that the boiling point of water is not constant, but depends on the surrounding pressure.

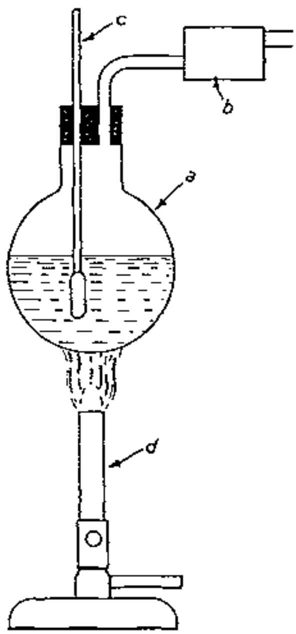


Fig. 2. Apparatus for first experiment.

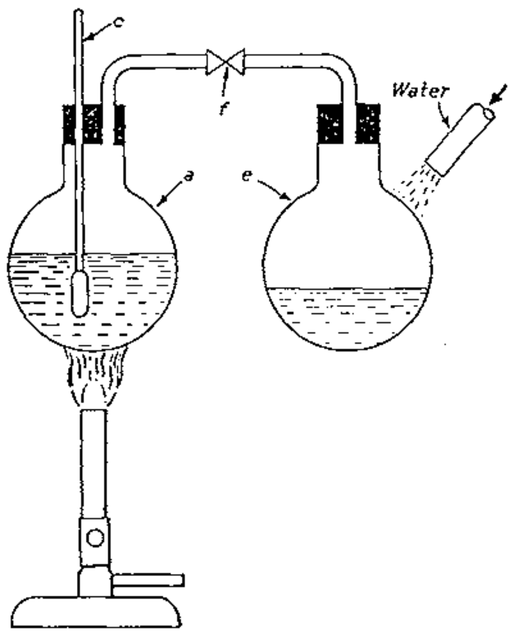


Fig. 3. Apparatus for second experiment.

To fully understand the operation of this interesting plant it is necessary to revise some of the facts about the boiling point of water. Suppose we connect up an apparatus such as is shown in Fig. 2, consisting of a flask (*a*), a vacuum pump (*b*), a thermometer (*c*) and a bunsen burner (*d*). Now, if we light the bunsen burner and heat the water we find that at normal atmospheric pressure the water boils at 212° F. If now, however, we start the vacuum pump, and reduce the pressure in the flask to a vacuum of, say, 10 lb./sq. in. we find that the water no longer boils at 212° F., but at 158° F. In other words, the water now boils 54° F. lower. Of course, the vacuum pump has to work fairly hard to draw off the steam and keep up the suction of 10 lb./sq. in., because if the steam were allowed to accumulate the pressure would rise and so would the boiling point. Similarly, if we increase the vacuum to, say, 13 lb./sq. in., the water boils at 84° F. Thus we see that the boiling point of water is not constant, but depends on the degree of vacuum in the vessel in which it is being boiled.

If now we change our apparatus to that shown in Fig. 3, where we have replaced the vacuum pump by another flask (*e*) and have put a valve (*f*) in the pipe joining the two. The flask (*e*) is kept cold by spraying water on to the outside. Assuming that the valve is shut and that the vacuum in (*a*) is

10 lb./sq. in. and in (*e*) is 13 lb./sq. in. We bring the water in (*a*) to the boil, and at the same time open the valve (*f*). The steam generated in (*a*) flows to the flask (*e*) due to the greater vacuum there. However, on entering the cold flask (*e*) the steam is immediately condensed back to water, thus maintaining the vacuum. As a result the process is continuous until all the water from (*a*) has boiled away and been condensed in (*e*).

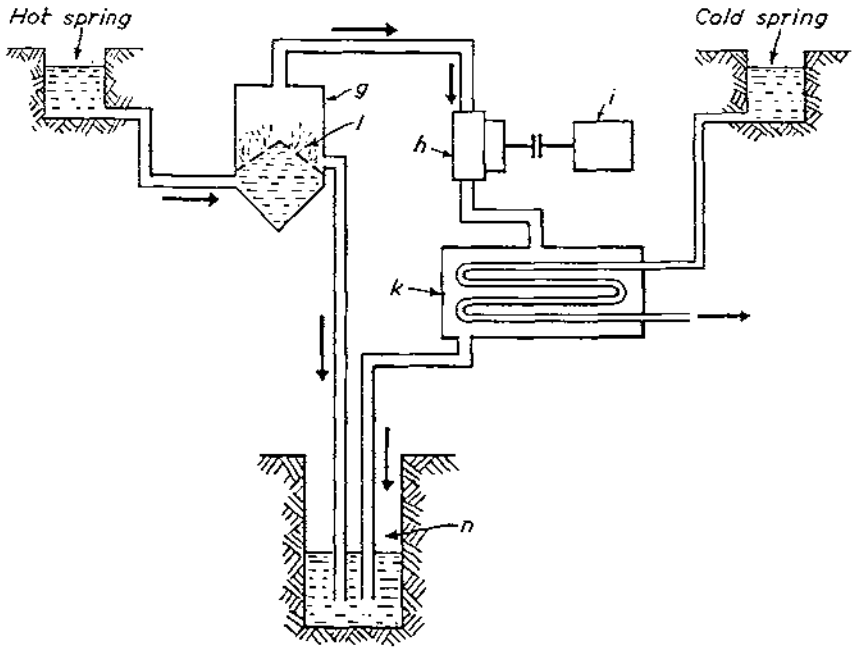


Fig. 4. Diagrammatic view of unit for extracting power from hot spring.

This then, is the principle which is adopted to get the power from the hot water spring. Flask (*a*) is replaced by the special boiler or evaporator (*g*) as shown in Fig. 4. The valve (*f*) is replaced by a low pressure steam turbine (*h*), which drives the generator (*i*), and the flask (*e*) by the water tube condenser (*k*).

The evaporator is maintained at a constant vacuum of 10 lb./sq. in. by the condenser. Water from the hot spring flows into the bottom of the evaporator and is sucked into the main chamber through the nozzles (*l*) in a fine spray. Due to the vacuum in the main chamber the water immediately boils and turns into steam. Any water that is not turned into steam drains away down a long barometric pipe to the sump (*n*).

When the steam leaves the evaporator it passes down the steam main and drives the turbine and then goes on to the high vacuum in the condenser, where it again becomes water. The high vacuum in the condenser is maintained by the condensation of the steam, which is caused by the water from the cold spring cooling it by flowing through the tubes. The condensed water is drawn away down a barometric pipe to the sump.

Thus by this simple and ingenious method the engineers at Belliss and Morcom were able to solve the problem which at first sight seemed impossible.

The plant has now run for many thousands of hours and is still in excellent condition. When working at full output it can develop 370 h.p.

While this installation is an isolated one, working under conditions that are relatively favourable, it must not be thought that this principle can only be applied to situations where there are hot springs. For instance, in some parts of the world the temperature of the sea on the surface is quite high, while deep down on the bed it is cold. This difference of temperature may in some cases amount to 30° F. Using the system just described power could be generated on an almost unlimited scale, the physical size of the plant, the initial cost and the heavy maintenance costs being the chief drawbacks. However, if ever the power needs of the world become sufficiently acute there is no doubt that this form of energy will be used.

Engineer Work in Julius Caesar's Army During the Gallic War

By MAJOR D. M. R. ESSON, R.E.

IT is now over two thousand years since our shores were visited by Julius Caesar: he has left an account of this excursion and of his other campaigns in a series of works known to schoolboys throughout Western Europe and beyond. His great successes were due not only to his own martial skill, but also to the superb discipline of his forces. Once again he showed, for all the world to see, the immense superiority of discipline over numbers. When with this discipline went martial zeal and constructional skill, the forces available to the master of the Roman world were irresistible. It is still a matter of interest for the modern sapper to read of the doings of the Roman pioneer, for fundamentally the tasks are the same. The three great tasks which fell to the lot of the Roman pioneer were the fortification of camps, the crossing of water obstacles and the provision of a water supply. It is the purpose of this article to discuss these and other engineering tasks which fell to the lot of Caesar's army, particularly in Gaul.

The organization of the Roman Army was based on the legion, a body of some 12,000 all ranks, predominantly heavily armed infantry, supported by ten troops of cavalry and a siege train. The infantry were subdivided into ten cohorts, one of which had a strength of 1,105 men, and the remaining nine 555 men each. The first cohort, whose duties included the custody of the eagles and the personal protection of the commander, formed a *corps d'elite*, service in the ranks of which was deemed a great honour. The cavalry, likewise, consisted of troops of 132 and sixty-six men each. The siege train, whose establishment must have varied from place to place and from time to time, provided the legion with battering rams (*aries*), catapults for discharging darts and javelins (*catapulta*), and rock-throwing engines (*ballistae*). It also provided the personnel for making mantlets (*vinea*), towers and other devises for use in sieges. Finally there were the auxiliaries, a heterogeneous collection varying from allied tribes of frontier barbarians to the polyglot of camp followers: some were first-class fighting material, others were not. They provided every form of service, from active fighting through all the graduations of protecting the camp and escorting supplies to menial duties of every variety. It was the pioneers of the siege train, assisted by such auxiliaries as were available and suitable, who provided the hard core of the engineering services of the legion, but for certain tasks the entire strength of the legion was deployed.[1] Certainly the legions stationed in Africa had a hydraulic engineer on the strength,[2] and we may assume that other technical officers were available as required. In fact the eighth book of *The Gallic War* was written at the behest of one Balbus, a Spaniard, who was Caesar's chief engineer (*praefectus fabrum*).

A fortified encampment of the legion, if required for any period of time, presented an almost uniform appearance throughout the length and breadth of the Roman Empire. A space of about 700 yds. square was cleared of all obstructions and levelled. Around the perimeter a rampart, about 12 ft. high and as broad on top, was thrown up and surmounted by a suitable palisade. Outside this a ditch of the same dimensions was dug. Inside, a space of some 60 to 70 yds. was left absolutely clear. In the centre lay the tents of the legion, surrounding both the commander's quarters (*praetorium*) and the eagles. The tents were laid out with precision, and between the lines was ample space. The object of such profusion of space was to avoid confusion in manning the ramparts at night, and to reduce the fire risks. The tents would be replaced by more permanent structures as the occupation of the site was protracted. All this work was done by the legion as a whole, and neither special personnel nor particular officers were engaged solely on this task.[3] The work was regarded as of such importance that it was written:

Universa quae in quoque belli genere necessaria esse creduntur secum legio debet ubique portare ut in quovis loco fixerit castra, armatam faciat civitatem.	*It was universally believed to be necessary in time of war that the legion ought to carry with it, wherever it pitches its camp, the appearance of a fortified city.*[4]

Frequently the work was done in the presence of the enemy, and often under attack.[5]

Sometimes the form of the camp was varied for tactical reasons. Caesar tells us how on one occasion he ordered double ditches to be dug with three-storied towers at frequent intervals, so that the camp would be easier to defend and might also encourage the Gauls to think that the Romans were very frightened.[6]

The bridging operations carried out by Caesar's army were not frequent, for the legionnaire usually forded rivers, and this was much easier in the days

[1]Gibbon: *The Decline and Fall of the Roman Empire*, Vol. I, p. 12–16.
[2]Binnie: Presidential Address. *J. Inst. C. E.* Vol. 10 (1938–9), p. 14.
[3]Gibbon: Vol. I, p. 16–17.
[4]Vegetius: *De Re Militari*, 1, ii.
[5]Caesar: *De Bello Gallico*, I xlix; II xix; III xxviii; V xv; VIII xxvi.
[6]Caesar: VIII ix–x.

before land reclamation works and river training schemes confined the waters into definite channels. When, however, Caesar wished to cross the Rhine, he had to build a bridge. He was offered boats to ferry his army across the first time,[1] but he says he thought this hardly safe and beneath his dignity. More probably the prospect of the return journey was not alluring, with the likelihood of a disputed crossing and a hostile army at his rear. This contingency was certainly in his mind, for when he advanced into Germany, he left a strong garrison at each end of the bridge.[2] The first bridge across the Rhine was built near Coblenz, and Caesar tells us how it was done. They drove pairs of angled piles into the river bed from rafts by some sort of machine, probably a block of timber raised by a tackle operated by manual labour. These piles were 18 in. square and 2 ft. apart. These pairs of piles held the transoms, which were 2 ft. square and 40 ft. long. These in turn carried the road bearers and the decking which were of poles and wattle-work. The whole structure was defended by fenders upstream and braced by raking piles downstream. Caesar does not tell us how far apart the trestles were, nor the species of timber he used. Any attempt, therefore, to classify the bridge by modern standards would be highly conjectural, but it might have run to Class 4; it was certainly satisfactory to carry Caesar's baggage. The whole work was done in ten days from collection of the timber to the passage of the legions, which for a bridge at least 400 yds., and probably 600 yds. long, appears to have been quite fast work. After his German expedition, Caesar broke up the bridge,[3] and set out for Britain. Details of this bridge were published in the *R.E. Journal* for September, 1945, and a model of the bridge is kept in the R.E. Museum.

Two years later Caesar again crossed the Rhine, this time a little farther up stream.[4] Due to their previous experience and their zeal, Caesar's troops did the work "in a few days". Again he left a strong guard at the bridge when he advanced into Germany. On his return, he only broke down 200 ft. of the bridge, and he left an entrenched garrison there, so that he could visit Germany again if he wished.[5] But the next Roman incursion into Germany was disastrous, for fifty years later three legions were swallowed up in the Hercynian Forest.[6]

There was one other bridging operation of interest to us. During the revolt of Vercingetorix, Caesar wished to cross the River Allier. The Gaul was ready to dispute the crossing and watched every move. The river was not fordable, so Caesar pitched his camp in a wooded place (*silvestri loco*), opposite one of the bridges which Vercingetorix had cut down. Hiding two legions in this wood, he marched off the next day along the river bank with the remainder of his force, which he opened out to deceive the Gauls. The ruse worked and Vercingetorix followed him. Once the Gauls had gone, the two legions emerged from their hiding place, and began to rebuild the bridge on the same piles as before, the lower parts of which were still intact. Caesar tells us that the work was soon done, and the legions were put across.[7] Before the days of explosives it must have been almost impossible to destroy the piled

[1] Caesar: IV xvi–xvii.
[2] Caesar: IV xviii.
[3] Caesar: IV xix.
[4] Caesar: VI ix.
[5] Caesar: VI xxix.
[6] Tacitus: Annales, I, i.
[7] Caesar: VII xxxv.

foundations of bridges, so that the task of a "fabian" commander was more difficult. It is also instructive as an example of failure to apply the maxim, "Obstacles must be covered by fire."

The cold damp climate of France presented Caesar with no great water-supply problem. The great aqueduct at Nimes belongs to a later period of great urban populations whose requirements were very different to the spartan needs of the legions. However, during the siege of Uxellodunum, Caesar found it possible to cut off the water-supply of the Gauls in an ingenious fashion. Uxellodunum, the modern Puy d'Issolu, was built on top of a precipitous hill near the middle of a river-valley, so that it had the advantage both of height and the propinquity of water. In addition the configuration of the land prevented Caesar from diverting the river, which meandered round the base of the hill. However, he made water-carrying an unhealthy task for the townspeople. Then he noticed that the town was being watered, not from the river, but from a spring just under the town walls on the side remote from the river. The spring was so placed that the water-carriers could be protected from the town walls, thus Caesar could not easily interfere with the operation. Accordingly he began a ramp, and pushed up mantlets, huts on wheels covered with skins and protected by a stout roof, in which his pioneers could work in reasonable safety. The garrison saw the point of all this and continually attacked the Romans: however the ramp continued to move slowly forward and upwards until it was 60 ft. high. At the end of the ramp a tower, ten stories high, was erected; the top floor of this was above the level of the spring; and Caesar's siege engines could dominate it with fire. At the same time the pioneers opened up some mines adjacent to the spring from the mantlets. The mantlets not only provided the miners with protection, but they concealed the work from the townspeople, who apparently never realized what was in progress. However, they launched an attack with burning tubs of grease and pitch, which destroyed much of the works, and considerably delayed the final Roman success. Ultimately the miners reached the feeders of the spring and diverted it. The garrison were thus deprived of water and were compelled to surrender.[1] Caesar's lenient treatment of his prisoners impelled him to cut off the hands of the combatants.[2]

But the most frequent tasks of Caesar's pioneers were in siege work. The central feature of this was the ramp (*agger*). This was constructed of earth and stones, revetted and reinforced with great baulks of timber. It would have been sufficiently wide, say about 25 ft., for the various siege appliances to be rolled back and forth, and the slope would have been sufficiently gentle, probably about 1 in 20, for this to be done with ease. The ramp was usually built by forward tipping, and was continued until a tower at the top could dominate the enemy-held works. The towers were of timber and were covered with hides to reduce the fire risk. They were often of considerable height; at Uxellodunum they were ten stories high, and at 7 ft. per storey, this would be 70 ft.[3] The ramp and towers were a sufficiently formidable sight in the early stages of the Gallic War to browbeat the Aduatuci into surrender.[4] Other siege appliances included mantlets of various sorts

[1]Caesar: VIII xl–xliii.
[2]Caesar: VIII xliv.
[3]Caesar: VIII xli.
[4]Caesar: II xxxi.

(*vinea, testudo,* and *musculus*); they all provided cover from enemy missiles, and were to some extent fireproof; screens of wickerwork (*pluteus*), which provided concealed approaches; and great hooks for tearing down stones from the walls (*falces murales*). All these devices would have been made up locally for each operation by the pioneers of the legion. In addition, they had another great task, mining under the walls, although the Gauls were better at counter-mining under the ramps.[1]

Two forms of obstacle met by Caesar are worthy of mention. The Nervii had no strength in cavalry, and so they developed an effective obstacle against horsemen. They cut into young saplings and bent them over. They then intertwined them with brambles and thorns. This sort of hedge was so thick that it could neither be penetrated nor seen through.[2]

The other obstacle was encountered during Caesar's second visit to Britain. Pursuing Cassivellaunus, Caesar came to the Thames, where he found a difficult ford, covered by a considerable force. He tells us that:

Ripa autem erat acutis sudibus praefixis munita, ejusdemque generis sub aqua defixae sudes flumine tegebantur.

The bank was protected by sharp projecting stakes, and similar stakes fixed under the surface were concealed by the stream.[3]

He goes on to tell us that he rushed this obstruction and drove off the forces of Cassivellaunus. It is believed that this fording place was at Wallingford, where the river meanders prior to passing through Goring gap.[4]

This then concludes a rough outline of the work of Caesar's pioneers. If Balbus could be resuscitated, would he find our work so different?

I am no classical scholar, and I have followed different interpretations of the text from place to place.

[1]Caesar: III xxi; VII xxii.
[2]Caesar: II xvii.
[3]Caesar: V xviii.
[4]See *R.E.J.* Vol. LXIX No. 4 (Dec., 1955), p. 345.

Service with the Federation Engineers in Malaya

By LIEUT.-COLONEL R. A. BLAKEWAY, O.B.E., R.E.
Commander Engineers, Federation Army

INTRODUCTION

EVERY year about eight R.E. officers and three or four senior N.C.O.s are selected for a three-year secondment to the Federation Engineers of Malaya. These numbers will gradually decrease, as more Malayan officers and N.C.O.s become fully trained, but there is likely to be little change in them for the next five or six years at least.

These R.E. officers and N.C.O.s are selected from a list of volunteers maintained by A.G.7 and R.E. Records, under the conditions of A.C.I. 484 of 1953. It is hoped that this A.C.I. will shortly be amended, improving the terms of secondment in some respects. An officer, before volunteering for any such service, would normally consult any of his friends who had been in the country concerned. However, since the Federation Engineers are comparatively young, and since the conditions of service in Malaya are changing rapidly, it is thought that some notes in amplification of this A.C.I. might be of value.

ORGANIZATION OF FEDERATION ENGINEERS

The Federation Engineers at the moment consist of a small Engineer Branch at Federation Army H.Q. in Kuala Lumpur, two large Independent Field Squadrons on a special establishment, and a small training detachment which is part of the Imperial Engineer Training Centre.

The Engineer Branch is responsible for the engineer control of the squadrons, and at times commands them; and for liaison between the P.W.D. and consulting architects and engineers on the one side, and Army H.Q. on the other, in connexion with works services. This latter commitment will involve the expenditure of many millions of dollars before all the new barracks and cantonments required by the Army have been built.

The squadrons, each with a large plant/park troop, either support their brigades in operations against the communist terrorists, or are detached under the Commander Engineers on major road and bridge construction projects. As time goes on it is hoped that other civil engineering tasks may come their way.

All plant, equipment and store backing is at present provided by the Imperial Army.

THE MALAYAN SAPPER

The Malayan Sapper may be a Malay, a Chinese or an Indian. At the moment the majority are Malays. They are a cheerful and very likeable race, capable of being trained to a high standard as infantry soldiers, and gradually learning engineer trades. They can be very smart and energetic when they feel the occasion demands it of them, but they will never give of their best until the importance or point of the task in hand has been fully explained to them.

They are slow to accept responsibility as N.C.O.s, but, and it is a big "but", every man has enlisted for at least seven years and has been picked from a large number of volunteers, since the Army is an attractive career to a Malayan, and they are proud of being soldiers.

The British seconded officer will find a lot of hard, worthwhile work in store for him. Good-humoured patience, firm leadership, a basic knowledge of the language and a strong desire to "know his men" are all essential. If he possesses these qualities he will be richly rewarded by the results he achieves, and by the trust and confidence he inspires in his men.

The British Seconded Officer—Engineer Tasks

Soon after he arrives in Malaya, the British officer will go on a month's language course in Singapore. After that he should find it fairly easy to pass the qualifying exam, with a reasonable amount of application, even though he was "bad at French" at school.

He will then return to his squadron and will soon be given an introduction to jungle patrols, and learn how to live, work, and fight in the jungle.

He will find that the engineer tasks carried out by his squadron are as varied, interesting and worthwhile as anywhere in the world today. Training is limited to short periods of annual infantry and engineer "Retraining". For the rest of the year the squadron may be supporting its brigade, perhaps by making helicopter landing zones, airstrips and jungle forts, perhaps by building operational camps, ranges, sports fields, etc. Alternatively it may be constructing emergency roads and bridges, later to be handed over to the P.W.D.

A typical emergency road project may involve the employment of a complete independent plant troop and an *ad hoc* works section in support of the squadron, the hiring of a large number of local labourers, the letting of contracts for culvert, etc., construction, and the building of a number of permanent prestressed R.C. bridges, Bailey bridges, and timber bridges. The road may pass through a combination of marshland, primary jungle, secondary jungle, padi fields and rubber plantations.

It is hoped that, as the Federation Engineers gain in experience and efficiency, so will the scope of the tasks allotted to them be increased; so that as time goes on they will play a full part in the development of their country.

Malaya Today

The emergency is still in existence, and movement "off the beaten track" is still very restricted in many areas, though gradually becoming easier. The country is very attractive with its jungle covered hills, padi fields, and rivers and beaches untouched by civilization. Some find the climate—seventy to ninety degrees throughout the year with high humidity—hard to get used to. Others find the acute shortage of eligible unattached European females a very grave disadvantage.

There are, however, opportunities for most games in the larger stations; there is sailing, and water ski-ing in a few seaside towns; some shooting, mainly pig and snipe on big estates; skin-diving on coral reefs off the east coast; and there are first-class opportunities for the bird watcher or animal photographer. The larger towns have good clubs and reasonable facilities for entertainment.

Much of the above depends, of course, on where an officer is stationed. The squadron officer in an operational camp, twenty or more miles from the nearest town, can usually manage to find, or build, a sports field for his men's games. Apart from this he has to fall back on his own resources and hobbies for his recreation. When he is on leave, or stationed in or near one of the larger towns, he can find plenty of opportunities to enjoy himself to the full.

Leave

End of tour leave is generous, and it is possible to take up to sixteen days of this leave each year in addition to the annual fourteen days. By so doing it is quite easy to visit Siam, Hong Kong, Borneo or Japan; alternatively, leave in the hill stations of Malaya, or by the seaside, or touring the east coast, has its attractions.

It is possible at the end of one's tour to obtain the equivalent in cash of one's passage home, and officers are, in fact, encouraged to return home by an "adventurous" route.

Pay

Pay and allowances are very adequate, for both the married and single officer. Few officers, "Imperial" or "Federation", leave Malaya without having saved some money and acquired a new car and perhaps a cine camera; and at the same time are able to enjoy their leaves without giving too much thought to the financial implications.

Family Accommodation

It is quite impossible to say whether any particular officer or O.R. volunteering to join the Federation Engineers will be given a quarter since this will depend on where he is stationed.

There are a number of quarters available in the Federation Army allotted on the normal points system, and furniture is provided. This furniture, however, is only the hardwood items plus mattresses and mosquito nets. All other items such as cutlery, linen, household utensils, glass, crockery and refrigerators must be provided by the officer or O.R. by either bringing out some with him or by buying the items he requires when he arrives in the country. For this purpose an interest-free loan of about £87 10s. for O.R.s, £116 for captains and lieutenants, and £175 for majors and above, is available.

Where quarters are not available, officers and O.R.s may find their own accommodation and claim on the Army for reimbursement of rent. In these cases the rent that they actually pay in the end is about £2 7s. plus 12s. for furniture a month.

Although officers and O.R.s have to spend a certain amount on furnishing their quarters, etc., when they arrive, the Federation Army rents (including furniture) are very much lower than those in the Imperial Army.

Family Life

Some families like Malaya, some don't. It is very difficult to be fair and to put all the pros and cons in a short article.

Family life in an Army station is very much what the individual family makes of it, and Malaya is no exception to this. Most children flourish in the country, some do not.

The main disadvantage is that the squadron officer is likely to be separated from his family, except for one long weekend a month, for about half the year and for periods of four months at a time or longer.

Family "A" may be miserable with the husband away half the year, the wife unable to drive a car and in any case not "sociably inclined", the family in a sub-standard hiring and the children ill. Family "B" may be comparatively happy and well under almost similar conditions. Family "C" may thoroughly enjoy the social life and the high standard of living, and the many opportunities for leading a full life (since the wife can divorce herself from household chores), even though the husband is away for long periods at a time.

Officers who allow their work to be adversely influenced by their concern over their family problems are not required in the Federation Engineers, and married officers should not volunteer for secondment unless they are reasonably sure that their families are robust and able to fend for themselves cheerfully.

CONCLUSION

The Federation Engineers are a young corps with, as yet, little tradition or experience to guide them. There is a great deal of hard work awaiting any seconded Sapper officer. He can expect to be given varied and interesting tasks, many in the remoter parts of the country; he will be well paid compared with other theatres and will "see the world".

At times, especially when the climate is being particularly trying, he will have to discipline himself to keep himself fit and energetic, and cheerful and patient with his men. If he is married, he can expect to be frequently separated from his family.

However, above all else, and perhaps more so than in other theatres, he should often experience the pleasure of being given a worthwhile engineer task to do, and of completing it successfully.

Why Not Teach?

By LIEUT.-COLONEL W. E. C. PETTMAN, R.E. (RETD.)

HAVING settled happily to a second career as a schoolmaster, I feel obliged to offer advice about it. Those to whom the idea is repugnant need read no further, since enthusiasm is essential, but for those who itch to pass something on, there may be a thrilling and rewarding future. The club and games life is attractive and keeps one young; only the senile need retire; and the holidays amount to one-third of the year, during which there may be some coaching. It is quite exciting to watch the raw material grow into whatever we can make of them.

The top maths or latin master at a preparatory school may get about £600 a year, plus board and lodging in term time, which is worth about another £150—quite a useful addition to a pension. Sometimes there is a superannuation fund as well.

A post at a public school or a grammar school is hard to get without a degree, or a resounding military record, or good and relevant testimonials. A university teaching diploma is the normal requirement.

Preparatory schools look more to the personality of an applicant. Service experience as an instructor is useful, and some headmasters realize that most of a service career is associated with the teaching of all sorts of matters to all sorts of people. Such pupils, however, are grown up; it remains to be seen whether one can cope with the young and, if so, whether best with the young at prep school age or with older boys of 14 to 18. The test of this is one's own reaction to "incidental young". Youth Club activity is another consideration.

How to start? Part-time engagements are preferable while gaining experience, and these spring from inquiries and the local paper. The beginner needs plenty of spare time to study textbooks, correct "prep", and generally to think about the whole business. The routine of school life takes a little time to digest, and an apprentice cannot afford too many mistakes. His future depends on testimonials.

Any teaching not already indicated by gaps found in class work is based on the syllabus of the next examination. This will be found at the school, and one can get a copy. The prep school target is the "Common Examination for Entrance into Public Schools". For this no syllabus is published, but the requirements are easily gauged from past papers, reprints of which can be borrowed or bought. Textbooks are full of useful forgotten teaching points, and no teacher should be without his collection of "*I.A.P.S. Pamphlets*". There is one of these for each subject, and they cost 6d. each from The Secretary, Public Relations Committee, Incorporated Association of Preparatory Schools, Hurst Court, Ore, Hastings. Maths teachers need also the *Reports on the Teaching of*—(various mathematical subjects)—*in Schools.* These were prepared by the Mathematical Association and are published by G. Bell and Sons, York House, Portugal Street, W.C.1, who also provide a list of them. *The Schools Year Book*, in any reference library, is interesting too. I have also found useful hints in books on the schoolmaster theme, such as *Down the Corridors* by Fielden Hughes, *Chalk in my Hair* and *Chalk in my Eyes* by "Balaam".

The I.A.P.S. run holiday courses for teachers, where one meets other teachers of one's own subject while learning how to teach it.

After part-time work one looks for full time. Two well-known London agencies, Gabbitas & Thring and Truman & Knightley, send out notices of vacancies in return for a percentage of the resultant salaries. An interview with them is advisable. *The Times Educational Supplement* has useful advertisements. All vacancies should be compared with the *Schools Year Book* and also if possible submitted to a colleague for advice. In this way one begins to learn about the world of schools. By this time the candidate will have some duplicated copies of his chief particulars and testimonials, ready to send with each application, of which there will be many. Travelling expenses to an interview are usually paid by the school that invited them, and only repaid by the candidate if he is offered the post and declines it. It takes a little practice to size up a school at a short interview, and to know what questions to ask.

It is prudent to try out a few short time posts before settling to a permanency which may prove disappointing. This, fortunately, is easy to do, because the big permanent changes happen at the end of the summer term, so there is often a gap to be filled for one or two terms only. Fortunately again, there is a tendency to pay rather higher rates for short engagements than for long. Thus one's experience may be widened without the appearance of being a "flitter". Meanwhile, testimonials and technique are growing.

How far my own beginnings may be typical I do not know. I retired at 51, and at 53, despairing of a future in accountancy, I tried a temporary part-time job teaching maths at a local public school. Another master's illness brought geography, history and english so far into the picture that I had to learn the next day's lessons in the homeward bus at night. The salary barely paid my fares, but the venture succeeded, partly, I am sure, because of a small share in the school play, and partly because of some advice which I obtained about a boy's national service. Moreover the C.C.F. did fieldworks.

While here, the headmaster put me on to some private tuition and to a "one day stand" at a small prep school whose staff was decimated by flu.

After a term of this I got a temporary part-time post at a Crammer's, where cricket, swimming, and make-up for the house plays were a useful side line. There was also a possibility of teaching book-keeping, economics, or commercial or company law, but no demand arose for these. Good pay here, but only four or five periods a day for two terms, so I turned to Gabbitas and Thring.

Fate and a colleague's advice steered me to a one-term vacancy at a good prep school within week-end range of home. This was my first full-time venture. Besides maths with each form, the Sixth Form and I revelled in an hour's science once a week. I took the lowest football game on an enclosed hard tennis court, and a little boxing. I am not fit for rugger but my Twickenham touchline voice was considered worth half a try a match. I learned much there which has been useful since, and found many friends.

By now, four terms' varied experience enabled me to become top maths master at a bigger prep school far from home, living there in term time. Here I took shooting and physical education, had full charge of hockey, and enjoyed cricket away matches too. Differences of opinion ended this after two terms, but the exam results had been good and I got to a grammar school, tempted by the higher salary and the higher level of teaching.

Ordinary grammar schools cannot fairly be judged by this particular establishment, which is now unable to keep its staff. I left it my first term, not asking for a reference but confident of finding something.

Fortune now relented. While hesitating between a prep school and another grammar school, I found a place at the junior school of my own former public school, and that ended this search for a second lease of life. Since then I have enjoyed one I.A.P.S. course and hope to enjoy more. One continues to learn.

Of course there is something between the lines of this bald tale. A degree would have helped, or greater prowess at games—boys still prefer off-breaks to theorems. A limp is only a slight handicap, but one would be better without it. On the other hand, some people were impressed by my commercial exam successes since retirement, and others by some Youth Club work. Other entrants will have other attributes and meet with different luck.

The value of hobbies and parlour tricks may be noticed. Whatever your accomplishments, they will come in handy. Plays are produced, games are played, hobbies encouraged, tales demanded, and wet days encountered. Contacts are useful, and the general running of affairs and discipline should come easily to "retired types". Some officers may rejoice that maths teachers are scarce.

How far is school life compatible with home life? Not at all, in my opinion, though some will disagree. Twenty boys will do in an hour more "prep" than one can properly examine in an hour, if one is to diagnose each boy's faults, allot and record his marks, write useful comments, and plan the next lessons accordingly. Out-of-school trifles crop up too. For instance I run the stationery cupboard; another runs the tuckshop; others run the games, the Scouts, the drama, the hobbies and the model railway clubs. I for one cannot steep myself in "school" while living at home, so I live "on board" in term time, and revel in the ample holidays plus an occasional "forty-eight". This is no novelty to service folk, and it widens the choice of a school.

Let me end, as I began, by emphasizing that teaching has no future for those who cannot like it, but an abundant future for those who do.

An Early Order of Battle

By Colonel D. M. Eley

An old drawing has recently come to light in the Chief Engineer's office at Gibraltar which is of especial interest to the Corps of Royal Engineers in containing what is one of the earliest, if not the earliest Order of Battle to include the Military Company of Artificers, one of the fore-runners of the Corps.

The drawing is entitled "A Plan shewing the Attack and Disposition of the Detachment which sallied on the 27th November 1781 from Gibraltar and destroyed the Spanish Batteries before that Garrison." It is to the scale of 200 feet to 1 inch, and though age, mice and neglect have destroyed all marks of its origin*, it shows in ink and water-colours the whole of the isthmus known as the Neutral Ground, the northern end of the Rock and City of Gibraltar and the route followed by the three columns forming the "Detachment" in their deployment and advance to the enemy lines.

The Order of Battle is given in a box on the lower part of the drawing and, reduced from its diagrammatic form, reads as follows.

The Detachment formed for the Sortie

Brigadier General Ross

(Right Column)	Lt.-Colonel Hugo	
	Reden's Granadiers (*sic*)	Captain Heideman
	La Motte's Granadiers	Captain Purgold
	Artillery	Lt. Cuppage Artillery
	Workmen	Lt. Johnson Engineer
	Hardenberg's Regiment	Major Issendorf
	56 L. Infantry	Captain Pigot
(Centre Column)	Lt.-Colonel Dachenhausen	
	39 Granadiers	Captain Vaughen
	39 L. Infantry	Captain Tuite
	73 Granadiers	Captain Sinclair
	73 L. Infantry	Captain Dalrimple
	Artillery	Captain Whitham
		Lt. Glasgow
	Workmen	Lt. Skinner Engineer
	56 Granadiers	Major Moor
	58 Granadiers	Major McMine
(Left Column)	Lt.-Colonel Trigge	
	72 L. Infantry	Captain Tipping
	72 Granadiers	Captain Ayton
	Sailors	Lts. Campbell & Muckle Navy
	Artillery	Lts. Siward & Hay Engr
	12th Regiment	Major Barlow
	58 L. Infantry	Captain Grant

* From internal evidence it is thought to be a draft of the plate in Drinkwater's *History of the Siege*, 1785.

	Offrs.	Sergt.	Drumr.	Corpl. & Private
Rt. Column	30	59	2	570
C. Column	28	40	0	620
Lt. Column	41	48	2	824
Total	99	147	4	2,014

Little more is to be found from the drawing, but the histories tell how complete was the surprise effected by the sortie—it captured a report written in advance by one of the Spanish Orderly Officers in which he stated that nothing extraordinary had occurred that night—and of the thorough job made by the sailors, the Artillery and the "workmen" in destroying the enemy batteries. They were under the eye of the Governor, General Eliott, himself an Engineer during the earlier years of his service, for he had followed the sortie out. But he had desired his Chief Engineer, Brigadier Green, to remain in the fortress, and the latter watched the operation from the North Bastion.

Brigadier Green's feelings can perhaps be imagined, for these "workmen" were the men of the Military Company of Artificers which he had been so instrumental in raising nine years before and of which he was the first Captain. True they had had their baptism of fire, the siege being already nearly two and a half years old, but this was the first occasion on which they would be coming into immediate contact with the enemy, and they were very much a mixed company. They consisted, in the words of the Warrant of the 6th March, 1772, which authorized their formation, of men "who shall have been bred to the trades of stonecutters, masons, miners, limeburners, carpenters, smiths, wheelers or gardeners", and they were recruited to a total establishment of sixty-eight N.C.O.s and men, partly from tradesmen serving in the ranks of regiments in the Garrison, and partly from among the directly employed labour brought out from England on which, up till then, the Chief Engineer had relied for the works services. But all went well, and when the Detachment was safely back within the Fortress, the Brigadier and his Brigade Major, Holloway, went up to the top of the Rock to reconnoitre the damage done to the enemy lines.

The drawing has now been deposited with other old records at the residence of the Governor and Commander-in-Chief of Gibraltar.

Colonel EEB Mackintosh DSO

Memoirs

COLONEL E. E. B. MACKINTOSH, D.S.O.

ERNEST ELLIOT BUCKLAND MACKINTOSH was born on 3rd November, 1880, near Chupra in Bengal. He was the son of Ernest Alexander Mackintosh, an indigo planter in Bihar, and Gina, daughter of C. T. Buckland, of the Bengal Civil Service and founder of the Calcutta Zoo.

He was sent to the family school at Laleham, kept by Frank Buckland, a well-known Eton and Oxford cricketer and a cousin of his namesake the naturalist. From there he went for a year to Temple Grove, East Sheen, of scholarship repute, and duly went on to Eton as a King's Scholar in 1894. While there he got the average number of prizes expected of scholars, and as a dry-bob got his colours for Second Upper Club and College Cricket: at football he got his College Field and College Wall, and twice won College Fives.

From Eton he passed into the R.M.A. Woolwich at the age of 16. His only prize was for freehand drawing, but in his spare time he represented Woolwich against Sandhurst at racquets, won the Billiard cue, and was band corporal.

Commissioned in the Royal Engineers he joined at the S.M.E. Chatham, in July, 1899. Courses there were curtailed owing to the South African War and, after learning Submarine Mining at Plymouth, Mackintosh to his chagrin was posted to Malta in 1901—both Malta and Gibraltar were brought up to war strength thanks to sabre-rattling by the German Emperor. Invalided home in 1902 he went to Fort Camden, Cork Harbour, for two years and then to Shornmead Fort, Gravesend, as Brennan torpedo officer: incidentally he won the Brennan Cup competition, and was Adjutant of the Thames Sub-Mining Militia.

In 1906 Mackintosh was seconded to the Egyptian Army and went to the Sudan as Asst. Resident Engineer for the construction of Port Sudan under the P.W.D.—the Resident Engineer being Lieutenant H. H. Kelly, R.E., an old friend and only six months his senior. Later he was transferred to Military Works in the Upper Nile and Mongalla provinces, where he found big game shooting almost on the doorstep.

He became A.D.C. to General Sir R. Wingate, Sirdar of the Egyptian Army and Governor-General of the Sudan, in 1908, an exacting job for the one British A.D.C., for which the chief qualification was Kitchener's motto "Thorough"—four sets of Royalties stayed at the Palace in Khartoum in one winter's season.

After three years as A.D.C. he joined the Headquarter Staff, under Colonel Asser, as D.A.A.G., becoming A.A.G. in 1913, and serving alternately in Khartoum and Cairo: awarded the 4th class Osmanieh.

He was retained in the Egyptian Army on the outbreak of war, with all other British officers, but finally was released to come home early in 1915.

He served in France in command of a field company, and, on the formation of Fourth Army Headquarters, as staff officer to the Chief Engineer, his uncle General Buckland. After some months in England with rheumatoid arthritis, he returned to France as an Assistant Engineer-in-Chief at G.H.Q. for the last eighteen months of the war, dealing with Personnel matters and organization of new types of R.E. units. He was awarded the D.S.O., Legion of Honour, Brevet Lieut.-Colonel, and mentioned in Despatches.

During the first half of 1919 he was Secretary of the Committee on the future of the Royal Engineers, of which Lord Rawlinson was Chairman, and then spent four years as personal assistant to the D.F.W., General Sir W. Liddell, and in one of his sub-branches. After that he served for a year as Staff Officer to Colonel Walker, Chief Engineer Eastern Command.

In 1925 he was posted to Hong Kong as Commander Royal Engineers. In his last year there he had suddenly to cope with the housing of a British Division, called the Shanghai Defence Force, which on arrival from England had to be accepted and quartered in Hong Kong before being drafted on to Shanghai.

On returning to England in 1928 he finished his Lieut.-Colonelcy in command of the Depot Battalion at Chatham, much of the time acting as Commandant S.M.E., while General Walker was away in his other role of Inspector of Royal Engineers. The battalion was safe in the hands of an excellent adjutant, Crawford, later to become General Sir Kenneth Crawford.

Promoted to Colonel in January, 1929, he had to wait eighteen months on half-pay for a job, mostly spent with his family in Italy. In 1930 he found himself back in the War Office as A.A.G. Royal Engineers and Corps of Signals, and two years later moved across the road to the Horse Guards as Chief Engineer Eastern Command, with the rank of Brigadier.

In 1933, the President of the Board of Education offered him the post of Director and Secretary of the National Museum of Science and Industry, colloquially the Science Museum. The organization and administration of such an institution, with its wide contacts with the scientific and industrial world, was too tempting—Mackintosh accepted and retired from the Army shortly before his fifty-third birthday.

His predecessor, Colonel Sir Henry Lyons, F.R.S., late R.E., who made everything burgeon which he dealt with in life, handed over the Museum as a lively and go-ahead place. Mackintosh found it easy to foster the spirit of camaraderie existing among the staff, which included eighteen ex-mechanics and foremen of works R.E., and to maintain the principle that their role was to provide efficient and helpful service to the public.

On the outbreak of war in 1939, Mackintosh was recalled to military duty and was appointed Commandant of the School of Military Engineering at Chatham, with the rank of Brigadier, and was responsible for the change from peace to war footing of the courses at the S.M.E. and of many Corps activities, official and social. During his tenure His Majesty King George VI paid his first official visit to Chatham as Colonel-in-Chief of the Corps of Royal Engineers. In 1940, on the return of the B.E.F. from France, Mackintosh was relieved by a younger serving officer and returned to his post at the Science Museum.

He at once set about evacuating some two-thirds of the more valuable national possessions in the Museum, including 100,000 old and rare books, to thirty country houses in Wales and the west of England—a formidable task under war-time difficulties of packing, transport and depleted staff. Finally, on reaching the age limit of 65, he left the Museum in 1945 and retired from public service.

As a younger man games of all kinds and amateur theatricals provided his recreation: in later years his hobbies were focused on Chinese art, concert-going, and old English glass—he was a founder-member and Vice-President of the Circle of Glass Collectors. From 1930 onwards he lived in St. John's Wood in London, where he was an indefatigable gardener. Blest with the bump of enjoyment and a quick, and sometimes witty, tongue he found "sermons in stones and good in everything," which assured him a full and interesting life and a wide circle of friends. He was a member of the Army and Navy Club and the Athenaeum: his cricket clubs were Free Foresters, Eton Ramblers and M.C.C.

Endowed with a tidy mind he was always well-groomed, and left his sartorial impress on his Corps by getting its colours changed from the voyant scarlet and blue to the correct Waterloo dark-red and blue, from the Waterloo medal ribbon.

Mackintosh was an F.R.G.S. and a member of the Royal United Service Institution, Newcomen Society, and Assn. of Special Libraries and Information Bureaux. Also a member of the Royal Institution, and for some time one of its Managers and Vice-Presidents. He served for twelve years as a Governor of the Imperial College of Science and Technology, and a Trustee of the Imperial War Museum. He was also Chairman of Clan Chattan Association, which embraces the clans of Macpherson, Mackintosh, MacGillivray, and some others, and over 100 septs. In Corps matters he served on the Council of the Institution of Royal Engineers and two of its Committees, and was the last Secretary of the R.E. Luncheon Club.

He married in 1923, Marion Constance, daughter of Major E. F. Talbot-Ponsonby, R.A., of Southwood, Tiverton, and had a son and daughter. His son, a Sergeant Flight Engineer in Lancaster Bombers, was killed over France in 1944 at the age of 19: and his daughter served two years in the W.R.N.S.

LIEUT.-COLONEL J. E. L. CARTER, M.B.E., M.C., R.E.

ON Saint George's Day (23rd April), 1957, JOHN EDWARD LOVELACE CARTER, died after a short illness. He was at the time of his death Chief Instructor in the E. and M. School at the S.M.E. He is, however, best known in the Corps for his pioneer work in the practice of package loading and mechanical handling of engineer stores and equipment for military purposes. He was, indeed, sometimes referred to in jest, as "Fork-lift" Carter, because of his bubbling enthusiasm for that ingenious piece of equipment, the fork-lift truck.

He was born in Karachi on 15th June, 1916, and passed into the "Shop" top of his term. He quickly made a number of friends, one of whom (J.C.) writes as follows:—

"I first met John Carter at the end of August, 1934, when I arrived at the Shop for my first term as a G.C. and found that I was to share a room with three other Snookers, one of whom was John Carter. The other two were Bill Adams (also now a Sapper) and John Anderson, who became a Signaller. We four got on very well together from the start and quickly formed a strong combination, which was well known to the authorities. Although, in the subsequent terms at the Shop we were split up into several different houses we still maintained a sense of companionship. This was demonstrated during

Lieut Colonel JEL Carter MBE MC RE

May, 1935, when the Shop received four tickets for Gentleman Cadets to attend King George V's Jubilee celebrations in London. Instead of being distributed in any other way, these four tickets were given to us, and we spent a cheerful day together in London, in our uniforms as G.C.s.

"John Carter had passed out top of the Shop in January, 1936, and was therefore head of our Batch; in this capacity he organized many functions both official and unofficial. He was clever and hardworking and this combination gave him clear leadership in all academic matters. Physically he was well built and excelled at P.T., but would try his hand at all sports. As Y.O.s we naturally took part in anything Chatham had to offer and when we went to Cambridge in the autumn of 1936, John and I had both chosen the same college, Peterhouse. From the start, John was determined to get First Class Honours and attended all the lectures punctiliously, as well as doing a great deal of work at home.

"When we came down from Cambridge in the summer of 1938 our successes in the Mechanical Sciences Tripos fitted exactly with the order of our Batch. John Carter as head of the Batch had a First, the next seven of us had Seconds, and the remainder Thirds. A very satisfactory and orderly arrangement! On returning to Chatham, however, we were told that the last ten months of our Y.O. course would not take place and we would be posted as a Batch to Corsham. Here a large underground project was in full swing and made useful practical training for Y.O.s. John's work was underground and he soon established an excellent relationship with the underground managers and a rather unusual labour force being employed. He quickly made a name for himself as a reinforced-concrete designer. He was very interested in music and while at Corsham he and David Edgar were associated in writing together an opera, which was never quite finished. In early 1939, one by one the members of the Batch were posted to units (mostly overseas) and, in March, John volunteered for an unusual posting in Trinidad. About a year after the war had started I heard from him again; by then, he had met Dorothy Mathison in Trinidad. John came home in 1942 and Dorothy followed him the following year and they were married in England. John was then posted to 53 (Welsh) Div. which formed part of the British Liberation Army of North-West Europe."

His first command was 244 Field Company; and the second-in-command of the squadron (B.C.E.) writes intimately of their association together between March, 1944, and July, 1945. The following is based on what B.C.E. writes of those times.

John Carter was a quiet, thoughtful company commander, who never rushed into any job. His main qualities were a clear, quick brain, and great personal courage. He paid minute attention to detail, and his company was quick to discover that nothing would be left to chance; that everything would be "laid on"; and that John Carter himself would be there to share all perils and hardships. The company thus placed implicit trust and confidence in his leadership and direction.

This was called to the proof at Rethem in Germany when building a bridge over the River Aller. Here J.C. takes up the story again. "The Germans on the far side were believed to have left, but this information was untrue and they put up a spirited fight; John's bridge was only got across after much personal gallantry. He had however put up a splendid show on several previous occasions and his M.C. reflected these also."

Of this time B.C.E. also writes:—"He was particularly interested gadgets; and his half track, which we shared, was complete with beds, lig and a plywood roof—a wonderful sight in convoy.

"During the operations he became adviser to XII Corps on diffic bridges. He was blown up on a mine when in a scout car and (as stated abo won the M.C. at Rethem Bridge.

"In his spare time he enjoyed a game of bridge and by way of relaxati during operations in Holland wrote an amusing and light-hearted paper fourteen pages on the *Theory of Potholing*.

"Despite his rotund figure, in 1945 he was still very fit. At the Shop had been a good gymnast, and I was surprised in a gym in Hamburg in Jun 1945, when he suddenly took off and performed a somersault in the a landing back on his feet, just to show he could still do it."

"After V.E. Day" (writes J.C.) "he remained in Germany for a while a then, at the end of 1945, when I had just joined the Staff of the S.M.E. Senior Instructor of Fieldworks, I was delighted to hear he was being post there as Senior Instructor Bridging. When he arrived we met Dorothy for t first time and soon regained much of the old camaraderie."

In 1947 he was posted to MEXE, at his own request. He had been give vacancy at the Staff College; but he turned it down, knowing that his b gifts to the Army and the Corps were on the technical side as opposed to t staff. At MEXE, he was employed in the design of the new Heavy Gird Bridge; and it was while there that he first developed his theories on t handling and packaging of stores. They seemed far-fetched and odd theori in those days though many of them are adopted as normal practice toda Among the many reports and articles he wrote in this connexion was a high informative one on the handling of goods through the Port of Rotterdam.

J. C. continues:—

"In 1953, I was most distressed to hear that his health had broken dow and he had been undergoing a very long and difficult period of sickness. 1955, however, we were delighted to discover that he was at Chatha apparently so much better. While serving at Chatham, he did again have very bad spell, but seemed to be in excellent spirits through the whole of t summer of 1956, by which time we thought he had thrown off, at last, t whole of his trouble.

"When The Queen paid her visit to Chatham at the end of 1956, Jo Carter was chosen as one of those to represent the Corps at the Headquart Mess to lunch with her, and he had the honour of demonstrating several his E. & M. exhibits to Her Majesty during the course of the afternoon. The included the oldest known steam engine, which worked perfectly. Geor Blyth and my wife and I were entertained at their house in Chatham on th day and we made a short colour movie film of the three of us wearing f regimentals and swords.

"The last time I saw him was in the beginning of 1957 at the R.E.Y. Guest Night. Again he seemed in perfect health and was in good form."

Many officers, besides those writing above, have mentioned the kindne and charm of the wife, whom John Carter leaves with two sons and daughter. It is with sorrow that the Corps mourns the loss of an unconve tional, versatile and promising Sapper; and his brother officers and ma friends express their sincere sympathy to his widow and children.

M.C.A.H.

Book Reviews

THE BUSINESS OF WAR

THE WAR NARRATIVE OF MAJOR-GENERAL SIR JOHN KENNEDY, G.C.M.G.

Edited and with a Preface by BERNARD FERGUSSON

(Published by Hutchinson of London. Price 25s.)

It is all very well for Field-Marshal Lord Montgomery to declare, in his puckish way, that he will not be found amongst the generals who snipe at Sir Winston Churchill in their memoirs. He was not in almost continuous contact with perhaps the most formidable mind ever vouchsafed to a Prime Minister of Britain. Nor did he have much to do with the supreme direction of the war. When the Field-Marshal writes his memoirs, which he also owes to the Muse of History, he will no doubt find plenty of other people who for their imperfections require to be sniped at a little. Major-General Kennedy, like Lord Alanbrooke, is certain to be charged with belittling the Prime Minister. Surely too many earnest individuals have talked great nonsense about this matter? They should give themselves a good shake and reconsider their verdict. In *The Business of War* they will find some fascinating new material to help them to do so. Take for example the sketch on page 271, drawn with almost affectionate admiration, of Sir Winston at a War Committee. It reveals a personality, whose grandeur even the debunking pen of a Lytton Strachey would find it hard to belittle. The fact remains that he was a hard taskmaster whom only the toughest of his advisors could withstand. War has always required human "balls of fire" to keeping it going, especially at the top.

So much for belittlement: other far more important issues call for comment. No other book of high-level memoirs, published so far about the British conduct of the war, has revealed so clearly the desire of the C.I.G.S. to exploit the North African and Italian successes rather in the Mediterranean than in Northern France. Fortunately the Americans, soon to be supported by the Prime Minister, stuck firmly to "Overlord." The higher strategy of the war thus took on its final shape and did so as early as practicable. If the *Business of War* had contained nothing else, this information would make it historically important. Defeatism is a topic which crops up here and there. This comparatively new word first came into common use in the First World War *a propos* of persons in high places, who lose their faith in victory. Since defeatism has particular application to modern war, it seems to deserve closer study in military circles than it receives at present. Assuredly a commander must be prepared for all eventualities. He will be wise, however, to keep strictly to himself his rough plans for dealing with the more gloomy ones. Otherwise leakage may result in loose talk, such as there certainly was in the Levant in the summer of 1942.

Neither Hore-Belisha nor Sir Winston Churchill seemed to have had much use for the old style full dress military appreciation. Hore-Belisha took one, which had consistently failed to move the Cabinet, and boiled it down into a short memorandum. The soldiers thought his paper was "dreadful", yet it achieved its object within a week. Sir Winston, for his part, could not bear "balanced statements." Perhaps a quasi legal document with factors covering every conceivable eventuality is pompous and out of date. The question is worth examination.

In spite of his multifarious activities, the Prime Minister constantly found time to correct small mistakes in English grammar. On page 307 we find him differentiating between "further" and "farther." But he did so, alas, without avail for on page 320 our author reports that Montgomery's "thoughts had moved farther."

Bernard Fergusson writes a thoughtful preface and has edited the book with praiseworthy detachment. Most readers will find *The Business of War* as exciting as a good novel. Many will welcome the sympathetic sketch of Mr. Hore-Belisha who with all his faults deserved well of the Army. Sir Winston Churchill emerges, of course, greater than ever. B.T.W.

OFFICIAL HISTORY OF SECOND WORLD WAR

THE WAR AGAINST JAPAN

VOLUME I. THE LOSS OF SINGAPORE

By MAJOR-GENERAL S. WOODBURN KIRBY

(Published by H.M.S.O. Price 55s.)

General Kirby and his four assistants have successfully carried out a long and complicated task. The disastrous campaigns in which Malaya, Hong Kong, and the Netherlands East Indies were lost to the Japanese are described with a full understanding of the difficulties, but without omission or concealment.

The main lesson of this book is that there had been in peacetime a dangerous lack of balance between the civil and military powers. None of the great groups into which a state is divided had had so little influence with successive governments at home as the Fighting Services. How different the position was in Japan is shown in Appendix 2.

When war came the British Forces were still suffering from the various effects of past short-sighted reductions in time of peace. These effects were not easily obliterated, particularly in the Royal Navy.

The Indian Army, after the inadequate measures of the first months of the war, had had to be subjected to last minute expansions known as Milking and Dilution, which left it with the essential numbers, but ill-equipped, short of experienced soldiers in the ranks, and with scarcely any competent junior leaders. Such an army is not fit to fight against a long established, well appointed enemy force.

Our naval commanders in the Far East lacked smaller vessels to support their capital ships. Military commanders had no armour. Both, when it came to the point, received negligible support from the air.

To say that in these conditions the Army in Malaya should have been more aggressive is to take for granted, in a secondary theatre, the rarest type of military leader. It is not to say that victory could have been won. Naval boldness fared no better.

General Heath . . . could afford to take no risks. The division had somehow to be preserved as an effective fighting formation. He could have stood and fought to the last man and the last round in a number of positions, and might have temporarily stopped the Japanese, but they had fresh formations to call on while he had none. Such action would have been spectacular but suicidal. He was thus forced to continue the withdrawal, gaining such time as he could.—Page 465.

The Army's Intelligence system is admitted to have been poor. Too much reliance was placed on the police, perhaps overlooking changes that had been made in that organization.

The authors have set out and illustrated the tactical errors made during the campaign in a way that offers valuable lessons to the military student.

Lieut.-General Sir Lionel Bond, predecessor of Lieut.-General Percival, had selflessly maintained that to put air-bases in North Malaya, and relegate the Army to local defence, was an unlikely policy, and the lesson must eventually have gone home. Despite the popular hope that the soldier was still to play an equal part in war with the seaman and the airman, most of the defence of Malaya was left, in the end, to the soldier alone.

As the authors point out, this volume is not a political history. Their analysis stops there. Yet the implications of the story they tell are inevitable, and belong more to a military than to any other statement. The cause of the fall of Singapore was that in pre-war years the man in the street, at home, mistrusted the advice of senior officers, and disliked the word Empire; whereas the man in the street, in Japan, revered the swords of his military leaders, and hungered for the wealth of the Golden South.

K.B.S.C.

BEFORE THE DAWN

By Brigadier Sir John Smyth, Bt., V.C., M.C., M.P.

(Published by Messrs. Cassell & Co., 1957. Price 25s.)

Destiny is always unkind to those whom she picks to command British formations at the beginning of a war. During peace they make bricks without straw knowing that equipment and training are inadequate, and when, at the outbreak of war, the inevitable disasters follow, they have to shoulder the blame for the nation's refusal to pay its insurance premiums. Sir John Smyth was doubly unfortunate in that the fates favoured him twice in this way—at Dunkirk in 1940 and in Burma in 1942. He is understandably bitter about the Army's treatment before the war, but he rightly places the blame not on the politicians or the Army Council but squarely on the shoulders of the nation as a whole.

Before the Dawn is in two parts. In the first part Sir John describes in a light and very readable style the hurried training, the alarms and excursions during the "Phoney War", and finally the grim battle of endurance during the withdrawal to Dunkirk of his 127th Infantry Brigade (T.A.), which was part of the 42nd East Lancashire Division. In the second part he is the commander of the 17th Indian Division, an *ad hoc* formation hurriedly sent from India to defend Burma when the Japanese entered the war in December, 1941. He throws new light on the mis-appreciation of the Japanese strength made by Field-Marshal Wavell, who seriously underestimated the efficiency of his enemy, classing them with the Italians whom he had driven out of Libya. This mistake led to the unnecessary exposure of Sir John's division to defeat in detail, and ultimately to disaster on the Sittang River.

There is one point of particular interest to Sapper readers. A myth has grown up around the Sittang Action, reinforced by Sir Arthur Bryant in *The Turn of the Tide*, that the only bridge across the river was blown prematurely through some fault in demolition procedure. The story has often been used as a warning in post-war demolition exercises, even at the S.M.E. In fact, as Sir John recounts, nothing went wrong with the demolition drill. Sir John was faced with the terrible decision of ordering the destruction of the bridge when two-thirds of his force were still on the wrong side. If he had not given the order to fire, the Japanese would have been able to advance in great strength direct upon Rangoon without let or hindrance.

Although *Before the Dawn* has a ring of personal apology, it is a timely reminder of the consequences of failure in peace to prepare for war. Since the last war, thanks to the Russian threat, the nation has tolerated a higher state of preparedness than ever before. It is now clear from the publication of the 1957 Defence White Paper that we are reverting to our traditional defence policy. Sir John Smyth's story is a warning of what that policy means to the men who have to pay the price for the Nation's parsimony, and should therefore be read with interest by soldier and layman alike.

W.G.F.J.

U.S. MARINE OPERATIONS IN KOREA

VOL. III. THE CHOSIN RESERVOIR CAMPAIGN

(Published by the U.S. Government Printing Office, Washington. Price $2.75.)

The first two volumes of this history dealt with the Defence of the Pusan perimeter and the counter-stroke at Ichon-Seoul, which cleared South Korea of the North Korean Army. In this volume we see 1st Marine Division landing on the east coast of Korea to form the northern arm of what General MacArthur called "a massive compression envelopment" which was to end the war in Korea. No doubt it would have done so, if the Chinese had not intervened. Unfortunately they did and the struggle continued for three more costly years.

As Chinese intervention could be described as probable, the Marine Division would perhaps have been strategically better placed on the flank of the Eighth U.S. Army on the west coast. As it was, the main supply route from the east coast to the Chosin Reservoir soon came under severe pressure. In fact one of the most interesting accounts of the fighting is that dealing with Task Force Drysdale, which on 28th November 1950 was ordered to push a convoy of reinforcements up the road. Lieut.-Colonel D. B. Drysdale was C.O. 41 Independent Commando Royal Marines and his unit of fourteen officers and 221 O.R. also took part in the operation. It was a pretty hot sort of affair, since the convoy was cut in half, Col. Drysdale was wounded and the Commando lost sixty-one casualties, of which eighteen were killed or missing. Nevertheless, some valuable reinforcements, including three-quarters of the Commando got through to the next defended perimeter, where some of them at once went into action.

The main Chinese attempt to destroy the Marine division took place between 1st–8th December and no less than seven enemy divisions took part in it. But the division fought its way through and on 11th December 1950 arrived at Hungnam on the Sea of Japan, as triumphantly as Xenophon and his Ten Thousand got to the shores of the Euxine in 401 B.C. B.T.W.

SOLDIERS AND GOVERNMENTS

Nine Studies in Civil-Military Relations—edited by MICHAEL HOWARD

(Published by Messrs. Eyre & Spottiswoode, 1957. Price 21s.)

The title rather dates this book, for it recalls the quarrels of soldiers and statesmen in the First World War. Yet the choice of such a name is a shrewd reminder that it is still quite a puzzle to establish a correct balance between civil and military power. These nine studies are therefore worthy of attention.

The theme is well set out by Mr. Michael Howard in his introductory essay on "Armed Forces as a Political Problem." Then follows the *modus vivendi* reached to date in respect of Britain, France, Germany, Russia, Japan, Spain, Latin America, and finally the U.S.A. China, rather surprisingly, finds no place in the list. The essays are each written by a distinguished authority on the country concerned and several of the contributors are already well-known historians. A high level of general excellence is consequently not surprising, although some of the writers presuppose a wealth of learning in their readers which may be sadly lacking.

The interesting chapter on Russia suggests that the Russian army has so far not been prone to political ambitions or even to political activities. It has, *per contra*, always discharged with great devotion the duty assigned to it by its prevailing government, however disagreeable such duty may have been. In fact, to the rulers of the U.S.S.R. their armed forces seem to present a lesser political problem than in any other land. In the U.S.A. on the other hand nothing appears to be more urgent than a recast of the Defence department, not merely in relation to the three services, but also to the American political system.

In general the various surveys are chiefly historical and make little attempt to grapple with the future. Nevertheless, it will be useful as a handy basis for further research. This is long overdue, since soldiers and their governments, not to mention sailors and airmen, have been overtaken by great events and have been hustled along neck and crop to the threshold of a new age. Never was a reassessment of the whole mechanism of political and military power more obviously necessary. Why should not the great universities, to which the nine writers of this excellent book all owe allegiance, lend a firmer hand in defence research than they have done in the past? Each university might set up an *ad hoc* "Faculty of Defence" to report on specific problems allotted to it by the Ministry of Defence or better still by a Royal Commission on the whole vast subject. The launching of some such inquiry would give full scope for another Haldane to apply abstract thought to practical ends. Admittedly finding another Haldane may be difficult: the need for one, however, is imperative.

B.T.W.

THE WAR IN THE MEDITERRANEAN
1803–1810

By Piers Mackesy

(Published by Longmans, Green and Company; Price 45s.)

In *The War in the Mediterranean* the author—son of the late General P. J. Mackesy—studies the political, naval and military direction of British operations on Napoleon's southern flank from the breakdown of the Peace of Amiens in 1803 until the tide began to turn against the French in 1810. Very little has so far been written about these operations because they have been overshadowed by greater events elsewhere. It is all the more refreshing to be reminded that Britain's contribution to the Allied cause during this period was not confined to Trafalgar and the opening stages of the Peninsular campaign.

The struggle in the Mediterranean falls into three phases. In each phase British strategy was dictated by the relative importance of two threats to our vital interests—the invasion of England and a French reoccupation of Egypt as a stepping stone towards India. In the first phase, which extends from 1803 to 1805, the threat to England prevented the British Government sending any army reinforcements to the Mediterranean. The safety of Egypt depended on Nelson's ability to maintain the naval blockade of French and Spanish ports.

The second phase begins at the end of 1805 with the reversal of the relative importance of the two threats. Austerlitz had drawn Napoleon eastwards away from the Channel ports, while Trafalgar ensured that he would never be able to gain command of the Channel. As the fear of invasion diminished so the threat to the Near East increased. The successful French diplomatic offensive in Constantinople showed clearly in which direction Napoleon's thoughts had turned. Between 1805 and 1807 sufficient British troops were sent from England to the Mediterranean to form a strategic reserve capable of striking from the sea when and wherever a suitable opportunity occurred. In Admiral Collingwood, the Government found a worthy successor to Nelson, but it was not so fortunate with its selection of soldiers and diplomats. By unhappy chance the Army won the battle of Maida in Calabria for the undeserving General Stuart, while Collingwood's long and steadfast service went unrewarded. On the only occasion when the French put to sea in strength, wind and weather robbed him of a fleet action.

In the last phase, from 1807 to 1810, the Spanish insurrection gave new heart to the people of Europe. The threat to Egypt diminished as Napoleon became more heavily embroiled in Europe. If there had been a second Wellington available to take over from Stuart, the Italians might have followed the Spaniards' example, and two "Peninsular" campaigns might have been fought simultaneously.

Throughout this study the author has stressed the difficulties of co-ordinating naval, military and diplomatic action, the difficulties of communication between London and the Mediterranean, and the uncertainty of amphibious operations. He pays a well-deserved tribute to Collingwood's sound judgement and devotion to duty, and at the same time rightly castigates the commanding Generals and H.M. Ambassadors at Palermo and Constantinople.

This is a valuable work in which the author has assembled a wealth of interesting material in a competent way. It will be of the greatest interest to students of the Napoleonic Wars and to those who are interested in the history of amphibious warfare, but it is probably too detailed for the general reader. W.G.F.J.

ROCKETS, MISSILES, AND SPACE TRAVEL

By WILLY LEY

(Published by Chapman & Hall. Price 50s.)

This is a revised and enlarged edition of the book first published with the same title in the U.K. in 1951 and reviewed in the *R.E. Journal* in June, 1952.

The book consists mainly of a detailed history of rockets from the earliest days until 1956. This is very little changed from the 1951 edition. The additions give details of upper atmosphere researches by rocket, carried out by the U.S. Armed Forces since 1951, and includes details of the newest type cast solid fuel rockets used as aeroplane boosters. The much enlarged Appendix 1 describes the rocket planes X1 and X2, and flights carried out by them in recent years.

The chapters on Peenemünde and White Sands have been largely rewritten, as more information has become available. It is interesting to note the author's statement (page 244) that the Americans acquired almost the entire German stocks of V2 in 1945, and also the greater majority of the German research engineers, whilst the Russians got only the production staffs.

Chapter eleven "The Shot Around the World" is an addition to the book. It explains the conception of an earth orbiting satellite, and outlines low altitude launchings proposed (in July 1955) by the U.S. Government in the current International Geophysical Year. Much information is given on the knowledge it is hoped to obtain from satellites; this knowledge to be shared by all nations. The author never even conceives that any nation other than the U.S.A. could carry out this ambitious project. For example, a note on page 355 refers to dog-carrying Russian rockets having reached a mere 60 miles altitude. This indicates how meagre was the information available from the U.S.S.R. at the time of publication (March, 1957). The *Sputnik* 1 was placed in orbit 300 miles up on 4th October, 1957. This new chapter eleven is therefore largely out of date already, as the American proposals were less ambitious than the Russian satellites.

Other additions include: notes on the legal aspect of space travel; a table of American rocket missile data; and details of other nations' rockets. The Bibliography has been increased from seventeen pages to thirty-one pages. However unfortunate the author may have been in selecting early 1957 for a rewrite, this book remains an excellently detailed history of rocket engineering, and a clear and logical exposition of extraterrestrial flights for the non-technical reader. J.E.

REINFORCED CONCRETE DESIGNERS HANDBOOK

By CHAS. E. REYNOLDS

(Published by Concrete Publications Ltd. Price 18s.)

EXPLANATORY HANDBOOK ON THE B.S. CODE OF PRACTICE FOR REINFORCED CONCRETE

By SCOTT, GLANVILLE, AND THOMAS

(Published by Concrete Publications Ltd. Price 12s. 6d.)

In July, 1957, the British Standards Institution issued a revision of Code of Practice 114 "The Structural Use of Reinforced Concrete in Buildings". Concrete Publications have now issued revised editions of these two well-known handbooks, bringing them into line with the code.

The new code of practice makes a large number of changes of minor significance but there are three of greater importance: advantage can now be taken of modern methods of mix design and quality control, higher stresses are permitted in steel reinforcement, and an alternative load-factor method of design is included for the first time.

Both books retain their original form. *The Handbook on the Code of Practice* reproduces the code verbatim with comments following each clause. The commentary on the new clauses is clear and helpful and in particular the section on the load factor method is very simply set out.

The Designers Handbook consists as before of an explanatory text with an extensive series of design tables, containing a vast amount of information in tabular form. There is a tendency in some of these tables to try to cram too much information into too small a space (as for instance Table 18 on Foundations), but generally the tables are well devised and well set out. It is perhaps a pity that no attempt has been made to compare the two methods of design now permitted. The load factor method can result in considerable savings in some instances and this is not well brought out.

This edition of the Code of Practice has adopted a new and in many ways unusual and complicated system of symbols. *The Designers Handbook* wisely makes no attempt to use this system, but *The Handbook on the Code of Practice* of necessity follows the code. It is surely high time that a standard system of symbols was adopted. C.R.S.

LANGENSCHEIDT'S DICTIONARY OF MILITARY TERMS

ENGLISH-GERMAN; GERMAN-ENGLISH

By VON F. KOLLMANN

(Published by Langenscheidt Kg, Berlin, and Methuen & Co., Ltd., London. Price 40s.)

As the title explains this is a dictionary of military terms only, and does not cover all ordinary words to be found in a general dictionary, nor does it cover all engineering terms, although it does contain many such terms which might be used in military reports. On the whole it covers the military ground well, and has been brought up to date as far as possible.

There is an introduction and a list of abbreviations used which should be carefully studied, as many of the abbreviations are strange to the English reader.

At the end of the book is an Appendix giving a table of comparative ranks in the German, U.S.A., and British Army, Navy and Air Force. Another gives the latest phonetic alphabet approved for the N.A.T.O. Forces, and a third Appendix gives comparative tables of Weights and Measures.

There is also a list of British and American military abbreviations with both English and German explanations. This should be quite useful, especially in connexion with American abbreviations, but the list varies very considerably from the list given in "Staff Duties in the Field" and must not be used for official purposes in lieu of the latter.

The dictionary should prove very useful for translating English military reports into German or vice-versa. It is printed in a pocket-size about 6 in. by 4 in. by 1 in.-thick, bound in pliable rexine. E.E.N.S.

Technical Notes

ENGINEERING JOURNAL OF CANADA

Notes from *The Engineering Journal of Canada*, September, 1957

Oil and Natural Gas

The September issue of *The Engineering Journal* contains eight papers dealing with the production of oil and natural gas. A good deal of interesting information is included, but most of it is unlikely to be of much practical value to the military engineer. The subjects covered include exploration, drilling, transportation of oil, processing and distribution of natural gas, petroleum refining, petrochemicals, and the Canadian economic aspect.

Notes from *The Engineering Journal of Canada*, October, 1957

St. Lawrence Seaway

(*a*) *Lock gates*

This paper describes in some detail many aspects of the design of gates and control valves for various locks on the Seaway, and it deals also with mechanical and electrical operating. The practical solution of an intricate engineering problem is always interesting, and the earnest student may find his reward here, but the general reader is likely to be confused by a mass of facts and figures hung on to an inadequately-conceived framework, and by an unfortunate layout of illustrations.

(*b*) *Montreal area bridge alterations*

To provide navigation clearance over the Seaway canal, four existing bridges between the Island of Montreal and the south shore of the St. Lawrence require modification. Two are road bridges, one a combined double-track railway and road bridge, and one a "twin" railway bridge, of which only the 60-ft. high approach embankment is affected by the canal.

Each bridge poses an entirely different problem. The solutions adopted and the sequence of operations involved in each case are clearly set out, and the variations of method employed to maintain traffic during construction are particularly interesting. Good illustrations emphasize the magnitude of this comparatively small element of the Seaway project.

St. Lawrence Power-house Project

(*a*) *Progress report*

After a concise summary of the main features of the project, this report takes the form of eighteen excellent photographs, for each of which a brief description draws attention to the salient features. Six further more general views are well captioned. The report provides a most valuable record of a major engineering project.

(*b*) *300-ton gantry crane*

The power house, with a rated capacity of 2,400,000 h.p., straddles the International boundary between Canada and the U.S.A. Crane facilities for the installation and servicing of equipment are of major importance, and it seems a pity that, to secure interchangeability between the two ends of the structure, the design and specification should be complicated by having to acquire two identical cranes, built by different companies in different countries.

It is interesting to note that, in this type of work, lowering characteristics are far more critical than hoisting requirements. Without its load, each 300-ton crane weighs about 600 tons, of which 470 tons are structural steel. The motor generator set for D.C. supply has an output of 125 kW., and twenty-five other electric motors are used. The general design, which is clearly described in some detail, has many interesting features, notably the vernier control for spotting heavy loads within 1/16 inch.

SHEAR, DIAGONAL TENSION, AND BOND STRESSES IN REINFORCED CONCRETE BEAMS

The *R.E. Journal* for December 1957 contained a note on a paper challenging the superiority of the plastic theory of design when applied to reinforced concrete structures, and contending that a better understanding of stress distribution is the prime requirement for safe and economical design. The present paper, by the same author, deals primarily with shear conditions at points of contraflexure of continuous beams, and includes a full discussion of the cause and effect of cracks and splitting. The importance of adequate web reinforcement is clearly demonstrated, but it should be remembered that criticism of building codes is directed at North American rather than at British practice.

Notes from *The Engineering Journal of Canada*, November, 1957

THE PEACE RIVER AND ALASKA HIGHWAY GAS GATHERING SYSTEM

This paper is of considerable general interest, and it provides a valuable practical example in extension of the more general and theoretical papers in the September issue (see above). The extensive layout required to collect gas from scattered fields comprises gathering lines from four to twelve inches in diameter, linked to a main collecting system of twelve to twenty-six inch piping. The technical problems to be solved in designing pipelines and handling facilities are well described, and some good photographs illustrate the nature and magnitude of some of the engineering work involved.

A MAJOR POWER PLAN FOR YUKON RIVER WATERS

A most interesting historical and economic discussion leads up to a clear outline of a major project which will stimulate development in the Canadian North-West. By stage construction it is proposed to increase power output from an initial 250,000 h.p. to a maximum approximating to 5 million h.p.

THE ROLE OF AERIAL SURVEY METHODS IN CANADA'S NORTHWARD DEVELOPMENT

Every Sapper appreciates the value of air reconnaissance and of aerial survey, especially in inaccessible areas, but it is probable that few are familiar with new applications and techniques developed in Canada since the 1939–45 war. These have made aerial photography a commonplace and essential part of the planning of large engineering projects, and the same methods are now being used in undeveloped areas throughout the world.

This paper is a symposium by experts in particular fields, skilfully compiled and edited into an interesting and informative article. Modern photographic interpretation covers a wide field of engineering factors, and the other applications described include economic planning, forestry, land-use, geology, and geophysics.

THE MILITARY ENGINEER

JOURNAL OF THE SOCIETY OF AMERICAN MILITARY ENGINEERS

MAY–JUNE, 1957

"Nuclear Power for Military Use" by Colonel James B. Lampert, Corps of Engineers.

The author at present holds the appointment of Special Assistant for Nuclear Power, Office of the Chief of Engineers, and Chief, Army Reactors Branch in the Atomic Energy Commission and has the responsibility of directly supervising the A.E.C.–Army nuclear power programme.

In an interestingly illustrated article the author summarizes the military advantages of nuclear power, the projects at present in hand, the problems still to be solved, and the future possibilities as he sees them today. While it is well known that a nuclear reactor has been used to propel a submarine with outstanding success, it is not as widely appreciated that the Atomic Energy Commission and the Army are developing nuclear power plants for use by the Armed Forces where power and heat are needed on land. The outstanding military advantage of a nuclear power plant is that it can operate for months or even years without refuelling and the nuclear fuel charge, or core, can be delivered in a single cargo aircraft. In the case of small stations of 200 men, included in the arctic aircraft control and warning network extending from Alaska across Canada into Greenland, an annual saving of some 50,000 barrels of fuel or 75 per cent of the annual re-supply tonnage can be effected by the use of a nuclear power plant. For use in mobile operations the author considers it now within the realm of possibility to build and operate a small nuclear power plant, transportable as a unit by C-124 aircraft, and mounted on a trailer, which would be capable of supplying several hundred kilowatts of power with virtual freedom from fuel and water supply problems. Larger plants, mounted on barges, could be used effectively in disaster relief and moved quickly to affected load centres by water.

The present military power reactor development programme aims to provide the military services with a family of nuclear power plants. The Chief of Engineers directs the Army portion of the programme. Most of the active development is carried out by contract with industrial organizations under the supervision of a technical staff of Army personnel, but including representatives of the Atomic Energy Commission, the Navy, and the Air Force. As with the submarine and aircraft propulsion reactor development programmes, the development group operates within the Atomic Energy Commission with active support from certain service facilities. Under development at present are: "The Army Package Power Reactor" (APPR–1), a 2,000 kW. plant made up of air transportable components; "The Argonne Low Power Reactor" (ALPR), a smaller 300 kW. fixed plant with air transportable components, for use in small, very remote outposts; "A Gas-cooled Reactor", comprising a gas turbine engine coupled to a nuclear reactor cooled by gas instead of by water as in the cases of APPR and ALPR. Such a system also promises greater efficiency and lower weight per kilowatt than either steam or internal combustion systems.

The author concludes that nuclear power plants will have military value initially in remote areas where transport is expensive and difficult, and where logistic effort affects the extra cost; the history of machines is that as more are built, more is learned about building them more cheaply, and design is simplified; the military exploitation of this compact, long lived, independent power source, deserves the most serious and continuous study.

JULY–AUGUST, 1957

"Airfield Paving Inspection" by Blair T. Hunt.

The author has been employed as construction management engineer in the Construction Division of the Jacksonville Engineer District for over four years, and in a detailed article deals with the training of inspectors and inspection procedure now necessary to ensure that the new permissible limits of grade tolerance for all airfield pavement is not exceeded. The permissible tolerance of 0.04 ft. from the theoretical grade shown on contract drawings has been made necessary by the increased speed of jet-powered aircraft. Rigid and well-organized inspection and control are required to obtain this degree of accuracy.

"Cordiner Committee Career Incentive Program" by Major-General C. Rodney Smith.

The author served nearly two years as Assistant Chief of Engineers for personnel prior to serving as the Army member of the Cordiner Committee. He summarizes in a one-page article the outstanding recommendations of the Committee's report dealing with the urgent need of the Armed Forces to improve their ability to attract and retain top quality career people, both military and civilian. It is of interest to note that the Committee found that progressive national inflation without commensurate pay adjustments has forced many service families to a degree of sub-standard and marginal living, which is frequently the crucial factor in causing the best men to leave the service. Today's complex weapons and greatly increased professional responsibilities create even greater demands for high quality service personnel. These demands cannot be met by the present out-moded pay system. In addition to a modernized pay structure the Committee recommend, among other things, an improved housing programme, a quarters' allowance brought realistically up to date, and incentive pay for remote and isolated duty. It is asserted that billions of dollars are being wasted annually in the Armed Forces by this inability to retain trained and experienced personnel.

September–October, 1957

"Engineer Support in Atomic Warfare" by Major Douglas F. Parham, Corps of Engineers.

The author, whose war experience includes service with the engineers of the 4th Armored Division, is now posted to the Department of Military Art, Army Engineer School, Fort Belvoir.

Within the limits of a well written and illustrated five page article the author first visualises the nature of ground operations in an atomic war, the type of tactical units of the future, together with their possible organization and employment, and hence deduces the engineer support required in atomic warfare of the future. He discards crystal ball gazing in favour of a logical assessment of what the army must basically have in a two-sided atomic war. He arrives at a Universal Division suitable for either airborne or ground action and made up of a combat support element, a logistic support element, and six to eight battle groups. In operations, groups would be sufficiently widely dispersed to avoid more than one group being destroyed by a single atomic weapon, and each group, self contained in itself, would be small enough not to present a worthwhile target for atomic attack. In terms of present units he places the size of the basic group as somewhere between a company and a regiment. The engineer organization for the Universal Division then follows conventional lines with an engineer unit attached or in support of each group and organized into an engineer group for each division.

The author then considers in detail the engineer tasks entailed in offence, defence, withdrawal, advance, and river crossings, and in a summary reaches the conclusion that in active atomic warfare the mission of the combat engineer remains unchanged. Greater mobility will reduce his work on communications, but the destructive power of atomic weapons will increase it immeasurably in other directions.

While the author agrees that the principles of war are unchanging and only their application varies, his assessment of the variation in application required by the introduction of nuclear weapons seems to be one of degree only. His appreciation of this problem of paramount importance is that the solution lies on conventional lines, and that ground forces as we know them today, but modified and dispersed, will have time to operate before the race for atomic supremacy is lost or won. Is this correct? Atomic supremacy in the form of two old-fashioned bombs resolved the Japanese issue—ground forces were required only for occupational duties. Will the race for atomic supremacy in a future war be decided in the first few hours, or possibly days if the protagonists are slow starters? Will anything less mobile than an airborne striking force ever have time to operate before the issue is decided? Should not active engineer support in atomic warfare, to be of value, be applied in time, that is before the outbreak of war and during the first critical hours? The principles of war are immutable but has not the introduction of atomic and thermonuclear devices modified their application more than the author visualises? Should not a larger percentage of Army engineers be employed on nuclear devices which might affect the issue rather than bridging and field works which may in future become only post-war reconstruction? The author's interesting article provokes many alternative lines of thought.

CIVIL ENGINEERING

Notes from *Civil Engineering*, September, 1957

Locating and Filling Old Mine Workings

Prior to building the new eight-storey Sheffield College of Technology it was found necessary to fill some underground galleries forming part of old abandoned coal mine workings. A number of alternatives were considered which were as follows:—

(*a*) To sink a shaft and drive a heading into each gallery; and although this was attractive because it would allow the cheapest form of filling to be used, it was not pursued on account of the greater danger to workmen inherent in this scheme.

(*b*) To fill the workings by pneumatic stowage: This course was not pursued because of the large plant installations that would be necessary to provide the volume of air required, which would be some 3,000 ft. cu. per min.

(*c*) To fill the workings by hydraulic stowage was also not pursued for fear of the trouble that might arise elsewhere from the flow of this water.

(*d*) The course adopted was to fill the workings by normal low and high pressure grouting methods, using such materials as fly ash and foaming agents to reduce the proportion of cement.

Pilot holes, 1⅞-in. diameter, were first bored, these assisted in exploring the extent of the galleries, and at a later date were used to top up the fill. Large 10-in. diameter holes were then drilled which allowed dams to be placed across galleries, and thus enabled the filling process to be restricted to the area covered by the building operation, with consequent economy of fill materials. Pea gravel was poured down the 10-in. bores, spreading being assisted by a vane rotated at the outlet of the bore near the roof of the gallery. Quantities used were 50 per cent in excess of calculated quantities, indicating the efficiency of the dispersion. When no more gravel could be placed, Portland cement grout was injected at pressures of between 45–70 lb. per sq. in. Final grouting was through the 1⅞-in. boreholes. Evidence on how well the work had been carried out was given when during the construction of the building part of a gallery was uncovered, and it was then seen that all corners and returns in some ancient brickwork lining the gallery had been grouted, and the adit was completely filled. The article is complete with four diagrams, two photographs and two tables.

The Use in Mass Concrete of Aggregate of Large Maximum Size

At first glance it may be considered that there is little new in the above technique; but what is referred to in the article is not the use of large "Plums" in mass concrete, a practice now established as causing voids at the underside of the large blocks of stone due to entrapped air. The article describes regular mixes made with maximum size of aggregate of 3 in.; 6 in.; 9 in. and 12 in. Some of the difficulties that confront anyone who intends to use such mixes can be imagined from the fact that there is no B.S.S. in this country for mixes using an aggregate larger than 1½ in. Experience in mixes employing large maximum size has been culled from America and the Continent, and as might have been inferred from experience gained from smaller sizes of aggregates; the larger the aggregate, the weaker the mix that may be employed. Surprisingly enough, little is to be gained by using sizes much greater than 6 in.; while the wear and tear on plant, and difficulties arising from segregation, make it definitely advisable to avoid sizes in excess of 6 in. Segregation, it is said, depends on critically small changes in grading of aggregates, and water/cement ratio. Rigorous control of both of these factors is therefore required. Air entrainment can help prevent segregation, and give better resistance against frost action. Water/cement ratio at about 0.6 seems to be a usual figure. Special precautions are called for in transporting this class of concrete; dumpers or shutes are not recommended. As might be expected only the heavier vibrators are effective in getting the larger sizes of aggregate to vibrate.

The article concludes with a plea that specifications calling for this quality of concrete and certain properties expected from it should also specify how the various properties are to be tested.

The Draining of Black Lake

Draining Black Lake in Quebec, Canada, affords an interesting example in muck shifting on the largest scale. The existence of asbestos deposits under the lake in sufficient quantity to last forty years had led the mining company concerned to undertake the drainage of the lake which covers an area of 500 acres. This will necessitate the dredging of 37 million cu. yds. of over burden, of which 30 million cu. yds. will be removed by dredging. The decision to adopt this course is calculated to have cut the cost by one-third the amount that any other method would have cost. The dredger weighed 200 tons and, was brought up in eleven sections. It uses a rotary cutter 7 ft. in diameter on the end of a boom, which is capable of moving a bank 250 ft. × 30 ft. × 8 ft. in forty minutes. The cutter is powered by an electrically-driven 800 h.p. motor driven at 24 r.p.m. The cut material is removed hydraulically by a 10-ft. diameter suction pump of 6,000 h.p., and is carried to the deposition area by a 32-in. diameter steel pipe with the assistance of other booster pumps.

Notes from *Civil Engineering*, October, 1957.

The Use of Soil Cement for Low Cost Housing in the Tropics

All Sappers will be familiar with soil stabilization by cement for roads and runways. This article describes what may be a new use of stabilization to most: that of stabilizing suitable soils for use in house construction. Large-scale projects have been carried out in India, South Africa and America. One project in the Punjab, India, describes how 4,000 houses were built using this material. In this instance for extreme economy a limit of 2½ per cent of cement for stabilization was laid down by the authorities. Good laboratory control permitted this; although no stabilization was attempted when the plastic index varied outside a limit of 8.5 to 10.5 with a liquid limit no greater than 25. Sand content was to be no less than 35 per cent. Generally speaking, if cement quantities exceed 5 per cent it is stated that the cost of soil bricks will not be competitive with other means of construction and based on this limit soils with a plastic index greater than 20 are unlikely to be suitable.

A number of machines have been developed by England, France, and South Africa, and test results indicated that bricks, or blocks produced by these machines are nearly 100 per cent better than hand-produced bricks or blocks. As might be expected other factors such as moisture content, cement ratio, compacting force, all effect the crushing strength of the bricks, which under favourable conditions at only 5 per cent cement ratio have been produced with a crushing strength of 2,250 lb. per sq. in. Machines which compact as they form blocks can achieve outputs of 2,000 bricks per day. Engineers familiar with mud brick construction in Cyprus will be interested to read that stabilized bricks have successfully withstood variation in weather from tropical heat to monsoon downpours in the Punjab project; although it is recommended that where bricks are likely to be saturated, then a reduction in strength of about 0.4 should be allowed. Generally speaking, a strength of 400 lb. per sq. in. is suitable for single-storey construction. The article is to be concluded.

Helicopters in Civil Engineering

The principles of helicopter flight are briefly discussed at the beginning of the article, but the bulk of the article describes uses to which this flying maid of all work has been put in the civil field. It is evident that the author is mainly concerned with aircraft whose payload is of the order 500 lb., nevertheless even with this modest lift, the author describes one formidable pipe-line construction task where a fifteen-day time limit was imposed by circumstances, in most rugged and inaccessible country. A single machine, during the five and a half days it was possible to fly, totalled sixty hours flying time. During this time it made 410 trips, and transported 108,000 lb., while stringing 174 lengths of pipe along the route required. Other applications of helicopter transport described are their use in Aerial Survey; and Powerline construction where lines were strung over trees without the need of cutting trees down. They have also been successfully used in inspecting power lines for faults, in which role it is possible to inspect 800 miles of line in a week. Some notes on cost of these small helicopters is given. In 1954 the cost of a single machine was put at £12,000, with a depreciation set at £4–£5 per hour of flying time. It was considered that new developments, such as pulse jets at the tips of the rotor, will probably reduce cost to about £6,000. Of interest is a sketch of proposals made for a City of London "Heliport", whether or not they will ever reach fruition is extremely debatable.

The New Runway at Bahrain Airport

A feature of the construction of the new airport at Bahrain is the way in which the Contractors, Holloway Brothers, had to "make do" with construction equipment which was to hand, and the manner in which they had to improvise for the work of spreading the crushed stone. A team of the crushers was grouped near the runway and charged by hand with stones picked up from the desert. The crushed material was then transported by improvised trailers drawn by Ferguson tractors, which incorporated spreading boxes at the rear. This primitive method of winning stone had the advantage that due to the natural process of weathering, only the harder portions of the limestone was used.

The site of the airport is flat and low-lying, and in some cases water level is within 2 ft. of the surface. The runway only varies in level by a few inches throughout its length, which has the disadvantage of tending to flood after rain. Drainage by pumps discharging over sea walls is therefore necessary. The existence of the water table close to the surface had the effect in some areas of causing the ground to heave and quake under the passage of a roller, and in these parts large quantities of imported fill had to be substituted for the soft material. An interesting method of guiding tractors during the compaction operation was to fit them with foresights and backsights which were aligned on targets placed at the ends of the runway. An incident that will find an echo in the minds of Sappers who have had some experience with contractors in the Middle East is an account of the difficulty in getting local contractors to deliver stone except at exorbitant prices, a difficulty which was overcome by building up a fleet of lorries to carry out the work by the main contractor. These were not required because deliveries from local contractors immediately increased.

The article gives tables showing grading sizes adopted for the aggregates and twelve photographs which show to what extent hand labour was used throughout the work.

Notes from *Civil Engineering*, November 1957

A New Centering System for Bridging

The method proposed by an Italian firm for providing light-weight centering for large span concrete arch bridges is strongly reminiscent of the method used in India, during the war, of making the "Lahore Shed". Like that system, small lengths of timber are fixed together to provide laminated chords for the arch ribs. Common thicknesses for the laminated planes are 2.5, 3, 4, or 5 cms., and the usual lengths about four metres. The laminations were fixed together by clamping, after the required curvature had been impressed in them. For this reason rough timber is preferable to planed planks. By using a truss construction, spans up to 100 metres with a 30-metre rise have been successfully centred. Advantages claimed for the system are:

(*a*) The centering is easily assembled and dismantled, and almost all the timber used can be recovered.
(*b*) A minimum of wood is needed, with no special cutting to shape.
(*c*) Clear spans are provided underneath.
(*d*) The framework is not exposed to floods.

Aluminium Alloy Structural Research

Aluminium alloys have been successfully used in the aircraft industry. In this article the author reviews some of the reasons why it is not more widely used in civil engineering, and he indicates problems that still require further study. It is pointed out that while basic structural theory does not change, one structural material can rarely be considered as a direct substitute for another. The design must reflect the physical properties of the material. In the case of aluminium alloys this means a weight and modulus of elasticity one third of that found with mild steel, while the cost per unit volume is three times as much. One effect of this cost ratio is that sections must be very much more economically proportioned, while the low modulus of elasticity, with its related modulus of rigidity, which controls stability, is of particular importance in aluminium alloy structures. Tensile strengths exceeding those of mild steel are possible; but there is a penalty to pay in the reduction of resistance to corrosion in these alloys. A figure of 18 tons/sq. in. for ultimate tensile strengths is common in civil engineering. A problem that arises with aluminium alloys is that of making junctions using riveted or bolted types of connexions. Cold driven aluminium alloy rivets with specially designed heads to ease the driving process have proved popular. Welding is being more widely used now, and while much has been written on the technique of welding, little has been written on the structural efficiency of the welded joints produced. The article includes some photographs illustrating research results, and graphs showing stress distributions in welded joints.

The Use of Gypsum Plaster as a Model Material

Enthusiasts on stress determination by model analysis will be conscious of the limitations that are often imposed from difficulties of producing accurate models with modest workshop equipment. The article describes the structural properties of Gypsum plaster, which make it clear that for models simulating concrete structures this is an ideal material. One precaution has to be adopted to achieve uniformity in performance, that is to subject the plaster to a vacuum of 14 lb. per sq. in. for 5 minutes. The article concludes that very close agreement between theory and experiment is possible.

The Fire Resistance of Prestressed Concrete

In the U.K., Codes of Practice specify acceptable fire resistance periods to which a building must comply. In the case of prestressed concrete construction no such code exists. It was with the object of providing data upon which a code might be drafted that this article has been written. Fire resistance tests were carried out by the Joint Fire Research Organization at Boreham Wood. The first tests were on pretensioned floor units, and investigations included problems on designing prestressed concrete beams with fire resistances of up to four hours. General conclusions reached were that prestressed concrete members were more susceptible to fire than their equivalent section in normal reinforced concrete; because their smaller section gives them less heat capacity; prestressed steel is affected by high temperature more so than mild steel: continuity of members is a factor that resists collapse, and this is more common in normal reinforced concrete construction. One factor, however, operates in favour of prestressed concrete sections, namely that steel is more likely to have greater cover of concrete. Particular conclusions and recommendations were as follows:

(*a*) Explosive spalling of unprotected beams with parts of their sections not less than 2 in. was unlikely.

(*b*) Failure of a beam is imminent when the cable temperature reaches 400°C.

(*c*) Fire resistance of 1 hour is achieved with a concrete cover to the cable of 1½ in. while 2 hours is possible with 2½ in.; and 4 in. cover may achieve 4 hours.

(*d*) Collapse is likely to be gradual.

(*e*) 1 in. of vermiculite plaster can add 2 hours resistance to an unprotected member.

(*f*) Binding steel is recommended in beams which have no protective plasters, to prevent loss of concrete cover.

Correspondence

ARMOURED ENGINEERS

Major S. E. M. Goodall, M.B.E., M.C., R.E.
O.C. 26 Armoured Engineer Squadron
8th October, 1957.

To The Editor,
R.E. Journal

Dear Sir,

The ideas which Colonel France put forward in his article on "Armoured Engineers", published in the September, 1957, *R.E. Journal*, are most welcome. It has been felt for some time that the title "Assault Engineer" creates a false impression of the modern role of such units and indeed assault squadrons have recently been redesignated armoured engineer squadrons.

Whilst not disagreeing with the main theme of the article there are one or two points raised which are open to question and which are misleading.

The first and most important is the suggestion that any field squadron can be converted overnight into an armoured squadron. It is agreed this did happen on one occasion during the war, but the circumstances were very unusual in that there was considerable urgency and it was possible to put in a very concentrated training period. Most of the armoured squadrons in the war were provided with ex R.A.C. drivers, and all commander and crew training was done under the supervision of R.A.C. instructors. It is surely presumptuous to expect a sapper to step straight into the shoes of the Royal Armoured Corps soldier who is a specialist in his own right, whether he be driver, gunner or signaller.

A tank is a far more complicated vehicle than a 3-ton truck and has nearly 500 items of kit to be stowed as opposed to about thirty on a "B" vehicle. The outlook of the crews must also be quite different from that of the ordinary sapper. Their tank is their home in which they must live and fight for long periods. Teamwork is essential if the best results are to be obtained from a crew working within its confined space. Its needs can only be fully appreciated by a trained tank man and it is easy to forget for instance that on a long day's run, an A.V.R.E. may consume 200 gallons of petrol and that the last parade on such a day will take several hours. The armoured or assault sapper must consider himself more a tank man than a sapper because it is primarily his machine that does the work and if it fails then he might as well not be there. In a fast moving battle the A.V.R.E. crews will rarely have the time for dismounted work and in rest periods they will be required on essential maintenance in preparation for the next round rather than performing the tasks of dismounted sappers. To take them from this maintenance is to prejudice their next operation. It is of interest to note that the nucleus of really experienced tank men at present in armoured engineers has been in tanks continuously since the war. Several were R.A.C. before becoming sappers. Without these men and their exceptional knowledge the armoured engineers would be hard put to function.

The second assumption which is rather dangerous is that skilled fitter support will be available for the divisional squadron from the corps squadron. For one thing the tactical situation is unlikely to allow this and for another the Corps Squadron will require all its own people. It is felt that most commanders would insist on having their own unit fitters or L.A.D. with them. Where also is the essential FAMTO (First Aid Mechanical Transport (Repair) Outfit) to come from?

If there is to be an armoured element within the sappers of the armoured division then it should not be in the form of an increment tacked on to a field troop of a field squadron. The field troop commander will probably know little about tanks and they will become neglected and then, when they fail to work, be regarded more as a nuisance than an asset. Good maintenance, coupled with an up-to-date knowledge of the vehicle history (i.e., documentation) is the key to efficient operation, and no field troop commander would have the time to keep an eye on this, even if he did know anything about it.

The proposed total of nine tanks in a squadron is also insufficient to provide effective support when operations are widely dispersed, and it holds little in reserve for casualties. Each division must therefore have its own armoured engineer squadron which can operate on its own, train its own reinforcements if necessary, provide sufficient machines to do the work required by three or four armoured regiments, and at the same time keep a little in reserve. Sections of field engineers mounted in half-tracks or other A.P.Cs. can easily be placed under the command of the A.V.R.E. troop commander to give what dismounted support may be necessary.

The armoured divisional engineers should therefore consist of two squadrons, one armoured, the other in A.P.Cs. with a high proportion of wireless sets. The armoured Squadron should have four troops of A.V.R.E. dozers and one of bridgelayers and the field squadron four troops of A.P.Cs., and wheeled dozers. They should be trained to work together in teams and should still maintain their own *Esprit de Corps* and carry out their own specialist training and administration.

If this is too lavish for a peacetime Army then one corps squadron must provide the support, with the A.V.R.E. troops affiliated to divisions for training.

Yours faithfully,

S. E. M. Goodall, Major, R.E.

THE DIVISION IN NUCLEAR WAR

Ministry of Defence,
Storey's Gate,
London, S.W.1.
5th November, 1957.

To The Editor,
R. E. Journal

Sir,

I have noticed with regret that contributions to the correspondence columns of the *Royal Engineers' Journal* have recently been few in number. Many of the articles in the *Journal* are historical or factual and do not lend themselves to comment or criticism, but lack of correspondence is perhaps a symptom of our present-day life when we have (or think we have) no time or energy for original thought.

A distinguished Sapper officer used to make a habit of riding through barracks each morning at eleven o'clock. Once I had the temerity to ask him how he found time for such a diversion. I received the withering reply "I am paid to think. I think better upon a horse." Others no doubt, like Archimedes, think better in their baths.

We Sappers have a heritage of originality. Though many of your articles dealing with the past bear witness to this, it is regrettable that all too few reflect original thought on future problems. The admirable article by Colonel Barron on "The Division in Nuclear War" published in the *R.E. Journal* for September, 1957, is therefore all the more welcome.

Colonel Barron's article deserves comment because it is forward-looking, and criticism because it is not in my view sufficiently forward-looking in two respects.

In my opinion Colonel Barron has not taken his reorganization of the command structure in the field far enough. The dispersal of battle groups requires, and modern signal equipment enables, a commander to control more subordinate units than in the past. The fact that each formation headquarters is to be duplicated for survival reasons means that for a special occasion two or more units can be grouped under the deputy commander. For this reason I think that the American pentomic divisional organization, eliminating brigade headquarters, is preferable to that proposed by Colonel Barron. Similarly, one of the higher headquarters, Corps or Army, as we know them today, should be dispensed with, though perhaps here there is a case for retaining a purely tactical headquarters without logistic responsibility.

Colonel Barron has shown that for the present, and perhaps for a considerable time, there can be no complete defence against new weapons. These new weapons will produce devastation so wide that all present concepts of mobility of ground forces will be of little value. Nuclear weapons will not only add enormously to the physical obstacles to conventional land movement but may indeed change geography, causing rivers to change their courses, intensive flooding and the disappearance of high ground and cover. For too long we have been talking about "a very high degree of mobility" in the conventional sense. How to overcome the obstacles of the future is a very appropriate problem for thought and study by engineers. The amphibian of the last war enabled some of the problems of mobility to be overcome. Perhaps an answer for the future will be a land vehicle capable of taking to the air for short distances. If such a concept verges on the improbable let it not be forgotten that in the past engineers have achieved the improbable and indeed the impossible.

I have ventured to comment in the hope that others will be spurred to leap from their horses (or baths) and record for posterity what Colonel Barron has so aptly described as "the pearl from the oyster bed". What could be more appropriate than that the discoverer should be a Sapper?

Yours faithfully,

A. C. Lewis, Lieut.-Colonel, R.E.

Editor's Note. Colonel Barron has since won the Bertrand Stewart Prize Essay for 1957. His article was published in the *Army Quarterly*, January, 1958.

Major-General G. S. Hatton (late R.E.) was second and his article is published in this issue of the *R.E. Journal*.

Both these articles deal with mobility in atomic war.

PRESTRESSED STRAIN GAUGES

The Editor,
Royal Engineers Journal,
The Institution of Royal Engineers,
Chatham, Kent.

Military Engineering
Experimental Establishment,
Barrack Road,
Christchurch, Hants.
8th November, 1957.

Dear Sir,

I would like to comment on a paper entitled "Pre-stressed Strain Gauges for Quick Determination of Safe Loads on Bridges" which appeared in the *Royal Engineers Journal of September*, 1957.

Whilst the authors are to be congratulated on their attempt to solve a difficult problem, and especially on the ingenious treatment of deadload stresses, I feel that a very serious warning against the uncritical adoption of the proposed method is necessary on the following grounds:—

1. The assumption is made that the position of maximum stress in a member can be determined by inspection, and that it will always be practicable to apply a strain gauge to this point. In fact, the stress distribution across the sections of most bridge members is far from uniform, and the point of maximum stress is rarely obvious. Moreover, it is often one at which it is difficult to attach a gauge.

2. Individual strain gauges are notoriously unreliable, especially when used in the field, and it is always essential to have a number of them to obtain cross-checks of their accuracy.

3. The strength of a bridge depends not only on its main girders, but also on its cross-girders, stringers and decking. It is essential, therefore, to determine which of these elements is the governing factor in controlling load class.

I hope, therefore, that it will be appreciated that classifying bridges by means of strain gauge observation is not as safe, simple or precise as the paper implies.

The strain gauge method could be of value in special cases, provided that its possible dangers and imperfections are fully understood.

It will be found that the new classification methods given in *Military Engineering*, Vol. III, Chap. 20, are much less conservative than the earlier methods, and in the majority of cases I feel they will yield reasonably accurate results quite quickly. In these new methods the carrying capacity of a bridge member is based on its physical dimensions, an assumed working stress and distribution factors which tests have shown to be closely representative of those occurring in actual structures.

Yours faithfully,

D. C. BAILEY,

Director.

The Editor,
Royal Engineers' Journal
Institution of Royal Engineers,
Brompton Barracks,
Chatham, Kent.

Chief Engineer,
H.Q. Eastern Command,
Hounslow, Middlesex.
30th January, 1958.

Dear Sir,

Reference Sir Donald Bailey's letter to you dated 8th November, 1957, on Major Fitzgerald-Smith's and my paper on prestressed strain gauges. It is indeed gratifying to have such an eminent authority as Sir Donald take the trouble and interest to comment on our paper, even though his comments were in the main adverse!

Dealing with Sir Donald's criticisms:—

(i) It is considered that we make no more assumptions than are made in the Standard Method of calculations used in *M.E.* Vol. III, Chapter 20. After all *M.E.* Vol. III only checks at points of maximum bending movement.

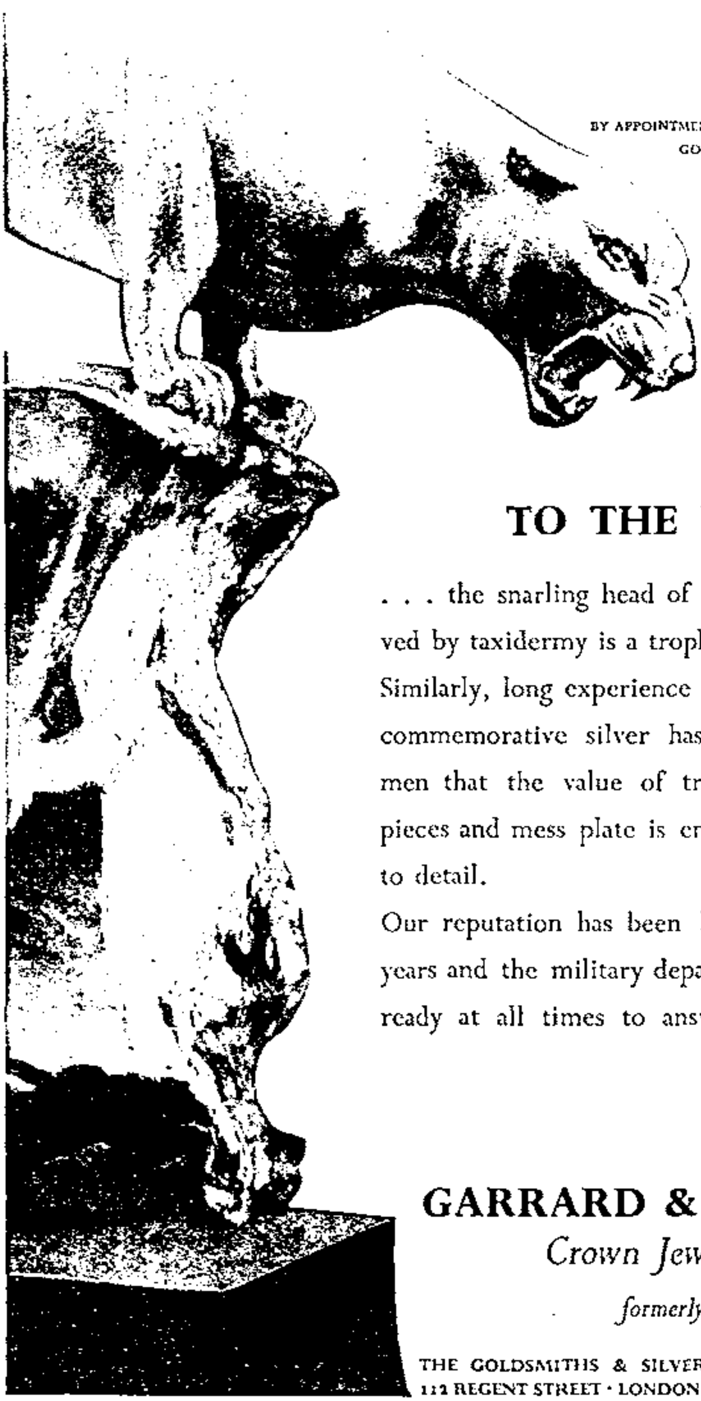
(ii) It is admitted that individual strain gauges are notoriously unreliable, and it was for this reason that we abandoned trying to stick them on to the bridge and went for the laboratory mounted strain gauge, which we then prestressed. The experiments went on for over a year. The adaptor design had teething troubles and new ideas kept being formulated. During this time there was no case of a laboratory mounted strain gauge going bad on us. It would thus appear that the unreliability of strain gauges is due rather to the difficulty in sticking them on, than to any inherent unreliability in the strain gauges themselves!

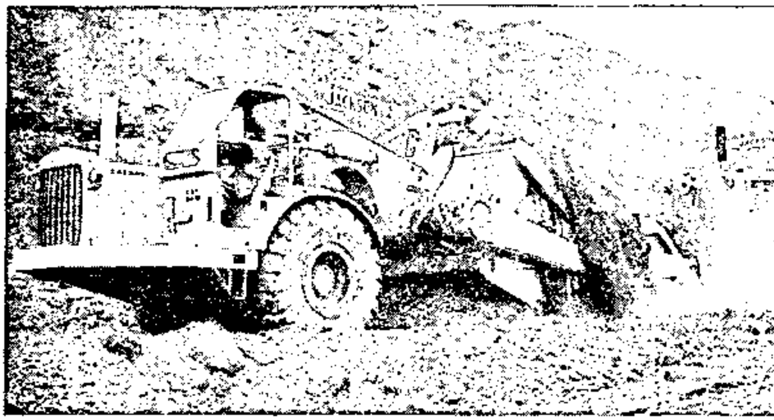
(iii) It is, of course, agreed that the strength of a bridge depends not only on its main girders, but also on its cross girders, stringers and decking. In the bridge in question we assessed the critical points to be not only the main girders on the bascule and approach spans, but also the troughing on the approach span.

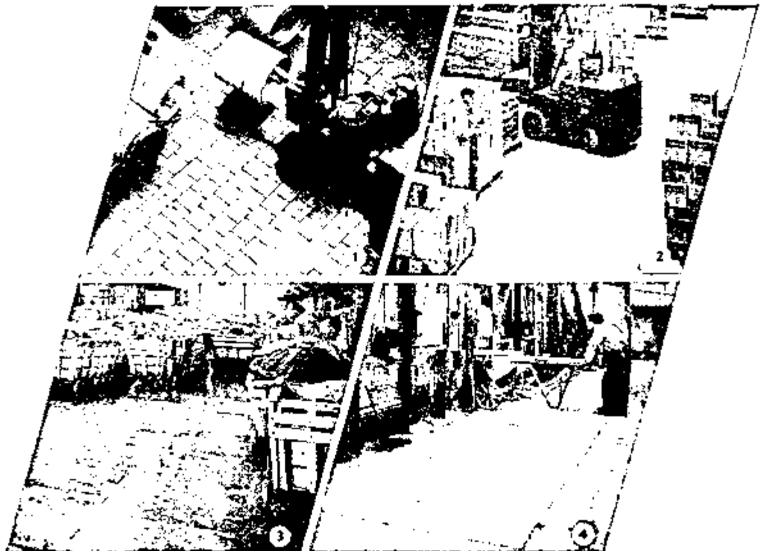
We fully realize the limitations of the method, but still consider it will give a quicker and more accurate result than the rule of thumb approach of *M.E.* Vol. III, Chapter 20.

Yours faithfully,

R. A. G. BINNY, Brigadier.







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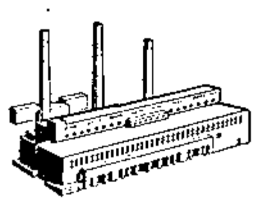

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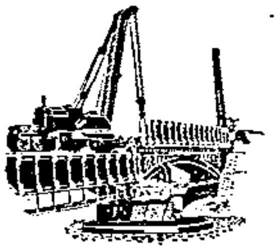

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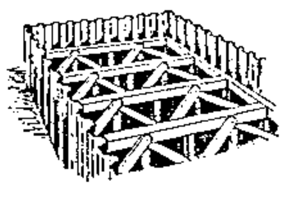

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