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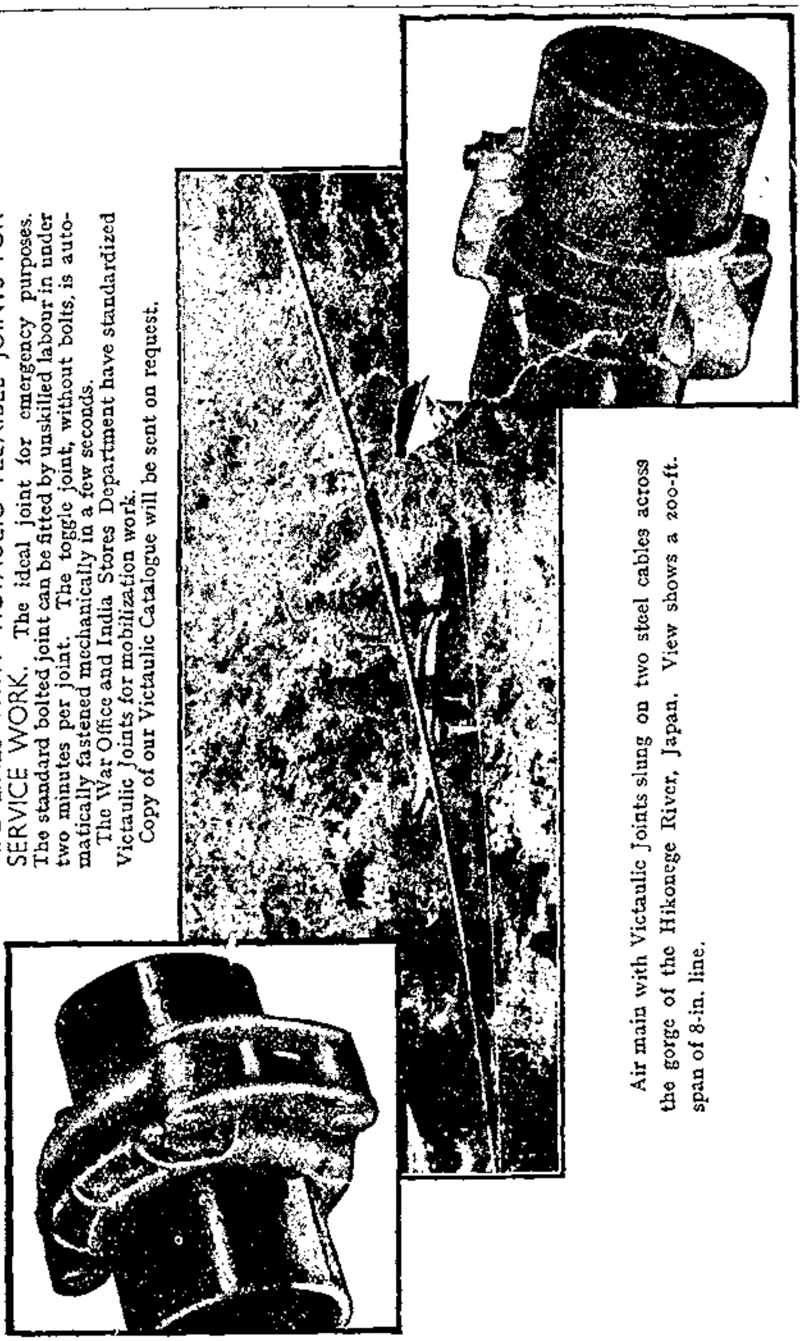

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MARINE WORKS IN INDIA DURING THE WAR

SUBMITTED BY E.-IN-C., INDIA

INTRODUCTION

IN compiling these notes, items of general information and interest have been presented rather than detailed technical descriptions of the difficulties and problems normally encountered during the planning and construction of such works. The ever increasing requirements for cargo handling and docking necessitated immediate expansions to the existing facilities. In order to ensure early availabilities, a special Directorate, composed of officers experienced in dock and heavy engineering work, was formed in the E.-in-C.'s branch in September, 1943, and at the head was placed an officer who had been responsible for similar work in the Middle East. Special arrangements were made to have field engineers and liaison officers on the sites and close liaison was maintained with all services, and relative Government and civilian bodies.

The contents are divided into sections as follows:

I. General Scope.
II. Transportation Works.
III. Naval Works.
IV. Combined Operational Works.
V. Pile Driving Notes.
VI. Appendices, Drawings and Photographs.

I. GENERAL SCOPE

There are three major users of docks and other marine structures, namely:

(*i*) Transportation.
(*ii*) Royal Navy and Royal Indian Navy.
(*iii*) Combined Operation Formations (Combined Training Centres).

In Britain it was normally a function of the Transportation Service to undertake constructional work connected with docks and harbours for War Dept. use. Civil engineers performed similar duties in regard to Naval works. In India, however, as in the Middle East, Engineer Works Services were in a better position to carry out such work due to the existence of large Military Engineer Services organizations built up mainly from the peace time nucleus. Neither Transportation nor Admiralty had any similar executive formations in India before the war.

All three "user" categories have items in common, but in India the Naval and Combined Operational requirements, generally speaking, involved lighter engineering work than the Transportation requirements. The main items of construction are as follows:—

(*i*) *Deep water berths*.—This title infers berths suitable to take ocean-going vessels. Such berths were constructed at Calcutta to take ships up to 500 ft. long, with drafts from 16 ft. unladen for laying-up berths to 30 ft. laden for import berths. The Naval jetties at Vizagapatam which were constructed for L.C.T.s, fall within this category, as prevailing conditions necessitated a depth of water of 23 ft. at low water. 1,225 ft. run of steel, 2,140 ft. run of concrete and 500 ft. run of timber quay face have been completed.

(*ii*) *Shallow water berths.*—This category includes berths and jetties for lighters, flats and minor landing craft. A minimum depth of water of 7 ft. is normally sufficient, but where large tidal variations are encountered or where provision has to be made for heavy loading of the quay structure (such as railway or crane loading), such berths may involve constructional problems almost as great as deep water berths in non-tidal waters. 3,000 ft. run of steel and 2,050 ft. run of timber quay face have been completed.

(*iii*) *Pontoon Berths.*—These were constructed in Calcutta and involved the mooring of large pontoons in the river and bridging between such pontoons and the river banks. The availability of suitable pontoons and army bridging equipment rendered these berths a comparatively simple problem.

(*iv*) *Loading Hards.*—Loading hards are new to India. The advent of major and minor landing craft brought with it the need for loading facilities suitable for these unusual craft. Such craft are designed to load and discharge on sloping beaches, but where natural facilities are used for practice and for loading on the eve of an operation, considerable wear and tear occurs to the craft and to the vehicles concerned and time is wasted. Accordingly a substantial reinforced concrete apron is laid having a slope that may vary from 1 in 7 to 1 in 15. It is not usual to take the toe of the concrete apron below low tide, but even so, much of the work has to proceed in harmony with tides. Another problem is so to site the hard as to involve a minimum of dredging to seaward of the hard and the economic balancing of cut and fill under the hard. Eight concrete hards were constructed with a total area of 207,000 sq. ft. and a total frontage of 1,280 ft. 13 L.S.T.s and 7 L.C.T.s could be accommodated.

(*v*) *Slipways.*—Landing craft, like all other vessels, require repair and maintenance. It has been necessary therefore to increase slipping facilities in India to cope with the large influx of craft. A slipway involves considerable work below low tide level, making a coffer dam necessary, and generally produces a number of engineering problems. Five slipways to accommodate minor landing craft and three to accommodate light coastal force craft have been constructed. Existing slipways were also converted.

(*vi*) *Mooring dolphins.*—Mooring dolphins are required by landing craft to enable them to be secured off-shore. Each dolphin may involve the driving of from four to eight heavy timber piles, and the construction of a large number of dolphins calls usually for a floating pile frame. Twenty-one dolphins at Cocanada (involving seventy-eight piles) and thirty-eight dolphins at Vizagapatam (involving 190 piles) were constructed.

II. Transportation Works

The Joint Transportation Committee held its first meeting in November, 1943. The J.T.C., under the chairmanship of the Principal Administrative Officer, had on it representatives of all services (including Royal Navy and Royal Air Force) and of all governmental and civilian bodies which were interested in transportation facilities in India. The scope of the Committee was broad and included ports, railways, inland water transport, and highways. The committee had no statutory executive powers but was convenient for speeding up the normal channels of procedure between planning and execution of works. It primarily interested itself in the development of the maximum possible limits, within a reasonable time, of the ports of Calcutta, Vizagapatam, Madras and Bombay.

The Joint Transportation Planning Staff was set up as a sub-body of and responsible to the J.T.C. The duty of this Planning Staff was to investigate any schemes put up to the J.T.C. by a branch or department which, in the opinion of the committee, required detailed and technical report. The Engineer-in-Chief was represented on the J.T.P.S. as well as on the J.T.C.

Development of Ports

The development of a port included not only the construction of additional berths and quays, but also the provision of extra moorings, cranes, railways, lighters and harbour craft, storage facilities, roads, and water supply, and the organization in the most efficient manner of the stevedoring and other docks and railway operating personnel. Of those items, E.-in-C. was responsible for the dock constructional work, storage facilities, roads, and water supply. In connection with that work, the closest co-operation with Transportation was essential and close liaison was maintained with the War Transport Department of the Government of India, and through that department with the Port Authorities (although in the case of Calcutta a variation to that prevailed, as described later). Specific examples of Transportation works are :

(I) CALCUTTA

Ultimate object.—Briefly the intention at Calcutta was to raise the tonnages handled (exclusive of coal) per month in various stages to reach the figures on the dates shown below :

Date		*Imports. Tons*	*Exports. Tons*
January, 1944	.. .. ..	240,000	200,000
March, 1945	.. .. ..	300,000	250,000
January, 1946	.. .. ..	360,000	250,000

Notes : (*a*) The tonnage of exported coal was to rise from 150,000 in January, 1944, to 300,000 in April, 1944, and thereafter remain at that figure.

(*b*) For the sake of brevity, personnel and M.T. have not been included in the above figures, but are by no means inconsiderable. Examples are : June, 1944, when 15,000 men and 1,000 vehicles were imported, and December, 1944, when 25,000 men and 2,000 vehicles were exported.

(*c*) Salt and oil imports are not included.

The J.T.P.S. visited Calcutta and made a comprehensive report on methods recommended to meet the target tonnages. Those recommendations covered improved clearance of the docks and transit areas, installation of extra cranes and other port equipment, lighterage, labour, moorings and laying-up berths, water facilities, adaptation of existing berths for other purposes, building of new berths, and improvements to railway installations. Consequently certain constructional duties devolved on the E.-in-C. Subsequently, however, as a result of further examination and close consultation between E.-in-C. and the Port Commissioners it was found possible further to increase the facilities so that the works given in Appendix " A " were undertaken. This table gives general data relating to these works. It is worthy of note that notwithstanding the target tonnage figure originally given to J.T.P.S., the J.T.C. agreed that, provided the time factor was not prohibitive, the physical expansion of the port should not be limited but should be the maximum possible using all available resources.

Personnel assistance to Calcutta Port Commissioners

Calcutta Port Commissioners in peace-time have a large engineering organization but, due to depletion by the war and the sudden large programme involved, E.-in-C. agreed to give all possible technical assistance. The Director of Planning (E.-in-C.'s Branch) personally visited Calcutta at frequent intervals to give advice and ascertain additional requirements. Three officers, all experienced in heavy engineering and dock construction, were lent for full time duties to the Chief Engineer, Calcutta Port Commissioners, while another officer at Calcutta and the Director of Planning's G.H.Q. staff devoted considerable time to this project. The senior officer attached to Calcutta Port Commissioners acted as direct liaison officer between the Commissioners and E.-in-C.'s Branch concerning all matters.

Stores and plant assistance to Calcutta Port Commissioners.

An idea of the stores and plant involved in the development of Calcutta Port and the assistance given by the E.-in-C. is shown by the figures of some of the major items given below:

STORES

Item	*Quantity required*	*To be provided direct by or ex-quota of E.-in-C.*
Steel sheet piles	2,450 tons	2,450 tons
Mild steel reinforcing steel	2,200 tons	2,200 tons
Cement	12,000 tons	12,000 tons
Aggregate	30,000 cu. yds.	—
Sand	23,500 cu. yds.	—
Road metal	17,000 cu. yds.	—
T.G. Sheds (44 No.)	915 tons	915 tons
Inglis double tube spans, 96 ft.	4 No.	4 No.
Small box girder spans, 96 ft.	2 No.	2 No.
Bridging cribs	250 No.	250 No.

PLANT

Item	*Number required*	*Number provided by E.-in-C.*
Pile driving plants	12	4
Concrete mixers	22	4
Compressors	4	2
Electric welding sets	4	—
Excavators	5	5
Dumpers	11	11
Bulldozers	1	1
Road Rollers	16	13
Crushers, 5 ton	5	5
Decauville trucks	75	75

Progress of works.—Excellent progress was maintained and in two instances the expected date of completion was well in advance of the original target date. In one case only, the restoration of Hastings Bridge, the original target date was passed, due largely to the impossibility of assessing with accuracy the work required before the bridge had been stripped of its deck.

(II) VIZAGAPATAM

Scope.—Besides roads, water supply, and minor items, the main jobs at Vizagapatam required by the J.T.C. after investigation by the J.T.P.S. were as follows:

(*a*) Demolition of six existing timber jetties.

(*b*) Construction of five lighter jetties in the Southern Lighter Channel; each jetty consisting of a 50-ft. high level reach and a 100-ft. low-level reach.

(*c*) Construction of a 500-ft. petrol lighter jetty and a 150-ft. general cargo lighter jetty.

(*d*) Construction of a 350-ft. lighter lay-by berth.

(*e*) Construction of a loading hard for three No. L.S.T.s.

Execution.—Vizagapatam port authorities had not the facilities for undertaking this work and in any case the port had been militarized. Accordingly this work became a M.E.S. responsibility. Siting details were arranged between Transportation and E.-in-C., designs were prepared by E.-in-C.'s Branch and the construction of the loading hard and the jetties (steel sheet piles and timber) was carried out in conjunction with certain Naval requirements.

(III) MADRAS

Scope.—Recommendations of the J.T.P.S. included no marine constructional work, although a loading hard had been constructed prior to the visit of the J.T.P.S., but E.-in-C. was required to construct only camps and to assist with water supply and the provision of certain stores and plant for port operating.

(IV) BOMBAY

Loading Hards.—Two hards were constructed and the original intention of the J.T.P.S. was that one hard should take two L.S.T.s and the other hard eight "Z" craft or an unspecified number of L.S.T.s if dredging was not prohibitive. It then resolved itself into the construction of one hard for two L.S.T.s and one hard for three L.S.T.s or for "Z" craft. Dredging and earthworks were considerable but not excessive.

(V) OTHER TRANSPORTATION MEASURES

Chittagong.—A 400-ft. lighter jetty was constructed to the E.-in-C.'s design.

Bansbaria.—This scheme resulted from further deliberation of the J.T.C. concerning the relieving of Calcutta of lighter traffic and further increasing the capacity of the Port. The project involved storage for 200,000 tons and provision of lighterage facilities for discharging ultimately 2,000 tons a day (first phase was for 600 tons discharge per day). The extreme range of water level between low tide ordinary and high tide monsoon (19 ft.) would have made construction of a lighter berth a major problem, equivalent to a deep water berth with small tidal range, and the time required for construction would have been prohibitive. Accordingly it was decided that considerable cargo could be manhandled ashore by means of gang-planks from beached lighters, and that heavy lifts could be dealt with by means of stiff-legged derricks mounted on piers protruding into the river. The piers were in steel sheet piles and had a semi-cylindrical head with the parallel sided portion connected to the shore. There were five such piers each involving the driving of about eighty to ninety piles. Another feature of this job was the use of bridging cribs to form a temporary landing stage (6 ft. wide) parallel to the shore against which lighters could be moored in pairs when discharging. The distance of this landing stage from shore can be varied (by moving the bridging cribs—a comparatively simple task) to suit the prevailing water levels as between monsoon and ordinary conditions. The five stiff legged derricks, each have a capacity of 5 tons at 60 ft. and 2 tons at 90 ft.

Khulna Barge Line.—Heavy timber jetties for loading barges were constructed here.

III. Naval Works

The majority of works for the Navy emanated from the Commander-in-Chief, Eastern Fleet, and such works were mainly due to the expected arrival in Indian waters of landing craft of all types. Slipways, jetties, moorings and loading hards were all called for, although the last named facility was, in actual fact, constructed more under the auspices of the J.T.C. and Director of Combined Operations (India) than under the Navy. Flag Officer Commanding R.I.N. required a few minor marine works. Examples of Naval works are:

Concrete floating docks.—With the development of the various types of landing craft came the need for a means of docking them, particularly the larger types which could not easily be hauled up on slipways. Floating docks which could be towed to wherever the need arose were the obvious answer. Reinforced Concrete was the material chosen, to relieve the demands on steel and shipyards. Construction was actually carried out at Cocanada and designs were prepared for Vizagapatam but no work was commenced there. The docks are composed of a number of pre-cast slabs joined together by bottom, deck and vertical joints of concrete cast in situ.

The "Factory" for producing floating docks is an assemblage of plant and equipment collected around a graving dock, generally referred to as a "basin." The basins each had ancillaries for independent production. The poor type of soil introduced early constructional difficulties. Essentially each basin consisted of an excavation 600 ft. long and 74 ft. wide containing two berths, one of concrete with a timber floor and the other of pebbles on laterite soling. This enabled the dock to bed down evenly. The basin gates are of sloping bear-trap type in four leaves which are lifted out by derricks.

Along each side of the basin is a concrete strip 100 ft. wide, 30 ft. being for the crane track and the remainder for making the precast slabs. Stothart and Pitt dockside cranes were provided at Cocanada. They were diesel electric driven, hand traversed, weighed 87 tons, and had a capacity of six tons at 60 ft.

The mixing plant for each basin consisted of eight half-yard mixers set up in pairs on each side of each berth and two small mobile mixers. Field tests were carried out by the beam method to ensure that the results of concrete tested at any specified age, were available immediately.

In the canal was a fitting out berth for each basin. These berths required dredging and the canal bank had to be revetted at a one in one and a half slope. The docks were moored to bollards ashore, and to keep them off the bank, and provide access, there were three dolphins. For placing fittings on the dock an American stiff-leg derrick capable of lifting five tons at 60 ft., and a twenty-ton floating crane were available.

The docks are cellular structures designed on geodetic principles, with the walls, the bulkheads and the gallery deck of thin pre-cast slabs. Not only does this pre-casting help to speed construction but it also minimizes shrinkage cracks. The bottom, the spine wall, the pontoon deck and the top deck are cast in situ as well as the vertical joints between slabs, and the four small walls at the swim ends. The reinforcement, left projecting from the pre-cast slabs, is bent as required to mesh with that of adjacent slabs before pouring the in-situ concrete. Timber blocks are fixed to the pontoon deck to cradle docked craft, and timber fenders are fitted to the sides. The docks are equipped with diesel-driven generating sets, electric welders, pumps, and crew's quarters.

Dimensions and quantities of materials are as follows:

1. Lifting capacity	300 tons	800 tons	1,000 tons
2. Length	210 ft.	264 ft.	267 ft.
3. Beam	61 ft.	64 ft.	67 ft.
4. Height of side	28 ft.	24 ft.	34 ft.
5. Draught	6 ft. 10 in.	6 ft. 2 in.	8 ft. 2 in.
6. Approximate displacement		2,850 tons	3,900 tons
7. Width of pontoon deck ..	46 ft.	49 ft.	48 ft.
8. Width of each top deck ..	7 ft. 6 in.	7 ft. 6 in.	9 ft. 6 in.
9. Height of pontoon deck above bottom	8 ft. 9 in.	8 ft. 10 in.	10 ft. 6 in.
10. Thickness of bottom slab		5 in.	5 in.
11. Thickness of pontoon deck		4 in.	4¼ in.
12. Thickness of top deck ..		7—13½ in.	7—16¼ in.
13. Volume of concrete ..		1,216 cu.yds.	1,757 cu.yds.
14. Weight of steel		382 tons	538 tons
15. Number of main slabs (put in position in No. 1 berth) ..		174	330
16. Number of gallery slabs (put in position in No. 2 berth)		36	44
17. Total number of slabs ..		210	374

N.B.—Drawing No. 1 shows the outline of an 800-ton dock and drawing No. 2 a cross section through the pump room.

There are ten main types of pre-cast slabs, the largest of which weighs six tons, and each type contains several variants in reinforcing, apertures, etc. The in-situ work contained some 260 cu. yds. The specified mix of 1 : 1·2 : 2·4 concrete required a minimum strength of 2,500 lb. per sq. in. at seven days and 4,000 lb. per sq. in. at twenty-eight days, but the preliminary tests barely achieved this due to dust in the aggregate. More care in the screening of crusher dust and in storage and transport of aggregate raised the seven-day strength to between 3,500 and 4,000 lb. per sq. in.

The stone used at Cocanada was a trap rock with a specific gravity of 2·8 to 2·9, giving a concrete which weighed 154 to 160 lb. per cu. ft. without reinforcement. This very heavy concrete would reduce the lifting capacity of the dock by some 150 to 200 tons. A search was made for a lighter aggregate but only a weathered sandstone, specific gravity 2·55 to 2·6, could be found and that 100 miles away. As this produced a poor concrete with a seven-day strength of only 2,000 lb. the heavier stone was used.

The layout of the casting yard required careful planning to reduce the transport of slabs to a minimum. Slabs of the same type were cast one on top of another with paper joints between them, and timber strips as shuttering allowed the two layers of reinforcement to project.

The total time a dock was under construction in the basin was from eight to eight and a half weeks. After completion, the dock was towed to deep water and submerged, leaving two feet of freeboard to the top deck. The tanks were then sounded for leakage.

Reinforced concrete jetties at Vizagapatam.—Two of these jetties with 23 ft. of water at low tide and capable of berthing L.C.T.s were completed. They involved considerable design work, and some 122 reinforced concrete piles were driven.

Slipway for L.C.M.(3)s.—This item necessitated the use of a coffer dam, as part of the slipway was below low tide. The coffer dam was built with approximately 300 steel sheet piles, and they were later withdrawn and used for Transportation lighter jetties.

Mooring dolphins.—Thirty-eight dolphins for mooring L.C.M.s were required, and they were constructed of five timber piles (about 40 ft. long) per dolphin.

Other works.—There were various other works for the Navy at Vizagapatam, including the erection of an Inglis Bridge, 400 ft. long (four spans) and the construction of a road.

IV. Combined Operational Works

Similar construction to Naval works was involved, but in this case the sponsoring authority was the D.C.O.(I). As examples: loading hards, jetties, slipways, and mooring dolphins have been constructed at Bombay and Cocanada. The latter place is quoted as an example.

Cocanada slipway

This was required for slipping L.C.M.(3)s. It involved underwater work and the coffer dam was formed by bunding.

Cocanada fueling jetty

A 300-ft. long timber jetty involving 175 piles was constructed, and used for fueling and maintaining L.C.A.s.

Cocanada loading hard

This hard will accommodate three L.C.T.(3)s. After initial difficulty in siting, it was located in such a position that all work could be executed in the dry without a coffer dam. Access to the hard was then obtained by breaking through the canal retaining bank and dredging as necessary.

Cocanada dolphins

These were required for mooring L.C.T.s and L.C.M.s. Twenty-one were constructed, involving the driving of a total of seventy-eight timber piles.

V. Pile Driving Notes

One of the main engineering operations in marine construction work is pile driving. On the jobs under review in these notes the following approximate figures of piles driven give an indication of the magnitude of this part of the work:

Number of steel piles	4,200
Number of timber piles	2,500
Number of concrete piles	2,000
Total ..	8,700

The piles varied in length from 20 ft. to 60 ft. and in weight from a few hundredweights to four tons.

Pile driving plant was in very short supply, but consignments from Middle East and U.K. met the requirements. Such plant, however, needed experienced personnel to erect and operate it, and they were very scarce. The task was made more difficult by the damage and loss sustained due to frequent moves from one site to another.

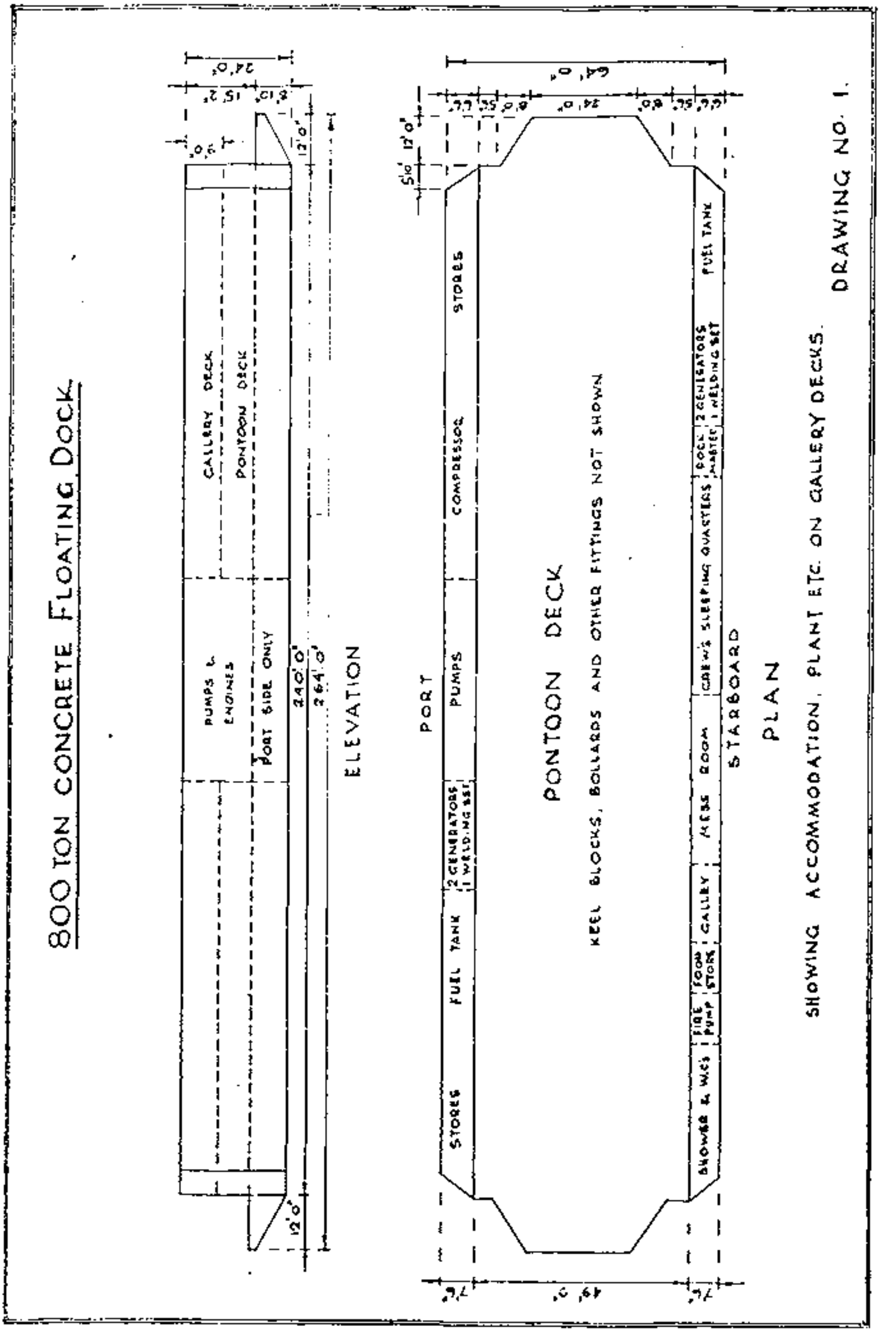
APPENDIX "A"

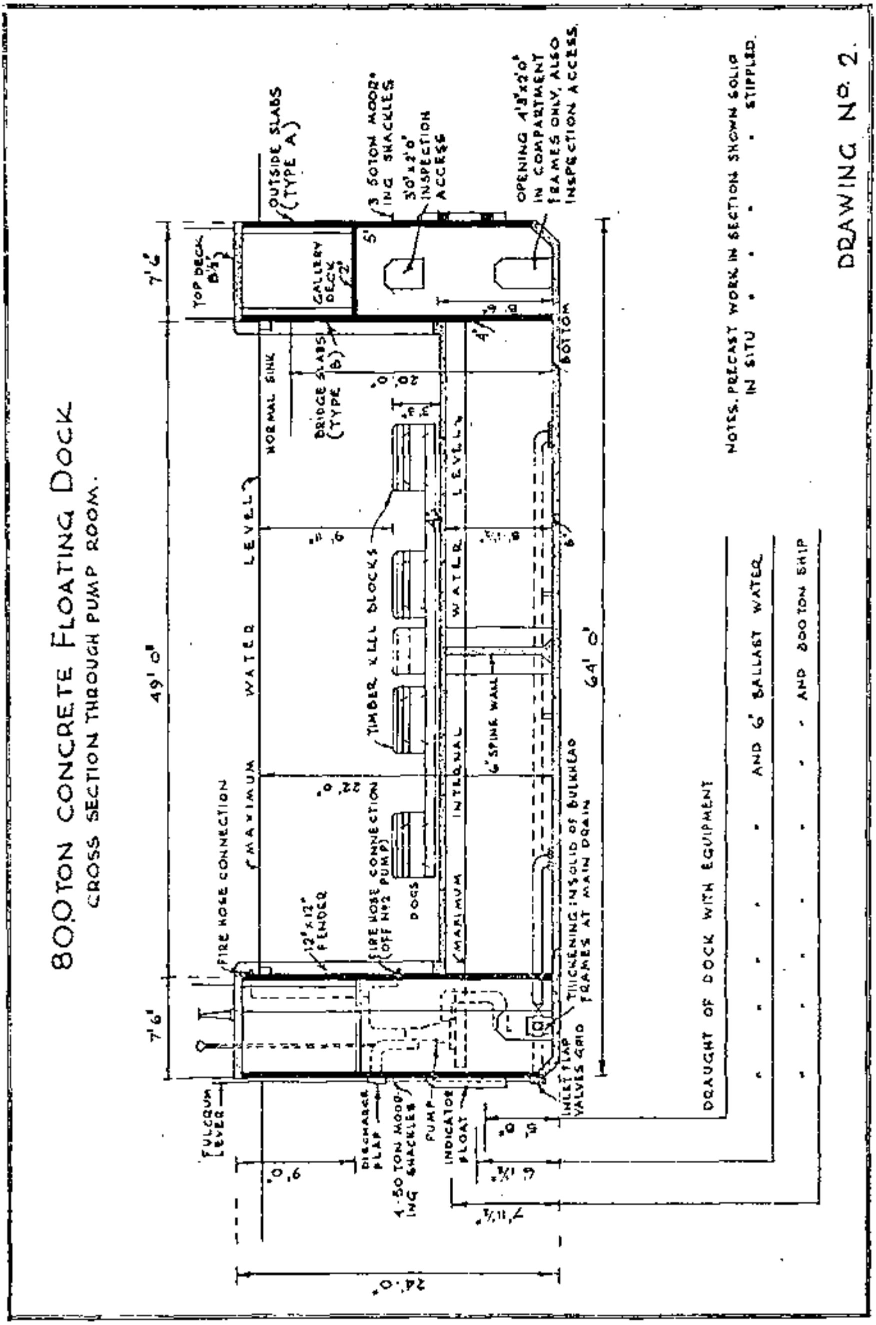
CALCUTTA PORT DEVELOPMENT—SUMMARY OF ENGINEER WORKS

Descriptions	*Cost Rs. lakhs.*	*Vessels accommodated Type*	*No.*	*Depth of water feet.*	*New Construction Quay length feet. Deep water*	*Other*	*Type of construction*
Conversion of existing berth into an Import Berth, K.G.D.*	5·0	500 ft. ships	1	30·0	EXISTING		
Additional Import Berth, K.G.D.* ..	10·0	500 ft. ships	1	28·0 16·0	550 175	—	Steel sheet piles
Laying-up berth, K.G.D.*	4·7	500 ft. ships	2	16·0	500	—	Steel sheet piles
Additional laying-up berth, K.G.D.*	0·6	500 ft. ships	2	25·0	EXISTING		
Two flat loading berths, K.G.D.* ..	4·0	Flat lighters	4	10·0	—	460	Steel sheet piles
Additional flat loading berth, K.G.D.*	2·0	Flat lighters	2	10·0	—	360	Steel sheet piles
Additional flat loading pontoon berth, Calcutta jetties	1·0	Flat lighters	2	26·0 at low water	PONTOONS		
Heavy lift yard extension, K.G.D.* ..	1·2	Lighters	4	6·0	—	575	Steel sheet piles
Three new Import Berths, K.P.D.†	53·2	500 ft. ships	3	31·5	1,880	—	Franki concrete piles with concrete deck
Conversion of L.S.T. loading hard to heavy lift yard, K.P.D.†	0·5	Lighters	2	7·0 at 20 ft. from toe of hard	EXISTING		
New Horse-cum-Coal Jetty, K.P.D.†	0·9	500 ft. ships	1	about 30·0	500	—	Timber piles with timber deck
Two Personnel Pontoon Jetties, Princeps Ghat	5·4	500 ft. ships 475 ft. ships	1 1	22·0 at low water	Pontoons with four Inglis spans to shore. Timber piles have been used for approach spans		
Other ancillary works	16·9						
Total ..	105·4			Totals	3,605	1,395	

Grand Total—5,000 ft. run new quay face

*King George's Dock. †Kader Port Dock.


800 TON CONCRETE FLOATING DOCK
GALLERY DECK
PONTOON DECK
PUMPS & ENGINES
PORT SIDE ONLY
24'0"
15'2"
8'10"
9'0"
12'0"
240'0"
264'0"
12'0"
ELEVATION
64'0"
24'0"
8'0"
12'0"
5'10"
PORT
STORES
COMPRESSOR
PUMPS
2 GENERATORS 1 WELDING SET
FUEL TANK
STORES
PONTOON DECK
KEEL BLOCKS, BOLLARDS AND OTHER FITTINGS NOT SHOWN
FUEL TANK
2 GENERATORS 1 WELDING SET
DOCK MASTER
CREW'S SLEEPING QUARTERS
MESS ROOM
GALLEY
FOOD STORE
FIRE PUMP
SHOWER & W.C.S
STARBOARD
7'6"
49'0"
7'6"
PLAN
SHOWING ACCOMMODATION, PLANT ETC. ON GALLERY DECKS.
DRAWING NO. 1.


800 TON CONCRETE FLOATING DOCK
CROSS SECTION THROUGH PUMP ROOM.
DRAWING No. 2.
NOTES. PRECAST WORK IN SECTION SHOWN SOLID
IN SITU " " " " STIPPLED.
DRAUGHT OF DOCK WITH EQUIPMENT
" " " AND 6' BALLAST WATER
" " " " " AND 800 TON SHIP
MAXIMUM WATER LEVEL
MAXIMUM INTERNAL WATER LEVEL
NORMAL SINK
TIMBER KEEL BLOCKS
DOGS
6" SPINE WALL
BRIDGE SLABS (TYPE B)
OUTSIDE SLABS (TYPE A)
TOP DECK
GALLERY DECK
BOTTOM
FIRE HOSE CONNECTION
FIRE HOSE CONNECTION (OFF No 2 PUMP)
12"x12" FENDER
THICKENING IN SOLID OF BULKHEAD FRAMES AT MAIN DRAIN
INLET FLAP VALVES GRID
FULCRUM LEVER
DISCHARGE FLAP
4-50 TON MOORING SHACKLES
PUMP
INDICATOR FLOAT
3 50 TON MOORING SHACKLES
3'0"x2'0" INSPECTION ACCESS
OPENING 4'3"x2'0" IN COMPARTMENT FRAMES ONLY, ALSO INSPECTION ACCESS.
49' 0"
64' 0"
7' 6"
24' 0"
22' 0"
9' 0"

SAFAGA—A PORT ON THE RED SEA

By Brig. G. Streeten, C.B.E., M.C., M.Inst.C.E.

Birth of the Project

THE entry of Italy into the War in 1940 had the effect of closing the Mediterranean to Allied traffic. The Middle East then became dependent on the long sea route via the Cape. Henceforth the port of Alexandria could only be reached by way of the Suez Canal. Port Sudan was used to a very limited extent for the supply of troops in Egypt and the Western Desert by metre gauge railway to Wadi Halfa and thence by Nile to Cairo. If the Suez Canal were to be blocked, Suez would be the only remaining port to serve the Middle East, apart from this small use of Port Sudan.

In June, 1941, the German Army in the desert was at the Western frontier of Egypt and Tobruk was besieged. The possibility of a blitz on Suez and consequent serious disruption of activities at that port had therefore to be considered.

One proposal put forward for the relief of Suez was to connect the Sudan railway, which reached no further north than Wadi Halfa, with the Egyptian State Railway, the southern extremity of which was Aswan. This proposal was dropped for the following reasons. The Sudan railway is metre gauge, whereas the Egyptian State Railway is standard gauge. Transference of goods would therefore be necessary even if the connection were to be made. Moreover, the proposal would involve a 600-mile railway journey from Port Sudan to Wadi Halfa before starting down the Nile Valley. In addition, railway material was in short supply and the length to be laid would be over 200 miles.

The only other solution to the problem appeared to be the construction of an alternative port on the Red Sea. This would have to be within a reasonable distance from the railway which runs down the Nile Valley from Aswan to Cairo and sufficiently far south to minimize the likelihood of damage by bombing. Reconnaissances were put in hand to choose a suitable spot.

As a result two places were in the running—Safaga and Quseir, both of which were used for shipping phosphates, mined on the Red Sea littoral. At Safaga there existed a jetty, alongside which a fair-sized freighter could berth, but it was too short to permit loading at more than one hatch at a time. Safaga island gave protection from all but southerly winds. Quseir also provided facilities for berthing a freighter for the loading of phosphates but was completely unprotected. Access by land to the Nile Delta involved the same problem for both places. There is a rough track running along the shore in a southerly direction from Suez by way of Ras Gharib and Hurghada to Safaga, about 330 miles distant, and continuing slightly inland to Quseir. Tracks also connected the two ports with the Nile Valley at Qena and Qift, the distance between the Red Sea and the Nile being approximately 100 miles. After due consideration of all aspects, Safaga was chosen for enlargement and development.

Rail connection between Safaga and the branch of the Egyptian State Railway up the Nile Valley was an essential part of the scheme. The details of the proposal for this railway, for the construction of a permanent road, and for the use of the existing tracks will be dealt with later.

Topography

The oolitic limestone escarpments on the east side of the River Nile give place, on approaching the Red Sea coast, to a range of granite hills rising to about 7,000 ft. at Gebel Shaiyib, the highest mountain in Egypt.

Midway between Aswan and Asyut the Nile makes a loop to the east so that at Qena is its nearest approach to the Red Sea coast.

Between Qena and the granite range the country is cut up by wadis interspersed with limestone hills. The going is rough and dusty and the beds of the wadis are generally very soft.

Above Safaga is an extensive plateau in the granite hills. This plateau was entirely unmapped. It is traversed by innumerable wadis, the direction of which is difficult to determine, the flow of water in them being governed more by the position of the storm which feeds them than by any fall in their beds.

The rainfall in the area between the Nile and the Red Sea at this point averages less than one inch in the year. In some years there is no rain at all and normally the storms are very local. Before 1941 there had been no appreciable fall of rain for four years.

There are two passes through the granite range giving access to Safaga, one by the Wadi Safaga and the other by the Wadi Hamamat (see Plate I). There are no villages and very little water. A few bedouin with sheep and goats may be seen in the neighbourhood of such wells as do exist. Apart from these the only animal one is likely to encounter is the gazelle, whose only drink is the dew on the sparse vegetation that grows in the wadi beds.

The hills are rich in mineral wealth which, apart from the phosphates, has been developed but little. In the Wadi Hamamat are granite quarries worked by the ancient Egyptians, whose hieroglyphics still adorn the rocky sides of the wadi. Not far away is a gold mine originally dug by the Romans. They were unable, with their primitive methods, to extract all the gold from the ore and left large mounds of tailings still rich in gold. The mine was leased, a few years before the war, by the Egyptian Government to a Russian count who, in partnership with an Englishman, made quite a good thing out of extracting the remaining gold from the tailings by the cyanide process.

Wolfram is also mined in the neighbourhood and outcrops of talc appear in the sides of wadis. The wolfram mines had not been worked extensively in recent times but were developed to a considerable extent during the war.

Water

The area between Qena and Qift, on the Nile, and Safaga and Quseir, on the Red Sea, contains but little water.

There is a good supply at Lageita Wells and a fair supply at Bir um Fowakhir, which is used for the gold mine. There are a few other small supplies, some of which are unfit for drinking. The only other supply is at Mons Claudianus, where there are the remains of a Roman Settlement (see Photo 2) and two wells giving a good supply. The development of this latter supply of water will be described later.

At Safaga itself there is no fresh water at all. The Phosphate Co. depended on supply by sea and had a small distillation plant as a standby.

It was proposed initially to supply Safaga with water by sea in water carrying vessels. This was to be supplemented by two distillation plants, each capable of producing some twenty-five tons a day, which were to be transported from Suez by sea and erected on the shore at the port.

On completion of the railway it was anticipated that water could be carried by rail from Qena sufficient in quantity for the use of the railway itself and for a proportion of the needs of the port. Later a project was formulated whereby water was to be piped from Mons Claudianus to the railway along the Wadi el Bula. Thence it was to be carried by gravity to Safaga.

LABOUR

On the whole the labour situation in Egypt during the war was excellent. There were a number of fairly large contractors, some European but mostly Egyptian, and labour for direct employment was easily obtained. The standard of workmanship, though generally poor, was good enough for war time needs.

In the Upper Nile Valley a plentiful supply existed. Directly the project was authorized, an officer of the Pioneer and Labour Corps was sent to Qena to recruit. This officer was employed in peace time by the Egyptian education authorities in Qena. He was thus admirably suited for this job. Not only did he keep the project supplied with such directly employed labour as was needed, but he also recruited several thousand men for work in the Nile Delta and in the Western Desert.

The recruitment of men for work at Qena was comparatively easy as they would be near their homes. For Safaga the problem was more difficult. Owing mainly to lack of water at that place, they were not allowed to take their families and did not like to leave them for any length of time. Consequently, after about three months, having made enough money, in their estimation, to warrant a return to home life, they would go back to the Nile Valley. It was therefore necessary to recruit continuously to replace such casualties, even after the main labour force had been collected. Moreover, being used to living on the banks of the Nile with an inexhaustible supply of what they considered to be excellent water—the Nile mud gave it body—they were unhappy with their meagre allotment of somewhat insipid clear water at Safaga.

Incidentally the troops at that place had to manage with a gallon of fresh water a day. In order to induce the Egyptian labour to stay they were given one and a half to two gallons a day. This naturally caused some dissatisfaction among the troops until the reason was made clear.

A base camp for the project was set up at Qena, the start of the road and railway, some two or three miles into the desert. Here such labour as was required at the base was housed in a special camp.

The rates of wages paid for unskilled labour were as follows :—

1. Those able to live in Qena village, six piastres a day without rations.
2. Those in Qena labour camp, five piastres a day plus rations.
3. Those at Safaga, six piastres a day plus rations.

The cost of the ration was estimated at from three to three and a half piastres a day. A piastre is worth 2½d.

The only R.E. company employed was the 19 New Zealand Army Troops Coy., which did sterling work, not only with its tradesmen but also in looking after directly employed labour and in supervising contracts.

Messrs. Fils Barthe de Jean, a large firm of building contractors in Egypt, undertook a considerable amount of the more technical work and a number of small local contractors were also employed, mainly at Qena.

Work on the Qena—Safaga road (see Photo 1), which it is not proposed to describe in detail in this article, was carried out by Egyptian labour directly employed by the Shell Co. of Egypt, who undertook the work on a cost plus basis within a maximum lump sum. They held their contract with the Roads and Bridges Department of the Egyptian Government, but were supervised entirely by the R.E. Works Services Organization.

Though many difficulties were encountered and some delays caused by lack of labour, on the whole the supply was adequately maintained.

Photo 1.—Qena—Safaga Road. 10 Km. from Safaga.

Photo 2.—Roman Tower by well at Mons Clausianus.

Photo 3.—Driving Reinforced Concrete Piles.
Personnel Camps in Background.

Safaga - a port on the Red Sea

Communications

The main line of communication at the outset was the sea route from Suez to Safaga, the existing phosphate pier being used at the Safaga end. Phosphates had still to be exported and it was only by careful timing that congestion could be prevented at the single berth. Despite all precautions, ships had sometimes to lie off the pier for some days before they could be unloaded.

A lighter wharf alongside this pier was included in the project. When this was nearing completion the situation was eased to some extent by the fact that it was then possible to offload a ship without bringing it alongside. The completion of this lighter wharf was of high priority as the general shortage of shipping made it imperative that ships should not lie idle.

A standard gauge line belonging to the Egyptian State Railway ran up the Nile Valley from Cairo to Aswan. This was used to some extent, as also was the Nile itself, for bringing stores to Qena. There was also a dirt road which followed the Nile from Cairo to Qena, a distance of some 400 miles. This ran by way of congested villages through which it was difficult for lorries to follow its tortuous course. Moreover, these dirt roads are kept in shape by gangs who flood them with water from the canals alongside. This makes the surface very slippery and many a lorry has skidded into the canal in consequence.

Of the two main tracks connecting Safaga with the Nile at this point, that from Qena to Safaga was the main route used by the employees of the Phosphate Company on their infrequent visits to civilization. This was the shortest route but, as will be seen above, was very dry.

The other, following the track from Qift to Quseir as far as Bir Seyala and then branching north, was considerably longer. The track from Qift to Quseir has probably been in existence as long as any known road. It was certainly used by the ancient Egyptians to carry granite to the Nile from their quarries in Wadi Hamamat. Quseir also served as a port for Egypt from the very earliest times and this track formed the most direct connexion with the Nile waterway.

From Qena to Qift there was no metalled track and the desert surface soon broke up into fine dust. Many tons of stone were needed to make it fit for lorries. From Qift to Bir Seyala the route was well consolidated but long stretches soon became badly corrugated with lorry traffic. The section running north from Bir Seyala had been little used and so required much maintenance.

Both these routes were used for carrying personnel and stores to Safaga during the building of the port and the construction of the permanent road and railway. On the proposal to build a permanent road between the Nile and the Red Sea the Anglo-Egyptian Treaty of 1936 had a considerable bearing. By this treaty the Egyptian Government had undertaken to construct metalled roads from Qift to Quseir and from Quseir to Hurghada. No date was laid down in the treaty for the completion of these roads. When war broke out nothing had been done about them and it was unlikely that the Egyptian Government would do anything during the war, with the certainty of enhanced costs.

Very careful consideration was given to the question of the route to be followed by this permanent road to Safaga. Either the track from Qena to Safaga or that from Qift via Bir Seyala could form the basis of the road, or else an entirely new line could be taken. If the Qift track was chosen it would follow the line of the treaty road to Bir Seyala and the Egyptian Government would be bound to pay towards its construction as far as that place. However, the objection to this route was that it was about fifty miles longer than that from Qena to Safaga.

The Egyptian Government therefore were asked whether they would agree to the amendment of the treaty by the substitution of a road from Qena to Safaga for those from Qift to Quseir and from Quseir to Hurghada. Though they would have gained considerably in the reduction in the length of the road for which they were liable, they would not agree and it was decided that it was not a suitable time to press for any change in the treaty.

The construction of a road along a new line following Wadis Merkh, Abu Shia and Um Tagher was finally decided upon as shown in Plate I. During the building of this road both the tracks referred to above were maintained for lorry traffic.

Materials

The only local materials that were used in the construction of the port were stone, gravel and sand. All the rest had to be fetched from Egypt. They were brought either direct to Safaga by sea, or by rail to Qena and thence by lorry over the rough and sandy tracks already existing.

There were large supplies of corrugated iron and sufficient timber in the Engineer Base Store Depots in Egypt. Cement was manufactured in the Delta. Piping was in short supply at times and pumps and machinery were hard to come by. Some stores such as sheet piling and anchor rods had to be ordered in U.S.A. and brought to Egypt round the Cape. Apart from grave delays in the shipment of these stores from U.S.A., the main difficulty was the actual carriage of stores from Egypt.

Shortage of shipping and urgent calls for other purposes on such as was available made it quite impossible to forecast with any accuracy the date on which any particular batch would arrive at Safaga. On occasions, stores already loaded into a ship at Suez had to be offloaded again, so that the ship might be taken for what was considered to be a more urgent purpose. Consequently it was not always possible to keep to priorities laid down and ships were often finally loaded with stores in no great demand at the expense of others which were urgently required. Very important small stores were therefore often sent by rail or road from Cairo to Qena and thence to Safaga by lorry.

Quays and Wharves

The general scheme for the port included the construction of the following quays and wharves (see Plate II):—

1. *South lighter wharf.*

This was 800 ft. long with its face parallel to the existing shore line and about 400 ft. away. It was constructed of steel sheet piling and gave a depth of about 9 ft. of water. The fill behind the sheet piling was some 150 ft. wide leaving a lagoon between the wharf and the shore. The northern part of this lagoon was also filled to provide space for offices, etc.

The southern end of the wharf was connected to the shore by means of a causeway formed of quarry boulders. In the centre of this causeway a small bridge with sheet piling abutments carried the railway and allowed the tides to refresh the water in the lagoon.

2. *North lighter wharf.*

This was built at the northern end of the site chosen for the deep water quay and was 600 ft. long with about 9 ft. of water. It was also constructed of steel sheet piling.

3. *Deep water quay.*

The original design of this quay was for a length of 2,000 ft. to berth four freighters with a maximum draught of 28 ft. Its face was to be formed of 60 ft. steel sheet piling driven some 30 ft. into the sand. Immediately behind the face was to be a crane rail carried by reinforced concrete beams on pile bents of the same construction (see Photo 3).

The piles, transoms and beams were made on the spot with very careful grading of the aggregate, which consisted of granite quarried from the side of a nearby wadi. Tests for crushing strength were carried out continuously. The piles were cured for the first seven days in fresh water. The curing was completed by immersion in the sea until they were required for use.

Two forms of anchor wall were used :—

(*a*) A box was constructed of driven sheet piling. The interior of the box was excavated and filled with mass concrete in which the anchor rail and rod ends were placed.

(*b*) Reinforced concrete caissons were built in situ and sunk by excavation from the inside. Three tiers of these caissons were used, successive tiers being constructed when the former had been sunk to ground level. The anchor rail and rod ends were fixed in position between the two top tiers and the whole filled with mass concrete.

The area behind the face of the quay was filled, as necessary, to bring it up to the required level, by means of scrapers with material from the rising ground inshore, the quay being finally surfaced with tarmacadam on stone soling.

The main line of the Phosphate Company's metre gauge railway was extended to the quay and sidings laid.

On the quay itself five transit sheds, of reinforced concrete framework and stone panelling, were to be constructed, in addition to offices and power stations for the supply of electricity to the cranes. A stores transit area was also planned behind the sidings.

The waterway at the quay face had to be dredged to give 30 ft. depth of water. Some dredging would be needed continually as a southerly wind tended to silt up the dredged area.

4. *Loco pier.*

It would be necessary to bring locomotives by sea to Safaga long before the anticipated date for completion of the deep water quay. The construction of a loco pier was therefore put in hand. This was planned originally for locos of thirty-five tons. The possibility, however, of having to use the pier for ninety-ton locos became clear later and the pier was actually constructed to allow for this.

It consisted of a cylinder about 7 ft. in diameter formed of sixty-six Larrsen No. 2 piles driven round the circumference. The piles varied from 36 ft. to 44 ft. in length. The cylinder was filled with concrete and stone and connected to the shore by a reinforced concrete bridge of two 25-ft. spans, supported by a piled trestle. Finally rails were laid across the bridge and cylinder top.

The pier was situated alongside the Phosphate Company's jetty.

5. *Petrol jetty and reservoirs.*

It was decided to provide facilities for the storage of petrol in the shape of two 6,000-ton welded steel tanks. These were sited on the lower slopes of the hills which protect Safaga from the west. They were placed in ravines whose rocky sides and bottoms were squared off to receive them. When erected they were to be completely covered over with the spoil of excavation to conceal them from the air. This excavated soil was dumped temporarily in a wadi while the tanks were being erected so that it would not be spotted by enemy aircraft.

The petrol was to be pumped from tankers along a pipeline, laid on a jetty specially constructed to receive it, and across country to the tanks.

The jetty was to take the form of an L-shaped pier constructed of a steel sheet piling surround filled with granite rubble. The pier was to be wide enough to berth a single tanker.

Ancillary Projects

1. *Accommodation.*

Before the start of the project there was at Safaga a small pier which could accommodate one ship only. There existed a metre gauge railway from the mine (see Plate I) to the phosphate works where there were sidings, buildings and plant for the purification of the phosphates and loading at the pier. There were, in addition, houses and a club for the European staff and a hutted village for the native workers; also a steel reservoir capable of holding a reserve of 3,000 tons of water received by sea. There were no other structures of importance.

Soon after the arrival of the engineers, pioneers and other troops to work on the project, a sub-area was formed. Offices and a camp for the staff had to be provided together with a garrison officers' mess and quarters. Camps had also to be built for the following :—

R.E. Works staff.
Army Troops Company.
M.T. Company, R.A.S.C.
Indian Garrison Company.
Port and Dock Operating Companies.
Movement and Transportation personnel.
Civil labour.
Prisoners of war, for use as labour.

A garrison institute, a Y.M.C.A. building, a cinema, a guard room and a small hospital were also needed.

These buildings were constructed in local stone and concrete blocks, and were roofed with corrugated iron sheeting.

2. *Installations.*

(*a*) A R.A.S.C. supply depot, consisting in the main of Romney sheds.

(*b*) A vehicle assembly unit for the assembly of vehicles to be shipped in crates from U.S.A. When ready for the road these vehicles were to be taken to Cairo under their own steam. The work consisted in levelling the site, the provision of a tarmac surface and the construction of battery charging rooms of stone, and sheds of timber and matting for the work of assembly.

(*c*) A dump for tinned petrol and a petrol supply point consisting of a reservoir, oil store and stand pipes for filling lorries.

(*d*) An ordance depot.

3. *Miscellaneous Work.*

(*a*) A landing ground existed but this was too small and the surface was not suitable for high speed aircraft. It was improved and extended, but even then did not satisfy requirements. Consequently a new landing ground was built some distance north of the deep water quay. The work consisted largely in levelling the surface and consolidating it with rollers.

(*b*) The following were also constructed :—
Cold store.
Slaughter house.
Petrol tin factory.
Tin filling plant.
R.E. store and workshops.
M.T. workshops.
Two distillation plants.
Wireless station and signal office.
Oil tank for railway use.
Power station.

(*c*) Two low level and two high level reservoirs for the storage of water were provided together with the necessary pumping plant, rising mains and gravity distribution. A spill trough for the collection of water brought by rail tankers was also built.

4. *Railway*

An integral part of the project was the construction of a railway from Qena to Safaga. Originally a standard gauge railway was contemplated. In view, however, of existing commitments in the way of new construction in Egypt—notably alongside the Suez Canal—shortage of rails and sleepers made it necessary to give up this idea. It was therefore decided to build the railway in metre gauge with material which could be made available in India and Eritrea.

The project involved a bridge over a canal which ran parallel to the Nile at Qena, a station and siding at Qena Base and approximately 100 miles of track across the desert to Safaga.

The only practicable route at the Red Sea end, where the range of hills sloped down to the sea, was by way of Wadi Safaga, which is steep and exceedingly twisty. Moreover, the granite hills on either side fell steeply to the wadi bed leaving little room to preserve the maximum curvature in negotiating the many twists and turns.

Some years ago the railway belonging to the Phosphate Company had been laid some way up the wadi to the site of their earlier workings. The lengths of twisted rail—sometimes bent almost double—which were still to be seen on the wadi bed showed the effect that might be expected from one of the storms that periodically visit the neighbourhood. There was no possibility of raising the line above the wadi without a prohibitive amount of rock cutting. It therefore had to be laid, like its predecessor, on the wadi bottom and the risk of a serious washout faced.

The Wadi Merkh, which it was to follow for the greater part of its course, (see Plate I) was very different from the Wadi Safaga. It was much wider and of gentler slope. Thus it was possible for the railway to avoid the deeper channels which would carry off the majority of water in a storm.

The railway was built by the Egyptian State Railway under the supervision of British and South African transportation staff. It took about six months to build, as did the new road which ran approximately parallel for most of its length. At the Safaga end it joined up for the last few miles with the existing railway from the phosphate mine.

Water was provided at loco filling points at Qena station. It had to be carried for use throughout the 100 miles length of railway.

At Safaga the existing station sidings had to be extended and spurs laid to the quay and wharves.

5. *Qena*

A camp in the desert east of Qena village formed the main base for the construction of the road and railway to Safaga and a transit camp for staff and other personnel en route from Cairo. The transfer sidings and marshalling yard connecting the metre gauge railway from Safaga with the standard gauge to Cairo were sited close to this camp. A R.E. park, consisting of stores, offices and accommodation, a camp for M.T. H.Q. and company, a cold store and a supply depot were also sited nearby.

Difficulty arose in connection with the control of the Egyptian labour at Qena on the camp, road and railway and it was found better to accommodate the majority of them in a camp in the desert rather than allow them to come to work from their homes by the Nile.

An ammunition and explosives dump and a large bomb dump for the R.A.F were hastily formed alongside the station at Qena when the enemy was approaching el Alamein, seventy miles west of Alexandria.

Initially, water was supplied from the existing civilian filtration plant in the village, but later a W.D. plant producing 600,000 gallons a day was erected on the bank of the Nile. The water was pumped to two high level reservoirs on a hill overlooking the base and distributed therefrom to camp and loco filling points.

6. *Qena Accostage*

The object of the Safaga project was, it will be remembered, the construction of a port to replace Suez in case it was put out of action by enemy bombing. If this did not happen, the expenditure on the project would be wasted.

There was, however, a further use to which Safaga could be put. A proportion of the stores for the Middle East base in Egypt was landed at Port Sudan and carried to Cairo by rail and river. The stores were taken north from Wadi Halfa in Nile barges. Qena is about midway between Wadi Halfa and Cairo, so that, if the stores could be put on board at Qena instead of at Wadi Halfa, the Nile barges, which were the bottleneck in this line of communication, would be able to achieve a double turn round in the time of a single one. If the stores formerly brought from Port Sudan, could be landed instead at Safaga and carried down the Nile from Qena, the barges could do double duty.

It would be necessary to construct on the bank of the Nile at Qena some sort of quay at which the barges could be loaded. Flood level on the river is at least twenty feet above low water level. The construction of a quay with a vertical face far enough out into the river to enable barges to be loaded during low water would obviously have been a major operation. If, however, the transference of goods from shore to barge were to be limited to such as could be carried by hand, the problem would be much simplified and what is known as an accostage would suffice.

It was therefore decided to work out a scheme whereby the edge of the Nile bank could be shaved off so as to give an even slope of about one in three from the water's edge to ground level on top of the bank. The area on the bank adjoining this slope was to be levelled and surfaced and paths were to be cut down the slope to the water's edge, diagonally so as to reduce their gradient. Barges could then be moored alongside the slope, whatever the level of the river, and planks placed from them to the paths where they entered the water. So natives could carry the stores down the sloping paths and along the planks to deposit them in the barges. Such was the design of the accostage. It remained only to provide for rail and road communication with the surfaced area on the top of the bank.

All these operations were put in hand, provision being made for the loading of about 2000 tons a day. They involved the extension of the metre gauge railway from the transfer sidings at Qena across the main line, which continued up the Nile from Qena to Aswan, to the river bank. The existing dirt road from Qena along the Nile bank had also to be improved in direction, widened and surfaced so as to connect up with the metalled area at the accostage. An existing bridge over a canal had to be widened to take railway and road and an additional bridge for the railway had to be constructed.

Progress of the Work

In July, 1941, a Garrison Engineer was installed at Safaga to make a survey for the *south lighter wharf* and a boring section followed to drive test piles for the *deep water quay*. Soundings were commenced for the latter and a final plan prepared in January, 1942. The letting of a contract to Messrs. Fils Barthe de Jean for driving the reinforced concrete piles followed soon afterwards, but it was not until April, 1942, that a 70 ft. pile driver could be made available. In the meantime some piles had been cast by the 19 New Zealand Army Troops Coy. and a start made by them in the construction of the caissons for the anchor wall. A total of 424 R.C., piles had to be driven in two rows to form the trestle bents to carry the crane rails. At the rate of eight piles a day with the three pile drivers which were available, they should have been completed by the end of June. Various delays, however, due to breakdowns of pile drivers, which were all old and unreliable, and to other causes, prevented completion till towards the end of July. By this time half the beams forming the tops of the trestle bents had been cast.

The 60 ft. steel sheet piles were to be driven from the crane beams on top of the bents and were started in July. The construction of the anchor wall proceeded with the driving of the piles, and about one third of each of the two sections, consisting of caissons and sheet pilings, was completed by mid July. Tie rods, which were to be $\frac{5}{8}$ in. and $\frac{3}{4}$ in. in diameter, were not forthcoming and work was henceforth continually held up on this account.

Difficulty was experienced in driving the sheet piles for the last quarter of their length and jetting was used successfully despite the danger of unsettling the feet of the R.C. piles which were only a foot or two away.

On completion of the sheet piling it would be necessary to dredge to obtain a depth of 30 ft. of water. No dredger suitable for the purpose was available in Egypt and one had to be brought from India. It arrived in October, 1942. The crew consisted of nearly 200 Indians with white officers. The dredger came without a charter and the master was unable to pay his men. Arrangements had to be made for this to be done with W.D. funds and for the crew to be rationed.

The conditions on board were very bad, the men being crowded together and the ship filthy. The local medical officer condemned the ship as being an unfit place for the crew to live and accommodation was arranged for the majority of them ashore. However, there was only one cook, who could not serve those ashore as well as those aboard. While the question of the transfer of the crew ashore was being argued, one night a German bomber came over. There was no A.A. protection whatever, presumably because the likelihood of bombing was considered to be remote and all available A.A. guns were needed more urgently elsewhere. Be that as it may, the bomber, being quite unmolested, got a direct hit in the middle of the dredger and sent it to the bottom with many casualties, about eighty of the crew being killed.

By December, 1942, the majority of the sheet piles were driven but all the anchor rods were not yet available for the first half of the length of the quay. By this time Rommel's army had been pushed back to Aghelia and there was now little chance of any serious blitz on Suez. It was decided, therefore, to finish only two out of the four berths in the 2,000 ft. of quay. Finally, in January, 1943, only one berth was completed, and Safaga was put into care and maintenance soon after, the deep water quay never having berthed a single ship. This was disappointing but there was consolation in the knowledge that it was an insurance which might have proved to be invaluable.

The *south lighter wharf*, including the filling of the considerable area behind its face, the construction of the causeway and bridge for rail access from the south and the laying of the railway, was completed in March, 1942, except for part of the surfacing.

During the construction of lighter wharves in the Middle East in wartime it was found that no sooner was the filling completed for such a wharf than Q (Mov.) asked if they could use it. This request was difficult to resist and the wharf soon became littered with goods. Henceforth the work of finishing off the surface became more and more difficult. Such was the case at Safaga and it was another six months before the tarmac was finally completed.

The *north lighter wharf* was not started until January, 1942. The sheet piling was driven by Messrs. Fils Barthe de Jean and the work finally completed in August, having also been delayed by the late arrival of anchor rods.

The *loco pier* was first decided upon in December, 1941. It was completed and six thirty-five ton locos were successfully unloaded in April, 1942, without settlement. Later the bridge from it to the shore was strengthened to take ninety ton locos.

The *petrol jetty* and *storage tanks* were first under consideration in January, 1942. The jetty was ready to take one ship by the end of the year but it was not finally completed until early in 1943. In the meantime the rising main from jetty to tanks and the pipe line from tanks to tin filling plant and lorry filling point were ready for use.

Accommodation generally was built by directly employed labour and pioneers under the supervision of the R.E. Works Services Organization and was completed by the end of 1942, the hospital, which was started in January, being in operation by the middle of October, though the work was held up for some time by lack of electrical stores. The various installations such as the *vehicle assembly unit*, the *petrol supply point*, the *petrol dump* and the *supply and ordnance depots* were finished about the same time.

Shortage of transport continually held up the work and at one time in the summer of 1942, it was practically at a stand-still from this cause. All transport available in the country was urgently needed in the Western Desert, where units were always below establishment in this respect.

Improvements to the existing *landing ground* were carried out early in 1942, and by the end of that year two landing strips for the new ground, 1,000 yds. and 1,700 yds. long and each 100 yds. wide, were completed.

Houses for the two *distillation plants* were built and the machinery erected by the 19 New Zealand Army Troops Company, the first by April and the second by June, 1942. It was found that one cwt. of coal was needed to produce a ton of water, each plant distilling 150 tons of water in a week. Later they were both converted to oil firing owing to the greater ease of obtaining oil than coal.

The *slaughter house, cold store, tin making factory* and *tin filling plant* were built by contract and after considerable delays due to difficulties in getting labour, they were finished early in 1943. By that time also the *power station* was running satisfactorily.

For the *Qena accostage* the original reconnaissance was made by Tn. in February, 1942, and the work was completed by the end of the year, including earthwork, railway, road and quay surfacing.

Development of Water Supply

It was estimated that 150 tons of water a day could be obtained from the existing wells at Mons Claudianus and it was thought that further prospecting in the neighbourhood might have useful results.

A South African Geophysical Section accordingly made a thorough examination of the area and advised where water was likely to be found. Two boreholes were sunk near the Roman tower well, but they only produced about fifty tons a day between them. The total yield of 200 tons, was, however, well worth piping to Safaga, whose needs, apart from those of the railway, amounted to about 300 tons a day.

In view of the large quantity of pipe that would be required, consideration was given to the possibility of constructing an aqueduct down the valley of the Wadi Um Tagher. Sufficient pipe could, however, be made available, so that this somewhat antiquated method was not adopted.

There were two possible routes :—

1. By the Wadi Um Tagher.
2. By the Wadi el Bula to the railway and thence along the track in the Wadi Safaga.

If the latter route were chosen it would be possible for an additional supply of water to be emptied into the pipe from railway tank wagons at the confluence of the Wadis el Bula and Safaga. As this would save railway carriage from this point to Safaga and back, and as the 6 in. pipe, which was available, would carry a considerably greater quantity of water than the 200 tons available at Mons Claudianus, this route was chosen. A 6 in. pipe was accordingly laid from Mons Claudianus to a point about half way down the Wadi el Bula, where two reservoirs were erected. Thence the pipeline was extended to the junction of that wadi with the Wadi Safaga, where another reservoir was constructed, with a railway spillway leading into it. From this reservoir a 6 in. pipe was laid to Safaga along the railway.

Pumping stations were necessary at the wells to raise the water to the source of the Wadi el Bula, whence it fell by gravity all the way to Safaga.

The project was put in hand in the summer of 1942. In mid October a storm of unusual intensity broke over the watershed between Mons Claudianus and Summit Station (see Plate I). In a very short time a torrent six feet deep was surging down the Wadis el Bula and Safaga. The pipe was picked up and thrown about the wadi bed by the force of the water and about twenty kilometers of railway were destroyed. Rails bent double were carried hundreds of yards down the wadi.

A camp belonging to the pipe line construction party was pitched in the Wadi el Bula. It was completely demolished, a 40 ft. length of 6 in. pipe being hurled straight through one of the tents, which had luckily been vacated a few moments before by its occupants, who had taken refuge on the steep side of the Wadi above water level.

When the flood had subsided the pipe had to be found, dug up, straightened and relaid. The whole job was completed by January 1943.

A South African Railway Company repaired the railway in a remarkably short time. It was only three weeks before it was running again.

Conclusion

A considerable sum of money and a large number of man-hours were expended upon this project with no apparent help to the war effort. Though disappointing to those engaged upon the work, this sort of thing is not unusual in wartime. What was, however, more exasperating was to have the work held up continually for lack of labour, transport and materials, with the additional annoyance that much of the only plant available was so old as to require constant patching and repair, thereby enforcing idleness upon the operators and delaying completion of the work.

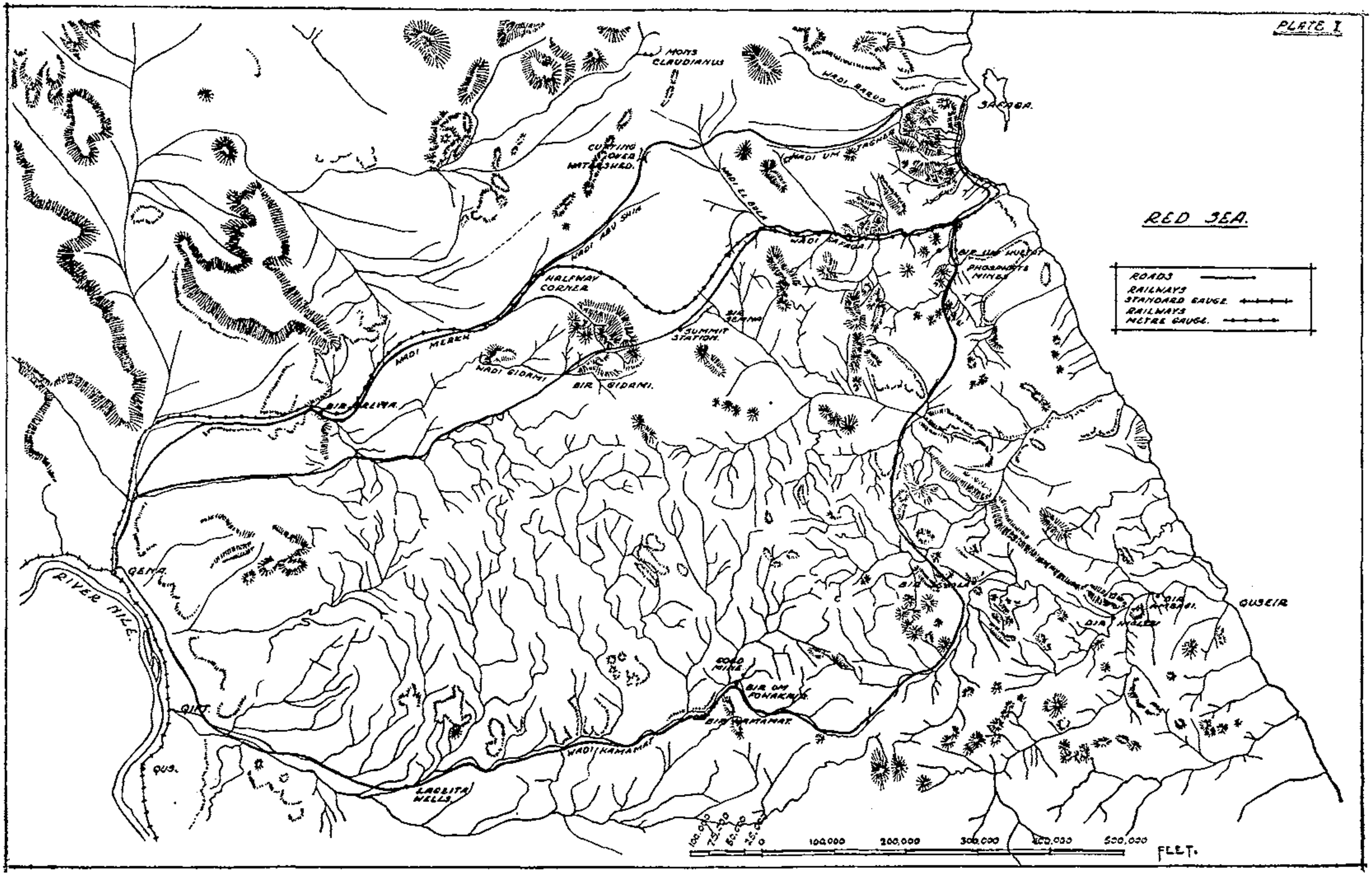
The following conclusions may be drawn.

First of all, the desirability of thorough preparation, in the assembly of labour and materials and in the provision of a sure line of communications before the work begins, was strongly emphasized. This was not practicable in this case, as the project was merely a sideline, being secondary to the fighting in the Western Desert, which took precedence in every way, particularly with regard to shipping, transport and the provision of stores.

Further, the need to do everything possible to keep the labour force contented became apparent, as also did the grave objections to opening a part of the work for use before it has been properly finished off.

On the technical side, local conditions must be studied carefully before such a scheme is worked out. The necessity for continual dredging was realized from the start and provision of a dredger made, though the neglect to provide adequate protection from the air, or at least a second dredger in the first instance, would have made it necessary, had the port been actually operated, to waste considerable time while a replacement was obtained. The fact that certain risks must be taken in wartime was thus exemplified. Another technical point that became apparent was the need for accurate soundings before the plans were made,

In addition to its value as an insurance, the work at Safaga gave good training for the R.E. Works Services Organization, the Army Troops Company and the staff and other troops engaged upon it in an operation not often met with in wartime.



MONS CLAUDIANUS
SAFAGA.
CUTTING OVER WATERSHED.
RED SEA.
PHOSPHATE MINES
ROADS
RAILWAYS STANDARD GAUGE.
RAILWAYS METRE GAUGE.
HALFWAY CORNER
SUMMIT STATION.
WADI GIDAMI
BIR GIDAMI.
QENA.
RIVER NILE.
QIFT.
QUS.
WADI HAMAMAT
GOLD MINE.
QUSEIR
100,000
200,000
300,000
500,000
FEET.

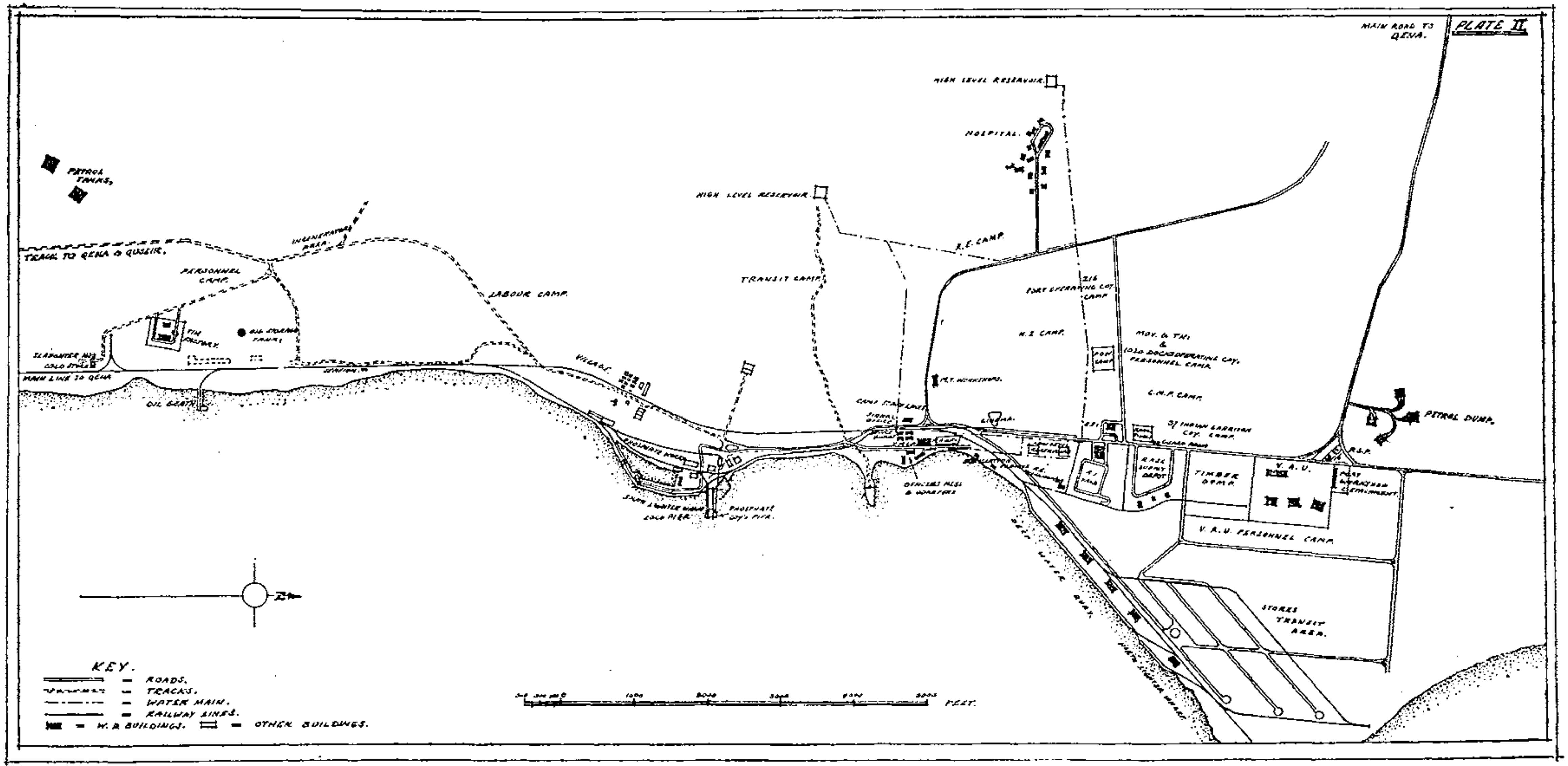


PLATE II
MAIN ROAD TO QENA.
HIGH LEVEL RESERVOIR
HOSPITAL.
HIGH LEVEL RESERVOIR
PETROL TANKS.
TRACK TO QENA & QUSEIR.
PERSONNEL CAMP.
LABOUR CAMP.
TRANSIT CAMP.
R.E. CAMP.
216 PORT OPERATING COY. CAMP
N.Z. CAMP.
MOV. & TN. & 1020 DOCK OPERATING COY. PERSONNEL CAMP.
M.T. WORKSHOPS.
C.M.P. CAMP.
PETROL DUMP.
OIL BERTH
MAIN LINE TO QENA
VILLAGE
PHOSPHATE COY'S PIER.
OFFICERS MESS & QUARTERS
R.A.S.C. SUPPLY DEPOT
TIMBER DUMP.
V. A. U.
V. A. U. PERSONNEL CAMP.
R.S.P.
STORES TRANSIT AREA.
DEEP WATER QUAY.
FEET.
KEY.
— ROADS.
— TRACKS.
— WATER MAIN.
— RAILWAY LINES.
— W. D. BUILDINGS.
— OTHER BUILDINGS.

ROAD REPAIR AND SURFACING

ANONYMOUS

INTRODUCTION

DURING the past war roadwork absorbed an undue proportion of manpower. It was mostly very uninteresting. The plant available was largely antiquated and unsuited to service conditions, or else it was of foreign manufacture.

In the post-war army the replacement of obsolete plant cannot be tackled piecemeal and produce a satisfactory result. The following paper was written to try and determine the best lines for future development as a comprehensive whole.

All methods discussed presuppose a properly compacted subgrade. In practise this is not always a fact. Roads have failed for this reason, as use by heavy military traffic was not considered when they were made. In new construction, soil compaction is an all important preliminary. This supposition is necessary to keep the length of the paper within reasonable limits, but in passing, it cannot be over-emphasized how important is the study of this subject.

Two of the processes mentioned need some explanation. They have been developed during the war years and will not be known to the majority of serving officers.

The more important of these was a discovery in the U.K. of the value of lime in bituminous road and airfield construction for work in wet conditions. A paper on this was submitted to the Institution of Civil Engineers by Dr. A. R. Lee, A.R.C.S., Ph.D. and H. J. E. Carter in November, 1943. A copy of this paper, and the subsequent discussion at the Institution is printed in pamphlet form and available from the Road Research Laboratory, Harmondsworth, Middlesex.

In this process one to two per cent of hydrated lime or cement is mixed with the aggregate before the addition of the binder. The aggregate may be wet and cold ; wet seashore sand can be used. The binder is usually heated, though trials with a cold application cutback are being considered. A cold emulsion has been used with success in very wet conditions in the U.S.A. The main criterion for the binder is that it should be the right viscosity. But any tar or bitumen can be used if it is cut back to this viscosity with creosote oil.

What exactly happens is obscure except that it is a form of emulsification with any water present in the aggregate. This emulsification assists the oily binder to flow over and thoroughly coat the surface of the individual particles. Normally any moisture present resists such an action, which has led to the road engineer being a fair weather worker or having to heat his aggregate. Experience in airfield construction is that it is simple to work and field control can be left under the charge of a reasonably competent N.C.O.

The Flux Oil and powdered bitumen process has been used in South America for mix-in-place roads in a dry climate. It is an attempt at obtaining the benefits of a viscous binder while avoiding the difficulties that the use of such a binder causes. Though full details of the process are still to be obtained, it can be described as analagous to concrete mixing. The powdered bitumen is in place of the cement and the flux oil in place of water. The use of the bitumen in solid powder form as a stiffener to a fluid binder is interesting, especially for those that have to pave roads in winter and yet produce a result that will last over a hot summer.

Powdered bitumen (which contains unbitumenous filler) is not yet in ready supply in all parts of the world.

Object

1. To determine the best process for Army use for road repair and for surfacing of new construction.

Considerations

2. *Army Requirements*

The ideal process should have the following characteristics. It should:

(*a*) Effect the greatest economy in use of transport, machinery and man-power.

(*b*) Permit the use of the greatest variety of aggregates.

(*c*) Permit the use of the greatest variety of bitumens and tars as a base for the binder.
The binder should also be useable for surface spraying.

(*d*) Permit surface laying or relaying with minimum dislocation to traffic. Remembering too that operational requirements may interrupt the process at any moment.

(*e*) Be adaptable to road repair or new construction in as variable conditions of soil and climate as possible.

(*f*) Permit laying at a pace that can compete with the speed of movement of present day warfare.

(*g*) Produce a result that gives service under heavy pneumatic traffic for a year, and lasts well under tracked traffic.

(*h*) Use the least complex machinery, and NOT call for highly trained technicians.

3. *Methods available using tars and bitumens*

(*a*) Mix-in-place methods, including wet sand mixes and methods of soil stabilization.

(*b*) Grouting (or penetration) methods.

(*c*) Plant mix methods.

(*i*) With heated aggregates and binders.

(*ii*) With heated binders and cold or wet aggregates.

(*iii*) With emulsions and cold or wet aggregates.

(*iv*) With cold application cut backs and cold aggregates.

(*d*) Prefabricated Bituminous Surfacing (P.B.S.).

4. *Mix-in-place Methods*

(*a*) *General.*—These methods have the advantage of speed and organization, in that by the utilization of special plant, train processes can be used.

(*b*) *Flux oil and powdered bitumen.*—This method is used for earth and low cost roads ; not suitable for all types of roads. It can be used with a greater variety of aggregate than any other method. With the additional use of lime it can be used with wet-aggregate. It has been used in America with success. Not much is known about it in this country, and powdered bitumen is not at present a commodity of general supply here.

It's main disadvantages are that it sets almost immediately after mixing ; and that it entails the carriage of two and sometimes three ingredients in the field. It is also believed that powdered bitumen may be liable to agglomerate when in storage.

(*c*) *Wet sand mixes.*—Cut back bitumen and lime. Has been used extensively for airfield construction where there has been a plentiful local supply of sand.

(*d*) *Soil stabilization methods.*—There are various successful processes other than mechanical stabilization by grading, in which different ingredients are mixed with the soil to produce stabilization. These ingredients include cement, oil, bitumen, emulsion, various patent products, and combination of two or more of these. One process using cement and emulsion claims a resulting flexible carpet of high tensile strength where the proportion of clay in the soil is high (up to thirty per cent).

5. *Grouting* (*or Penetration*) *Method.*—This method avoids heating the aggregate if the weather is dry, and avoids also the use of a mixer. But work is limited to warm dry weather, and the aggregate in operational conditions is limited to something that is mechanically strong before the binder is added, and does not contain too great a proportion of fines. It is a good process for warm, dry climates where there is plenty of stone, and labour, and machinery is lacking. It very often has to be used as a supplement to plant-mix-methods due to shortage of plant.

6. *Plant-Mix-Methods*

(*a*) With heated aggregates and binders. This method is only suitable with the large scale use of machinery. It has the further disadvantage that only dry clean aggregates can be used. Materials made by this process can be stored in stock-piles for periods up to three months and can then be transported and laid where required.

This method is suitable for static conditions, and where one central plant can supply a large mileage of road. It is usually not suited to mobile warfare or new construction in an undeveloped country.

(*b*) With heated binders and cold or wet aggregates. This method is known as the lime process, as, to make the mix possible, one to two per cent of hydrated lime or cement is added to the aggregate. It entails less machinery than method 6 (*a*) and still produces a result that can either be laid at once or stock piled for a week to a fortnight. It also permits the use of a great variety of aggregates from stone to sand, and even a small percentage of clay. For proper working the binder must be cut back to a certain viscosity, and in the case of bitumens, a wetting agent added. This can, however, be done before the binder is supplied in the field. Hydrated lime or cement can very often be found in a theatre of operations. But even if this is no tpossible, the quantity that would have to be imported is only about one-third the weight of water imported in emulsion. Even this one-third comparison is unfair to the lime process, as in wet conditions lime should be used with emulsions.

(*c*) With emulsions and cold or wet aggregates. These have the advantage of cold application, and the fact that use in damp conditions is possible without the addition of lime. It has also been shown in America that with the addition of one to two per cent lime, use is possible in very wet conditions.

Disadvantages are :

In cold weather emulsions freeze ; though on the other hand there is no definite evidence of any satisfactory method of road-making using general purpose binders, at temperatures in the neighbourhood of freezing point. They are awkward to handle in bulk owing to a liability to break when pumped. This disadvantage causes complications when designing an emulsion sprayer. Aggregates that absorb water cause the emulsion to break before coating has taken place. Only certain bitumens are suitable for emulsification ; and no really successful tar emulsion has been produced. Forty-five per cent of an emulsion is water, for which containers and carriage over long distances have to be provided. After mixing with an aggregate, the result has to be left to cure. This time lag depends on the atmosphere's ability to absorb moisture and is normally longer than with a cutback in temperate climates. If used as a spray the above mentioned time lag is equally a disadvantage, as until there is a bonding with the grit dressing, traffic cannot be put onto the sprayed surface, and too, there is the risk of heavy rain washing the emulsion away.

(*d*) With cold application cutbacks and cold aggregates.—To date no technique has been developed using a cold application cutback with wet aggregates.

However, there does not appear to be any insuperable obstacle to this, possibly using lime.

Accepting this as a possibility, cutbacks have the same advantages as emulsions without the following disadvantages.

They are not liable to break, so handling in bulk is simplified. Wasteful carriage into a theatre is less than half than is the case with emulsions.

Time lag for curing is generally rather less than with an emulsion. This time lag can be reduced by heating the binder. There is no risk of freezing. But as is the case with emulsions, with some types of aggregates there is difficulty in obtaining a satisfactory coating owing to the volatile oils being absorbed.

7. *P.B.S.*—The advantages are :

(*a*) An immense saving in labour, plant and haulage for new construction.

(*b*) It can be used for the repair of very worn macadam roads. This permits the restitution of a riding surface by soil from the roadside. This is a method that can only be chosen after consideration of the merits of a particular case.

The disadvantages are :

(*a*) In present stage of development roads are not produced that are suitable for tracked traffic.

(*b*) It is not suitable for use in waterlogged ground, or ground liable to inundation.

(*c*) It depends on ability to compact the earth surface over which the P.B.S. is laid.

(*d*) It cannot be laid mechanically on roads that are not straight or are set on too steep a gradient.

(*e*) If used, the demand is for large quantities, and availability is dependant on having production organized. There is at present no large scale demand for civil use, though it is hoped this may develop.

Courses Open

8. There are four alternatives, that is apart from mix-in-place methods, which have their special application :

(*a*) Develop the flux oil and powdered bitumen process so that :

(*i*) The provision of the two ingredients in the field is as convenient as possible, and

(*ii*) It is possible to control the period after mixing that the asphalt remains workable, and so adapt it as a plant-mix-method.

(*b*) Develop a mobile emulsification plant so that the process can be carried out as far forward in the field as possible.

(*c*) Develop the lime process in conjunction with tar and bitumen cut-backs :

(*i*) To increase to the maximum the range of materials that can be used as aggregates.

(*ii*) To make the provision of the hot binder to the man on the work as simple and reliable as possible.

(*iii*) To produce a binder that can be mixed cold without necessitating curing before laying, but still permitting stock piling, if required, for up to a week.

(*d*) Develop P.B.S. for all-purpose road use.

9. *Development of flux oil and powdered bitumen method.*—To date so little is known of this process in this country that it is NOT considered sound for the Army to depend on its development for finding the answer to all road making problems. It is a process for consideration and obtaining all possible information with a view to long term development.

10. *Emulsions.*—The machinery for emulsification in the field is NOT complex, however, control of the process is. Obtaining the right grades of bitumen, selecting and providing suitable agents, ensuring that they arrive at the emulsification plant in the field, these together with the chemical tests that must be carried out at the plant to determine the correct treatment, are all leading to a complexity that cannot be accepted.

It is improbable that an emulsion produced in this way will remain stable for longer than forty-eight hours. If it is only going to last that time it will have to be carried by tanker ; it is uneconomic to put it in barrels. Such an arrangement would have no advantage over supplying a heated binder in an insulated tank.

In northern latitudes, and in winter in temperate latitudes, the use of emulsion is not normally possible. Provision will have to be made for supplying a hot binder. This, for large scale roadwork will entail duplication of machinery.

In general, apart from the fact that they are good in damp climates, they are hardly to be commended for further experiment.

11. *Lime Process.*—This process would seem to be the best for immediate development, being the most adaptable and flexible. Satisfactory results in aerodrome construction are known to have been obtained using a wide variety of aggregates. It is not, however, expected that the qualities specified in 8 (*c*) will be obtained in a single binder, or that a heated binder can be ruled out for all classes of work.

12. *P.B.S.*—To date development for road use has largely been limited to India and the Far East. In N.W. Europe it was little used owing to the large proportion of tracked traffic, and the fact that there was no great demand for new construction, as against repair and improvement of existing roads.

It is essentially a method for use in areas poorly served by existing roads, and for such use its further development is essential.

Its use for repair work needs examination, though it seems doubtful at present that it will be suitable for general adoption, other methods seeming more flexible.

Conclusions

13. From the above notes it follows that work and experiment should be carried out as follows :

(*a*) Carry out no further work in developing machinery for manufacture and handling of emulsions, unless there is complete failure in developing a cold application cutback that is as useable as an emulsion.

(*b*) Obtain further information on the flux oil process for long term experiment.

(*c*) Carry out further tests with the lime process as suggested in paragraph 8 (*c*).

(*d*) Develop the machinery required for rapid large scale road repair and construction with the lime process.

(*e*) Develop P.B.S.

- (*i*) To cheapen and simplify manufacture.
- (*ii*) To overcome as far as possible the disadvantages stated in paragraph 7.
- (*iii*) For use for repair and widening of existing roads.

(*f*) In conjunction with the development of P.B.S. to develop earth compaction machinery and methods to the greatest possible degree of efficiency.

(*g*) Develop suitable British made plant for an adaptable mix-in-place method.

TOO MUCH WATER

BY " SENTRY ".

All your better deeds
Shall be in water writ.

John Fletcher.

A WELL-KNOWN man, who was incidentally a successful author, once stated that the evolution of a plot was a matter of the utmost simplicity. His method was to pick on three or four strikingly dissimilar events or sets of conditions. He then carefully devised a chain of circumstances which would convincingly bind together his irreconcilables. His literary fabric was then turned inside out, and presented to the public in about three hundred pages. Another twenty pages sufficed to give it a bit of a dusting, and to reverse it. He claimed that the public were overwhelmed at the astuteness of the author, and that even the critics wrote, " Wah ! Wah ! He is indeed a clever fellow."

George, a junior Sapper Officer, was struck with this system, and decided it was an easy way to fame in the school of ingenious fiction. In practice, matters were not found to be so easy, but real life has in the meantime provided some illustrations of unlikely combinations of unusual circumstances.

To illustrate the preceding paragraph, here are three facts. An officer discovers an entirely new, and highly effective pick-me-up ; the Shyok Dam bursts ; an eminent Nawab is disclosed in an immense cooking-pot. It will be shown that these three events took place during the course of a single minor adventure, and were bound together by the inexorable logic that pervades the universe.

It may be news to some that the Shyok Dam was a rickety edifice of mud and ice, with a good many million tons of water balanced behind it, some 12,000 ft. above sea level. For some years this dam bided its time, and then, when all the five rivers of the Punjab were already distributing alligators among unwilling villages, it gave a gurgling chuckle, and collapsed. This little joke resulted in more than a mere trickle of superfluous water reaching the Indus ; so much so, that quite a large number of telegrams were immediately exchanged.

One of these originated in a long and narrow District, bounded on one side by the Indus, and on the other by the combined efforts of two or three of the other members of the Big Five. The District Commissioner stated he was still afloat, but only just, and would some one please do something about this extra consignment, which he could well do without. This telegram undoubtedly reached the Punjab Secretariat in Simla, and its contents were tactfully disclosed to the Governor, one evening after dinner. What the Governor did is not precisely known, but the following telephone conversation was reconstructed by George, a fellow subaltern, Jonah, and Dog David, during their subsequent rush across India, while waiting three or four hours at a big railway station.

GOVERNOR OF THE PUNJAB: Hullo. Hullo. Get me the Viceroy.

VOICE: You can't have the Viceroy.

G.P.: Of course I can. Why not?

VOICE: Its never been done before.

G.P.: Shut up!

VOICE: WHAT! Who are you anyway?

G.P.: I was only trying to stop the dog scratching. I'm the Governor of the Punjab.

VOICE: I beg Your Excellency's pardon; please hold on. (Pause). Hullo.

G.P.: That you Bimbo?

VOICE: It isn't Bimbo, Your Excellency. His Excellency the Viceroy is just coming.

VICEROY: Hullo, Masher. Its Bimbo here. You'll have to speak up. The dog's making such a din.

G.P.: Yes I know; its that Mitha Pani Wallah. Look here, I'm losing one of my districts. D'you mind?

V.: Yes, of course I do. There would be an awful row in the Assembly, and there might even be a question in the House. Good gracious! The dog's just jumped out of the window and bitten a Fakir.

G.P.: So's mine. It must be the same dog. Well, you've got to stop all this water then; its yours, and I don't want it.

V.: What water?

G.P.: The Shyok Dam; belongs to your foreign and political people. Kashmir, you know.

V.: Oh! Is that all; a water supply matter. Send for the Sappers.

At about the time this conversation may have been going on, George and Jonah and a few others were conducting an interesting experiment, and one which today would be rather tantalizing. Outside the mess on a concrete paved arena, there stood a table fan. George was throwing eggs into the fan from different angles, and Jonah with a piece of chalk was carefully marking out the pattern made by the splash. It was hot and exhausting work calling for much refreshment, but at last final drinks were demanded. The Khitmagar was then told to sluice down the concrete. At the moment he did so, he gave a loud cry, and passed out. It emerged that some electricity had broken loose, and attacked the poor man's bare feet. Luckily he revived quite soon.

The result of all this was that George was still feeling a little dull at 3 a.m. when he was roused to find the stately and spectacled figure of the Adjutant at his bedside.

"Your Company has got to start for Bhoozaffanagar at 9 a.m."

"Go away, Bill. You ought to be in bed."

"Come along. Its a do."

"Where is the gory place?"

"Don't be silly. You know its only thirty miles away."

"Steady. Thats Pore not Nagar isn't it?"

"Yes. But it's probably somewhere nearby. It's something to do with a flood they're expecting."

"Look here, Bill. I don't trust this Nagar business. Do go and find out, and if its a long way off, set me up with a couple of thousand chips; and I must have a bloke to go with me; let me take Jonah."

"All right, if its all that way, my little pet. We're looking after the regatta side of the equipment for you. Nine a.m. at the station. Get cracking."

George got out of bed, and felt his head to see what had happened to it.

He was not medicine-minded, but it was clearly a moment for medicine. He remembered someone had left a bottle of tonic pills in his room. He went to the cupboard, extracted a couple of brown pills, swallowed them, and looked at the bottle. It was marked "Pinklefoot's best fine grain developer."

He quickly mixed a very strong and large doze of salt and water, swallowed it, and hoped that he had deferred death at the expense of a horrid upheaval. After five minutes nothing had happened, and he was feeling better. He took another pint of salt and water for luck, and very soon felt in the pink of condition. He had just sent for his various minions, when Jonah walked in.

"Bill told me to tell you I'm coming somewhere with you, as its a long way away."

"Jonah, you're looking awful. Have a couple of these with a pint or two of salt water. They're grand."

This was too much for Jonah, and when he came back George continued. "It's probably the best thing to have happened. There's nothing fine about you, and what you needed was a coarse-grained developer."

For a few moments it looked as if there was going to be a fight. Luckily for George, there were heavy steps on the veranda, and a stately Sikh Subedar came in, followed by an athletic looking British Serjeant Major. As they fell in, and saluted, Dog David came on the air from under the bed with some ferocious growling.

George's toilet had by now reached the puttee and hosetop stage, so he felt ready to give off some orders; he was almost immediately interrupted by the reappearance of the Adjutant, with some announcements.

(*a*) Bhoozaffanagar was well beyond Multan.

(*b*) The Viceroy himself had fixed up the train, which was to run at super-mail timings, and should get the party through in thirty hours, thus beating the Shyok dam, travelling via the Indus, by a few hours. He hoped the train would win, as once you get there, you should never get out, and he'd never see you again, thank goodness.

(*c*) Under the circumstances, he was only too glad to let Jonah go too, and much against his better judgement here were two thousand chips.

(*d*) The regatta outfit was all fixed up, complete with loading arrangements, and he, Bill, was off to bed.

The inter-war Sapper and Miner Coys. were only rivalled in efficiency by the best types of Indian Bearers. Even so, George was surprised to find that by 5 a.m. he had decentralized and inspected everything, and could afford about two hours sleep under a fan. At nine o'clock, he was gazing in all directions for the train. At 3 p.m. he was still so employed, when the station-master came up with a telegram which stated that there had been a delay, and the train might be two or three hours late in arriving. George promptly sent a wire to the agent, or managing director, of the line to tell him the Viceroy was getting a bit impatient, and sure enough, five minutes later the train came in.

The circumstances of the trip made it possible that the train might develop from being a mere conveyance into becoming a home. Little could be done about overall accommodation for the troops, but George was determined to have good overheads, such as hospital and office. For these and for officers' accommodation he would rely on a really good first and second class coach. What arrived was an interesting relic of the India of the mid-Victorian era. This gave rise to the only point of interest in the trip across India; in these days it might be called the Battle of the Bogies. Apparently the authorities had ruled that this particular coach should not have bogies, or possibly bogeys; the result was that the better classes of rolling stock were debarred. George is never happier than when attacking a brick wall, and in this case he felt he could use the Viceroy and the Governor of the Punjab, instead of his usual instrument. The outcome was a series of offensive wires, operating on a crescendo basis, as station succeeded station. Needless to say, a superlatively suitable coach materialized, and in due course the train steamed into what would probably soon be the last solid bit of India in those parts. The heat-stricken remnants of the Garrison Commander of Multan were on the platform, together with a huge stock of rations. The farewells were cordial, and within a short time the train passed over a lengthy bridge spanning a vast and sinister tract of fast flowing water. The journey to Bhoozaffanagar took twenty-six hours, against the estimated thirty, and the Deputy Commissioner with his Chief of Police were waiting on the platform. They were the only Europeans in this district.

"Glad you've come. You are coming straight on with me in your coach. Leave your Second-in-Command here with the troops; the Police will look after everything. We've just got time to see the district from the railway; I'll show you where I think you had better go to start with. Later we shall probably be cut off from each other, so I am going to tell you all I can, as you may have to do some of my sort of work. The Indus is only just beginning to rise at Attock, so we have at least thirty hours here yet before things even start."

By the time they got back, George had the whole picture. The railway ran right up the district, north and south, with the Indus parallel, some dozen miles to the west. The railway was on an embankment; when the Indus flooded, it would break its banks, and nothing could save the country west of the railway from inundation. The embankment itself would probably be breached near Bhoozaffanagar town, and away to the south. George would with luck be able to run his train backwards and forwards over sixty to eighty miles of line; the main emergency would be to the west of the railway, but the floods would extend through culverts to the east. It was agreed that it would be wrong to block culverts, although there would be local pressure to do so. Apart from ferrying folk in to the railway, evacuation problems would arise. The D.C. would open a refugee camp, but it would be for George to get refugees down to the Bhoozaffanagar railhead, including any ferrying necessary over gaps. He should also encourage people to clear out to the north, if possible.

The local administration would try to function, but Tehsildars concerned were being told to take their line from George. The D.C. was obviously paving the way for George to take over rather more than seemed necessary for the Shyok emergency, and he asked why. The D.C. said that in any case the district was so big that he felt inclined to put as much on George as he could, but he was also concerned with the possible results of the Indus flood coinciding with further floods to the east. In that case, the worst emergency would be around Bhoozaffanagar town, right at the south, near the confluence. He would then be fully engaged on problems which he could not at the moment foresee, but which would be extremely difficult. A real emergency would arise, and it would be for George, in his part of the district, to take complete control, as there would be no one to help him.

"I was glad to see you had brought a few rifles. You never know with these people; there are some real blackguards about; but I hope you won't have to go that far. The Government have given you and me 'clear the line' telegraphic rights, and for the present you will send daily 'clear the line' progress reports to me and to the Punjab Government. You must use your discretion about using it for demands and so on. I will do all I can for you."

George was very impressed with all this. He had often heard about the work of district officers of the I.C.S. He had arrived on the eve of what was certain to develop into a fairly grave emergency, and of what might even become a catastrophe. He found the D.C. with all his facts absolutely clear, complete with deductions based on the most minute knowledge of his district. The man was obviously a first-class executive himself, yet here he was apparently willing to hand over without any restrictions very considerable responsibilities and powers to a subaltern he had never met or heard of before. The immense advantages of working on these lines were immediately borne in on George. He grinned and replied.

"What happens if I send clear the line messages to the Commander-in-Chief?"

"Its up to you to try it on. If you do, send a repeat to the Secretariat. Personally, I think you'd probably get what you asked for, and you can take that as you like."

The D.C. also grinned.

The little Special Train steamed into Bhoozaffanagar late at night. Reports indicated a big rise in the Indus at Attock, with hourly increases.

"Come and have some food now. You'll have time to think things over for a few minutes. Let me know when you'll be off."

George contented himself with an order "No move before 6 a.m." and towards the end of dinner the D.C. asked, "What about it?"

"We'll push off at 7 a.m. and drop off overheads at Azad. That'll give time to get the lads up to the north by about 2 p.m. We'll hang on there till dusk; it's no earthly good trying to do anything at night, so we'll go into residence permanently at Azad. It's about midway, and shouldn't get swamped."

"Just what I expected. Don't bank too much on the water coming in first from the north. It all depends where the Indus bund goes first. I doubt if you'll have any fun till the day after tomorrow."

"Yes, sir. That's as I saw it."

The train pulled out exactly on time, and reached Azad a couple of hours later. The Company had been given a school on the outskirts of the small town. George ordered a parade on the station in two hours time, and left the soldiers to settle in.

The view was typical of the whole district. The flatness of the countryside was relieved only by the villages, each on its own little bump, from six to twenty feet above the plain. The countryside was richly grown with date palms, and well cultivated. Here and there, scrub and tamarisks took the place of the green corn; there were just occasional patches of brown Mother Earth. Right across the landscape, the railway ran on an embankment about 15 ft. high. This may sound a rather narrow margin, but in fact it was quite generous. The top of the Indus Bund was approximately 6 ft. above the level of the plain, and the river was running within a foot of the top of the bund. The railway embankment could be relied on to take 6 to 10 ft. of water, except in certain places where there would be heavy scour. These places were known, so with reasonable luck it would be possible to keep communications of a sort open. Moreover, it would require an immense amount of water to raise the general high watermark another four or five feet, and threaten the embankment everywhere. So far as his command was concerned, George was quite happy, as their home was yet another five feet up, a giddy twenty feet above the plains. The only precaution he took, was to rig a very high pole, to carry a lamp at night, in case an emergency sortie had to be made in the dark.

The regatta party entrained in due course, and pushed off for the north. Nothing happened that day, but it was very usefully spent, all concerned seeing the country, and thus being prepared for orders that night. The train was left loaded, with orders to have steam up by 6.30 a.m. Just before orders, news came in that the Indus bund had gone about forty miles to the north, and that the railway embankment nearby had been breached.

Next day the party set off, and began to see evidence of inundation about twenty miles north of Azad. As the train steamed on, the ponds and streams were seen to coalesce until, some five miles short of the breach, it was water everywhere, except for trees and villages. The pontoons and skiffs were launched, and paddled off happily. Within quite a short time they were all back, complaining bitterly that no one wanted to be saved.

This was unfortunate, as George knew that an extra three feet of water was certain to arrive, and that when this happened, prejudices would break down, and a rush might be expected. People were holding back because they were fairly used to floods of the four-foot variety, which quickly subsided. Last time a relief organization had operated, moreover, the villagers had been taken from their villages, and told if they did not at once stump up hard cash they would be marooned on the nearest tamarisk.

To indicate the speed with which these floods spread, by about 2 p.m. the water was up nearly another two feet, and prejudices were dissolving. George sallied forth in a pontoon, and was not surprised. Some diehards in a tiny village had retired to the roofs. Scour set in, and one after another the huts came down. It then became necessary to transfer to the tamarisks. By the time a tree was accommodating fifty chickens, half a dozen goats, one or two cows, and about twenty humans with ages varying from three days to ninety years, it only needed a couple of snakes to convince the most tenacious that the time had come for a move.

It was curious to watch the loads coming in. Orders had been issued to bring full loads, and to bring them quickly. With only one engine, dispersal of effort was impossible, so it might be several days before a second visit could be made to this part. As an apparently empty pontoon came in, George raised his voice in wrath against the Naik (or Indian Corporal) in charge. The Naik saluted politely and grinned. He had concentrated on the helpless. By the time the pontoon was really empty, three helpless cripples, four or five women whose families were obviously not yet complete, another four or five women, and just under fifty infants had come ashore. It was a load that no one would have thought possible.

A little later a telegram arrived. It read

"Bund badly breached about opposite Azad. Advise look out for your rear."

It was about time to close down anyway, so the order was given for the engine to blow the pre-arranged signal for assembly. Unfortunately, the order about full loads had been given so explicitly, that assembly or no assembly, no one dared come back without a respectable collection; in addition some of the N.C.O.'s had started betting on numbers. George got impatient, and broke loose on the engine whistle himself. He was so happy at this work that later on it took the engine about a quarter of an hour to get up enough steam to take the brakes off. Rescuers and rescued all piled in somehow, and the train steamed into Azad well after dark. There was no sign of a flood to be seen in the gloom, though apparently it was known that there would be plenty of water next day.

Two S.O.S. messages had come in. One came from a headman some ten miles to the north, and seemed to be well justified. In fact, it was pretty clear that it would be worth while concentrating efforts in that area next day. The other stated that a big party was stranded close to the bund, nearly opposite Azad. No less a personality than the Tehsildar Sahib was amongst this crowd, and he stated that there was great danger. On top of this, there was information of more breaks in the bund further south, and that in one zone the railway embankment had subsided in a well-known weak place, and might be expected to be breached by the morning. On top of this, there were about a thousand refugees to get rid of.

Jonah suggested he should try to reach the Tehsildar's party and if possible go on, to see what a breach looked like, in case it could be stopped. George rather reluctantly agreed to this, with the proviso that he must wait for water if necessary, and go all the way by boat. The alternative, at that time possible according to the messenger, was to walk and wade, finishing off on a raft. The distance seemed to be about ten miles each way, so it was likely to be quite a strenuous day.

The rest of the party, less two pontoons and crews, were to concentrate to the north, under the Subedar.

George decided to go down later with the refugees, who would travel partly in the troops' coaches, and partly on the pontoon "flats." He would take the odd two pontoons, with men and gear to leave behind, if necessary, to open a ferry, so that the refugees could be evacuated into Bhoozaffanagar. This turned out to be a good idea, as the railway embankment was found to be badly breached. Later, there was always quite an interesting scene at this point. Two trains would draw up, each with its engine twenty or thirty yards from the breach. The two pontoons could be seen hard at work. The railway lines, with sleepers attached, sagged some three feet under the water. Occasionally an enthusiastic railway official would insist on running his trolley across. The sappers always told these gentlemen that it was quite safe, but did not tell them how wet they would get. The trolley used to take on a most alarming tilt, and on one occasion, all hands abandoned ship, and had to be rescued. They were then sent back along the rails to rescue the trolley by their indignant boss, who screamed orders and abuse from a point of complete safety.

Jonah reappeared very late and very angry. He had started in about three feet of water, and it had been a muscle cracking operation getting out to the bund, even for the two extremely powerful sappers who had rowed. He was most annoyed to find the Tehsildar Sahib, who had sent off the S.O.S. eating a huge meal in a most comfortable bungalow "perfectly safe, with no water within ten feet of him," on being asked where the dangerously stranded multitude could be seen, it emerged that that item had only been put into the report to give colour to the idea that the Tehsildar was staying at the point of danger. Finally, the Tehsildar declined an invitation to be rescued.

As he was quite useless in his bungalow, and "as there was no risk of the blighter being drowned," Jonah decided to rescue him, whether he liked it or not.

He then spent the rest of the day visiting the bund, and apparently doing his level best to capsize the boat, presumably out of kindness to the Tehsildar. The bund he reported on as an absolutely major operation, with a breach over a hundred feet long, and a tremendous current coming through.

George got back fairly early. The water was by then about four and a half feet deep, and the locals were evacuating themselves in small parties. All that could be seen from a distance was a dot and a ball on the surface of the water.

This resolved itself into a head, with an enormous bundle on it. All through the evening these oddities appeared to be drifting steadily in to the railway.

The soldiers returned, very pleased with their day's work, with a great multitude of refugees.

So closed what proved to be a very typical day. The general tenor of the work, so far as the sapper was concerned, did not vary greatly. The officers had plenty of variety, and enough problems for reasonable interest, without undue worry.

The day's work, having thus degenerated into something like routine, interest value was to be obtained mainly from incidents and occasions. For instance, George decided to entertain the local notabilities, and marshalled his resources. These included a sufficiently respectable collection of vegetation, bunting and furniture to stage quite an impressive outdoor counterpart of a Durbar Hall. For refreshment, the usual revolting sweets and stickinesses were prepared by cooks from a variety of castes, duly set out, and labelled "Hindu," "Mussalman" and so forth. Liquor is always a difficulty for this sort of party, and George's resources were limited to gin, and, of course, water, of which there was more than enough.

The guests arrived, and included one particularly cross-eyed and disreputable individual; something prompted George to ask the Tehsildar about him.

"Sir, he is political agitator. He is ardent Hindu, and great trouble maker. He is also murderer."

Here was a man who was clearly worth cultivating, and he was accorded every honour, and filled to the brim with Brahmin prepared atrocities. Meanwhile, he was diligently converting George to his own ways of thought. When George offered him half a tumbler full of gin, there was a tremendous struggle. The undoubted progress made with this polite young Sahib would be lost if his hospitality was refused. On the other hand, gin was a bit over the odds for a pious Hindu. George's stricken look at his hesitation turned the scale, and the gin went down—furtively, but extremely quickly. Some ten minutes later, the miserable man reeled off. The Tehsildar's comment was,

"Sir, today you have done good work. The whole district will hear of this gin, and we will have no agitations from this man for a year."

The next variation from routine was more than an incident; it was an occasion. His Excellency the Governor was paying a visit to the stricken area. He arrived on a motor propelled railway inspection trolley, adorned with a Union Jack, and surmounted by an immense umbrella which had turned inside out. H.E. was most cordial, and made a very generous gift to the troops; he also presented Jonah and George with a ham and a case of much needed beer. While these transactions were in full swing, attention was diverted by something rather odd moving on the surface of the waters. There seemed to be a second umbrella, and the heads of four men. The nucleus of the party was something large and round which pitched and rolled and gyrated as it approached the railway embankment. At last, a huge pot was beached nearby, and curiosity as to its purpose and contents took the Governor's party across.

The immense cooking pot, for such it was, was found to contain a crumpled, green-faced, and nearly moribund Nawab of considerable eminence, who had come in to pay his respects to the Governor. He was tactfully extracted, and as he staggered to a seat, he cast a glance of indescribable venom at the cooking pot.

The next affair was quite different. A riot developed on the Azad Railway Station. George reviewed the situation, and came to the conclusion that the matter would be solved, if only the people could be stopped talking. He therefore detailed an Indian officer to stand by to order silence. A bugle then sounded a stirring call, and the I.O. announced that talking was against orders. Ten sappers, each over six feet tall, and each carrying a pickhelve then advanced down the platform, and lightly tapped on the head anyone who was still talking. The effect was so remarkable that George now recommends the United Nations defence organization to base itself on a Dumb Ray rather than on an Atomic Bomb.

The waters began to subside, after a week or ten days, and the time came to think of a move. Before the Company left, the D.C. came up to say good-bye and a real regatta was staged. This went off quite well. The highlight was a race between sappers in borrowed bath tubs, all of which sank. The climax came unexpectedly, at the beginning of a swimming race. The competitors took off from a pontoon raft. This responded by receding some two feet, and the stately Subedar, who was the starter, did an unsuccessful balancing trick, and needed a lot of comforting and wrapping up.

George had one final fling. He disapproved of the timings for his special train, back across India. So he sent a "clear the line" telegram to the agent of the railway, cancelling the timings from Army Headquarters, and substituting his own. This action was not only effective, but called forth no rebuke.

This little adventure was not without interest. The forethought and power of incisive decision of the Deputy Commissioner have already been mentioned; and he was undoubtedly prepared for a much greater emergency than actually took place. The attitude of the Indians in this isolated part of the country, to two young Englishmen, was also very satisfactory. It was almost overwhelmingly trustful and friendly; it was, in fact, rather touching. Finally, the effect of the backing given to this little expedition by high executive authorities was superlatively helpful. These three factors undoubtedly bred the strongest determination to spare no effort on the spot in doing all that could be done.

On return to headquarters, the necessary corrective was applied. The Adjutant was behind his newspaper, at the breakfast table. When he rose to leave the room, he observed George.

"Oh, it's you, is it. I thought something had gone wrong with the drains. In a way I'm glad you've come back, as you're just in time to take your turn as Duty Officer next week."

THE STORY OF AN ASSAULT REGIMENT R.E.

By Major R. T. Wiltshire, R.E.

THIS is the story of the 5 Assault Regt., R.E., which was one of the three Regiments formed from R.E. units especially equipped with armour to help in the assault on the coast of France in the D Day operations.

The much advertised Atlantic Wall was put to the test by the raid in strength at Dieppe and from it was learned many important lessons, one of which was the fact that sappers could not do their jobs in an opposed landing without some form of protection while crossing an open beach. It was obvious that armour in the form of a tank was the answer. After considerable investigations as to the availability of tanks and their capabilities, the Churchill was accepted as the best and sundry internal alterations were made such as the mounting of a Petard in place of the gun, and the inclusion of exploders, detonators, explosive charges, mine-detectors and other R.E. equipment.

The crews were all R.E., except the drivers who were ex-R.A.C. Each A.V.R.E., as it was called, carried a crew of six and twenty A.V.R.E.'s made a squadron. Four squadrons formed an Assault Regt., R.E.

Intensive training was carried out in Scotland. Many different sorts of gadgets for the overcoming of likely obstacles were tested and new ideas were being constantly tried up to the last moment. This meant a tremendous physical effort and although everyone cursed, inwardly they felt it was for their own advantage and in the interests of the operation. A special feature of the plans was the fact that the B echelon vehicles were not to land until D plus five weeks. This meant that each man had to be self-sufficient for that time, with the one exception of rations of which a fortnight's supply were carried. A certain amount of sardonic humour arose due to this and the main theme was that the assault force would be written off and it was simple to cancel the despatch of the remainder.

The role to be played by the A.R.E. was briefly this. Assault teams made up of A.V.R.E. and Flail tanks, in composite troops, were to make gaps from the beaches to the first lateral road. Flails were manned by R.A.C. and they were to make gaps in minefields and wire. The A.V.R.E. were to make Class 40 gaps over esplanade walls, anti-tank ditches and dunes and reduce reinforced concrete walls that were in the lanes or gaps. To achieve this end training together was carried out from the time the team's composition was decided. The horn beams of the S.B.G. bridge were used for the esplanade mounting and fascines for the ditches. The Petard was capable of knocking down thick R.C. and could be used instead of the S.B.G. if required. If the worst came to the worst the sapper crews were to get out and remove any obstacles by hand-placed charges, pick and shovel and mine-detector. In addition close relations had been established with the Navy and several exercises were carried out, using the actual craft to be employed on D Day. Eventually everything was loaded and everyone could sit down for a breather. Three days were spent aboard ship before the signal came for sailing, giving ample time for final checking of the waterproofing of tanks and gadgets and for briefing. When sailing was delayed a day it was a great disappointment as the reaction, to a man, was, let's get on with it. Morale was high and not one case of absence was reported.

The crossing was rough and *mal-de-mer* and the tense feeling due to the occasion tended to damp even the stoutest hearts. L.C.T.'s can behave in the most upsetting manner and their cargo of tanks put them almost awash. Eventually dawn came and the whole sea behind seemed full of ships of all sizes. Planes roared overhead and heavy naval gunfire rumbled in the distance. Every eye was on the sky watching for the Luftwaffe, but they were not to take a hand in this show. Familiar objects, seen many times on wave top photos, at last made themselves clear while all the time the crescendo of battle increased. Craft of all kinds supported the run to the beaches and to put the final touch to the bombardment, Rocket ships and S.P. guns loosed off their contribution. The latter gave the leading wave some anxious moments as some of their shells fell short. In certain places the D.D. tanks, who were to land first and cover the assault teams with 75 mm. fire, failed to swim and the teams were the first to land. Enemy fire was coming back at the craft and all crews were shut down ready for the order " Down Door." On that signal, teams were to get out of the craft as quickly as possible and get going on their breaching to the first lateral road. Some tanks never got ashore, others never got across the beach and the worst happened when our gallant C.R.E. who had inspired all ranks with his enthusiasm and fighting spirit was killed on board his craft. His loss was felt by all who had the honour to serve under his command.

Before passing on it is worthy of note that there was a stowaway for this greatest landing in history, and it was in the form of the Brigadier of the Assault Brigade R.E. Unbeknown to his superiors, this officer chose to be with his men in their battle and by his example and the mere fact that " THE OLD MAN IS ABOARD WITH US," made a tremendous difference to all ranks.

From the first moment of actual land fighting there was no doubt that the day was to be won. Reports of success at different gaps started to come in and all the paraphenalia of war commenced to pour inland. Shelling and sniping were taking their toll but gradually around the beach area, where the teams were maintaining the gaps, enemy retaliation died away. The cost to the Regiment had not been light in lives and tanks, but taken as a whole they were much lighter than was ever expected.

Life in the bridgehead was not dull and in all the battles the A.R.E. took their place. Keenness and the will to fight had not been dulled by the first impact of battle and although this resulted in the A.V.R.E.'s being used as " I " tanks it was all good innoculation for the tests ahead, and it gave Divisional C's.R.E. a chance to learn something about the A.R.E. La Deliverande, Hill 112, Bocage, Carpiquet, Caen, Cintheaux and Falaise to mention only a few places, give some idea of the scope of the Regiment's activities.

After the breakout the Regiment was left behind, much to everyone's disgust. The chase was on and rafting training was rather an anti-climax. The Seine was the place where the enemy would make a stand and A.R.E. were earmarked to do the rafting. Signs such as " OUT OF BOUNDS TO ALL TROOPS " sprung up like mushrooms and a browned-off feeling was hard to suppress.

Suddenly new life was put into everyone with the news that the Regiment was to take over some new sort of amphibious tank. This was rather mysterious, but it boiled down to the fact that Buffaloes were the new toy. For those uninitiated, a Buffalo is a tracked vehicle capable of taking thirty fully equipped men or a carrier or any smaller vehicle and also anti-tank guns. It is capable of crossing fast flowing rivers and getting in and out of the water over quite soft going. In summer the whole thing was a pleasure cruise and made up in its way for the staying behind.

Eventually the Regiment was moved up to Belgium for final training in a fast tidal river and action appeared imminent.

The Canadians were having a difficult job in dislodging the enemy on the south bank of the Schelde. Around the Breskins pocket bitter fighting was in progress and no headway could be made in the clearing of the estuary. Antwerp was in our hands practically intact and the importance of it as a port could not be exaggerated. To get things moving it was decided to get at the Boche by getting in by the back door. To do this the Regiment was moved to Ghent where it picked up a Canadian Infantry Brigade and swam up the Ghent Terneuzen Canal. From Terneuzen this force was to swim down the Schelde and land at a place called Savoyaards Platt, which was at the back of the enemy holding the Leopold Canal in the Breskins position. The force was completely Army and is perhaps the only one of its kind in history. It was hoped that the landing would be made at 02.00 hrs., the 8th October, and at that time exactly the buffaloes touched down and the Infantry were put ashore dryshod. No opposition was encountered and very soon guns and carriers were consolidating. The operation was a complete surprise and success and during the following days the build-up went on. Shelling of the beaches by the guns at Flushing caused casualties, but taken all round the losses were negligible. In a very short time the effect was felt by the hard put troops holding the canal line, and it was not long before the whole pocket was cleared up.

This gave the Allies complete control of the south bank of the Schelde but the enemy was fighting desperately for the causeway to South Beveland, just north of Antwerp, and a similar loosening of this line was planned to take place at Barland on the north bank. For this landing larger forces were to be employed, so another Buffalo Regiment manned by the 11 R.T.R. was brought in. They were new boys at this game and the Regiment gave them some valuable tips. As before, the touchdown was to be in darkness. Terneuzen was the start point and with Infantry from the 52 (Lowland) Div. the force set out on the 26th October. Opposition was met, but the bridgehead was well established by dawn. A fog came down early on the first day which complicated navigation and the build-up was slowed down. The Regiment was told at the end of the first day to be ready to move to another area and this could only mean a concentration for the final lap, which was the clearing of Walcheren. The enemy was falling back on this stronghold and hoped to deny Antwerp for some time to come.

Ostend was the destination, and in that area the 4 Royal Marine S.S. Commando Bde. was also concentrating. The plan of attack was as follows. A force of one Army Cdo. in L.C.A. was to do a frontal attack from Breskins to be followed by elements of the 52 Div. on the 1st November at 04.30 hrs. Another force, composed of three Cdos., loaded in Buffaloes, were to be carried in L.C.T. to the vicinity of Westkapelle and, if the Flushing operation was a success, the assault was to start at 09.30 hrs. There was to be no build-up for the Westkapelle force so an additional squadron R.E. of Buffaloes and a few R.T.R. were attached to carry Medical personnel and small parties of attached troops. Support was given by a Naval squadron of three 15-in. ships and a variety of close support craft. The attack on Flushing was successful and it was now the turn of the main attack to get ashore. From the outset the enemy appeared to be determined to remove this force from the sea and his guns, which were numerous, opened a deadly fire. The close support craft fought a very gallant action at point blank range and, due entirely to their valour in taking the brunt of the fire, the craft with the landing troops got ashore. Most of these craft had been hit and fires started. The last lap to the shore seemed a lifetime, with craft going down with guns blazing, and near misses engulfing many. At last the doors were lowered and out went the Buffaloes, glad to get away from the huddle of L.C.T.'s which were still under direct and accurate fire. The enemy for some unknown reason used almost all A.P. shot, which saved untold lives. The craft touched down, but despite this the Buffaloes had in most cases to swim and climb through a maze of concrete, sand dunes and bomb craters to reach the inside of the main dunes, where the Commandoes deployed to take the actual gun and infantry positions. A large gap had been blown by the R.A.F. in the sea wall to ensure the flooding of the interior of the island and its success was very evident with the miles of flooded country which could be seen. Mines had been laid in all likely landing spots, causing casualties to Buffaloes and men. Resistance on land was fierce at the start, but the Marines gave the defenders no respite and gradually all resistance ceased. This took six days to complete and during that time the Buffaloes worked unceasingly in supporting and supplying the most forward troops, evacuating wounded, clearing mines and guarding hundreds of prisoners. In the words of a Commando C.O. " The sappers were magnificent and without them and their Buffaloes the show might have been a costly failure. The A.R.E. took to themselves the silent cloak that the Navy so often affect and no mention was made in the newspaper accounts of their work in connexion with one of the most heavily opposed landings of all time. Similarly no military recognition was given to the Regiment.

From the estuary battles the tide of war moved east and several engagements were added to the Regiment's laurels, such as Kapelsche Veer, Nijmigen and Millingen.

About this time the Regiment was reduced to three squadrons, one only retaining its Buffaloes, the others re-equipping with A.V.R.E. The stage was being set for the crossing of the Rhine and training for 50/60 rafting had to be carried out. At this crossing the Regiment played its part by taking the first troops over at Wesel and operating many rafts for the ferrying of armour. After this it went on with the advance and finished its fighting career at the crossing of the Elbe.

The Regiment had won four D.S.O.'s, nine M.C.'s, two D.C.M.'s, and eight M.M.'s for its part in the defeat of the enemy. Those who took their place in the ranks of the Regiment can be sure that they have won for all time a place in the history of the Corps of Royal Engineers.

THE GIBRALTAR TUNNELS

By Col. T. W. R. Haycraft

Preamble

During the Great Siege of 1779–83 a system of tunnels was blasted by the Sappers on the North Face to enable guns to fire on the Spanish lines. The tunnels lie some 15 to 20 ft. behind the face of the cliff which is almost vertical. There are various levels, some connected by inclines, the top level or Upper Gallery culminating in an observation post on the top of a pinnacle of rock jutting out from the cliff face at a height of some 1,000 ft. above sea level. Approach to the whole system is by way of open trenches and tunnels cut in the rock on the N.E. side of the town. These trenches are connected at the different levels by sunken stairways and tunnels.

All these tunnels are beautifully made with arched roofs and neatly trimmed sides. When it is realized that the work was done entirely with jumping bar and gunpowder, with drills about twelve inches apart and under siege conditions the magnitude of the task accomplished is astonishing. The guns were kept in openings off the main tunnels and run forward to fire through embrasures in the cliff face. Up to the beginning of the recent war the tunnels were hardly used for any military purpose. The old muzzle-loading cannon remained in place and certain sections were open to the general public.

During the period between the Great Siege and the end of the last century various tunnels were made by the Sappers in connection with the defences overlooking the harbour. Some of the work on the North Face may have been done during this period also.

Modern Tunnelling Prior to 1939

A tunnel was driven through the Rock from Sandy Bay by Cochranes Ltd., contracting for the Admiralty, for the purpose of bringing stone from their quarries on the east side for construction of the Naval Dockyard. This tunnel carried a spur of the meter gauge railway serving the dockyard. The tunnel passes through a certain amount of bad rock and sand and is lined with brick over these portions.

Between 1908 and 1911 a tunnel was driven by the City Council to bring fresh water from catchments on the east side of the Rock to three rock cut tanks above the town. The tunnel was just wide enough to accommodate a Decauville track as well as the water channel. Between 1911 and 1939 more and bigger tanks were excavated along the line of the tunnel itself, including a second tunnel immediately under the first for removal of spoil eastwards and distribution of water westwards. Work was still in progress at the beginning of the war.

At various times since about 1890 the Admiralty did a considerable amount of tunnelling, the principal works being:

(*a*) Extensive Magazines in the Dockyard area.

(*b*) Oil and water storage on the east side of the Rock, the pipe lines being brought through the Dockyard tunnel.

(*c*) Tanks for petrol storage at the west end of the North Face.

All this work was carried out by Spanish and Gibraltarian labour working directly under the departments concerned or for British Admiralty contractors. The standard of workmanship was high and, with the exception of the Dockyard magazines, rock cover exceeded 100 ft. The excellence of the work may well be due to the high standard set by the Sappers ever since 1780.

September 1939 to June 1940

In 1938 the City Council commenced tunnelling a series of air raid shelters in the town. The City Engineer had organized and trained in peace-time a very good tunnelling department using Gibraltarian labour with a Gibraltarian engineer in charge. This department had been engaged on enlarging the water supply storage. On the outbreak of war this work was stopped and an unfinished reservoir had a three-storey barrack built inside it.

Immediately after the fall of France the Garrison was increased to four battalions organized as two brigades and measures were taken to put the fortress in a state of defence. These measures consisted of the following: —

(*a*) Defence against land attack on the North Front.

(*b*) Protection of all possible landing places against sea attack.

(*c*) Local protection of coast defence batteries.

(*d*) A.A. Defence.

(*e*) Provisioning the garrison and remaining civil population for a possible siege.

As regards (*a*), in addition to the construction of defences on the North Front, the existing trenches and tunnels in the north and north-west faces were strengthened and made proof against modern weapons as far as possible and fully armed and manned. Lyon lights and other available searchlights of various sizes were emplaced in the old gun embrasures to illuminate the whole of the North Front up to the frontier fence. The tunnels were bunked up to capacity to hold the manning details and cookhouses, latrines, etc. were provided as far as possible underground. Accommodation was wet and very uncomfortable.

The works required for (*b*) (*c*) and (*d*) do not really concern this article, but all available old tunnels were used to their fullest extent, ventilated drained, bunked, etc.

As regards (*e*) the target set by the Chiefs of Staff was to provision the Garrison and civil population for nine months. All women and children and all males not required by the Services or for public utilities and essential distribution were evacuated. Balanced stocks of ammunition and food were stored up to the capacity of available accommodation. This ranged from tunnels to tarpaulins, emphasis for safety being laid on food. Some of this accommodation was very bad, a good deal of food was lost through deterioration and the Garrison had to live on reserve rations to a great extent in order to ensure a turn-over.

St. Michael's Cave, a ramification of stalactite caves about 500 ft. up the Rock overlooking the harbour and well known to visitors for half a century, was converted for ammunition storage. Brick and concrete magazines were built in all accessible portions of the cave and concrete stairs provided. The caves were very wet and maintenance and turn-over of ammunition entailed an enormous amount of labour.

Tunnelling Companies

Until September, 1940, the whole of the defence works and tunnelling were carried out by two small R.E. Coys. and one Tunnelling Coy., all under the C.R.E., Gibraltar, with the valuable help of the City Engineer's branch. In September, a Chief Engineer was appointed, the first since 1925, who arrived from the U.K. with two C.R.E.s (one to command the tunnelling group), one Tunnelling Coy., one General Construction Coy. and one Pioneer Coy., all at full strength, some 900 men in all. These were followed by an Army Troops Coy. and another Tunnelling Coy., making three Tunnelling Coys. in all.

These Tunnelling Coys. were recruited almost entirely from the coal mines, i.e., men with no experience of hard rock mining, but the officers, drawn from the ranks of the Institution of Mining and Metallurgy, were fully experienced and in a surprisingly short time the companies settled down to the unusual conditions and made heavy inroads on the Rock. The equipment of these companies was of the simplest—jack hammer drills and small compressors, the latter more suitable for field company work than the continuous service of rock drilling all round the clock.

Later in the year a welcome addition in the form of a Canadian Tunnelling Coy., some 300 strong, arrived. This Coy.'s equipment was more modern than ours, and they drilled wet with drifters. A section of diamond drillers with full equipment came out attached to the Coy. This section did invaluable work in prospecting, of which more later.

Tunnelling from 1940 to 1945

It will be convenient to divide the whole period of war tunnelling into three phases. Phase I will cover the initial urgent requirements of the Fortress, consisting primarily of accommodation for the garrison of the North Face with a tunnelled hospital and safe storage of supplies as a second priority. This was a difficult time as work had to proceed concurrently with planning, plant was very scarce and all spoil removal was necessarily manual. Working parties were difficult to arrange as there was so much other work to be done. This phase covers approximately the period June, 1940, to January, 1942.

Phase II covers far the largest yardage of excavation. Forward planning and survey were now well ahead of actual tunnelling, the work consisted of straightforward galleries and chambers in proved good rock and the plant situation had much improved. At the conclusion of this phase, about March, 1944, all essential work to enable the garrison to withstand a year's siege was virtually complete and Tunnelling Coys. began to be withdrawn.

During Phase III only one Tunnelling Coy. remained on the Rock. Having inherited all the resources accumulated during the war, this company worked under ideal conditions until its withdrawal and the cessation of all tunnelling work at the conclusion of the Armistice.

PHASE I

The following were the main tasks comprised in this phase listed in order of priority.

(*a*) Expansion of the old galleries by the provision of additional lateral communications, additional inclines between the various levels, an additional gallery at ground level to cover the N.E. approaches, and a shaft down to ground level below the North Face for the use of reliefs by day and patrols by night to avoid the long detour by the old routes. A large number of new embrasures were broken out to accommodate infantry weapons.

(*b*) A gallery at a slope of about 1 in 20 leading from the old system in the North Face southwards to the western end of the lower water works tunnel. This included additional and better accommodation for the garrison, some supply and ammunition storage and engine rooms for lighting and cooking in the whole of the Northern system. The gallery provided covered communications to the back of the town and, via the water works tunnel, to the east side above Catalan Bay.

(*c*) Tunnelled accommodation for water distilling plant, required as an insurance against the possible destruction of the catchments.

(*d*) Tunnelled accommodation for a military hospital (Gort's). This was combined with

(*e*) A through east and west tunnel providing direct covered access to the east side of the rock (Harley Street).

(*f*) Tunnelled accommodation for supplies, Ordnance and R.E.M.E. on the south-east side of the rock.

(*g*) A big cave (Monkey's Cave) overlooking the sea on the east side of the Rock was enlarged and provided with a tunnelled approach. A five-storey convalescent hospital was built into the cave.

The City Council continued their programme of air raid shelters during this phase.

(*h*) A gun operations room with accommodation for manning details was excavated at the south end of the Rock.

The City Council continued their programme of air raid shelters during this phase. Some of the shelters were appropriated to Military use as hospital, etc.

Details of Construction

In order to save time in setting out work, to save yardage of rock to be excavated and in order to use materials immediately available, chambers were excavated approximately rectangular in section. Linings consisted of brick or concrete walls built clear of the rock sides with flat roofs supported on the walls or hung by means of mild steel rods grouted into the rock roof. A slight fall was provided in the length of the chamber. This method had two serious drawbacks. Firstly, such linings took a very long time to build and, secondly, in the case of long or wet chambers, a great deal of water had to be carried away by the roofing sheets at the lower end. In some cases the allowable fall was so small that the slightest unevenness caused leakage at the overlaps. Galleries were not lined.

Concrete floors were laid throughout. Galleries were driven to a slight fall and a gutter provided on one side to carry off all water seepage in galleries and chambers.

Tunnelling Procedure

The Tunnelling Coys. confined themselves entirely to survey, blasting and operating such mucking machinery as could be supplied with air (not much). The majority of mucking was done by hand using infantry and R.A. working parties under supervision of the tunnellers. Removal was by Decauville side-tipping trucks pushed by hand. Tunnellers and mucking out parties normally worked three eight-hour shifts, the latter having a set task of trucks per head. The tunneller's task was normally one round per shift.

A diamond drilling section of the Canadian Tunnelling Coy. did essential work in exploring the rock for tunnel planning. Apart from the great fault which occurs about a third of the way along the Rock from the south end there were many unpredictable pockets of inferior rock, and time spent in exploration was fully repaid. A 1-in. diameter core was removed and the line of the drill reconstructed by re-assembling the cores. Holes were also drilled for power and signal cables.

Lining, concreting, installation of services and other work in the tunnels was carried out by an Art. Wks. Coy., an Army Tps. Coy. and a Pioneer Corps Coy. Considering their lack of tradesmen the P.C. Coy. deserved great credit for the manner in which they tackled the work.

Phase II

By January, 1942, most of the excavation for the first programme had been completed, though construction lagged far behind. To speed up construction work Iris and Romney 35 ft. and Nissen 24 ft. and 16 ft. span hutting was ordered from U.K. and future chambering was excavated to accommodate these with one to two feet to spare all round. Sheets were given a priming coat of red oxide and two coats of lead base or bitumastic paint before erection (when paint ran out coal tar was used obtained from the local gas works). The inside was given a coat of limewash after completion. Besides being very quick to put up and shedding the water well, this method gave a more stable roof which allowed chambering to be done in more inferior rock. Chambers could be spaced closer together. The tunnellers got very expert at trimming the chambers to an accurate radius, but tunnelling man-hours per foot of floor space provided rose slightly. It was realized that, once erected, the sheeting could not be treated again and its life was limited. In view of the great advantage of this system, however, and the fact that the sheeting would probably survive to the end of the war, in spite of the warm damp conditions promoting rust, this was accepted.

Plant

By now there had been a great improvement in the plant situation. Whereas in the autumn of 1940 there were a few compressors of 100 C.F.M. capacity, by the end of Phase I there was a fair number of 250 C.F.M. and at least two of 500 C.F.M., all mobile. The last, being painted blue, were called "Blue Trains." Later in Phase I a couple of old 600 C.F.M. static oil engine driven machines were received from U.K. These took a lot of time and labour to instal and recondition but finally did sterling work and, being massive and slow revving, gave little trouble. During Phase II more 500 C.F.M. mobile diesel machines came in, amounting to twelve by 1944. The later arrivals were painted brown and were nicknamed "Blue Trains Browned Off."

In order to economize in drivers, to faciliate maintenance and to keep up the supply of air during repairs, most of the machines were grouped into stations. This involved big mains (mostly 6-in.) and a good deal of pipe maintenance and leakage but, once the total supply of air was assured, this was accepted and the principle amply justified itself.

Early in Phase II a static diesel driven 1,000 C.F.M. machine of massive proportions and age was moved from Corsham (where it had worked for many years) and installed in a ruined factory on the north front. It took a deal of installing; but for the arrival of a first-class erection foreman the job would have been quite beyond local resources. As it was the effort of keeping the machine going was very great and was abandoned when sufficient blue and brown trains arrived on the scene.

All this additional air not only speeded up drilling, but made possible the use of mechanical mucking machines (of which more were received), pneumatic winches, lights and fans and other items all tending to speed up the work.

Planning

Planning could now proceed on bolder lines. The following were the main items :—

(*a*) *Ammunition Storage.*—Two tunnelled magazines were planned, one in the north and one in the south to serve C.D., A.A. and Infantry in the two Brigade Areas. Each was to have road access, lorry size galleries and chambers lined with 35 ft. span huts. Good rock was chosen in each case.

(*b*) A lorry-size tunnel just inside the cliff face on the east side of the Rock connecting from the chambers already made for supplies on the east side to the Naval oil tanks (Arow Street—being the initials of the Tunnelling Officer in charge).

(*c*) Further supply and accommodation chambers at the north end of Arow Street.

(*d*) A tunnelled connection from (*c*) to the Admiralty oil and water tanks and on to the Dockyard—tunnel at Sandy Bay.

(*e*) Further supply chambers along Harley Street.

(*f*) Tunnelled accommodation for the two Brigade H.Qs.

(*g*) A lorry-size tunnel along the west side of the Rock connecting up Gort's hospital, the two Brigade Headquarters, the northern magazine and the northern tunnel system. This was named the Great North Road.

(*h*) A chamber at the south end of the Rock for petrol storage with road access on a down grade from a disused quarry. The other end of the chamber connected with the sea, also on a down grade, so that, in case of fire, burning petrol would discharge harmlessly into the water.

(*k*) Emplacement of a 6-in. three-gun battery in the cliff on the east side of the Rock. The gun pivots were about 10 ft. from the edge of the cliff giving a training arc of 150°. Magazines, stores and accommodation were to be tunnelled immediately behind the guns. An incline of ample dimensions with rails and hoist gave access from the tunnel system on the S.E. side.

(*l*) The lower part of St. Michael's Cave had always been difficult of access and involved a long carry up and down some hundred steps. Direct horizontal access from outside was planned to debouch on an existing road.

In addition it was planned to use a further cave connected with, but not accessible from, the main cave and some 150 ft. below the main entrance. This was to be done by means of a second horizontal drive from outside. This cave was really a large fissure some 20 ft. thick lying at a slope of about 45°. A lot of benching and building would be required to suit it for ammunition storage.

(*m*) A shaft leading down from the tunnel system on the east side to a small beach at the base of the cliff. This was to be combined with a boat hoist in a section of rock overhanging the water. These were to provide facilities for supplying the garrison, during siege, by submarine.

(*n*) A communication tunnel leading from the Naval tanks to the east end of the North Front, thus completing the entire circuit of the Rock without coming out into the open.

(*p*) Various tunnelling work connected with C.D., A.A. and Infantry defences.

Execution of Plan

This plan was carried out with a few modifications and additions introduced as the work proceeded. The most urgent item was the two magazines. This work was the first to be executed as a deliberate mining operation on a carefully prepared plan which included the disposal of the enormous quantities of spoil produced. The southern magazine was eventually connected by a lorry-size tunnel with the east end of Harley Street with stores and personnel accommodation, latrines, cookhouses, etc. for the Southern Brigade.

The Great North Road was connected by an east and west tunnel, lorry-size (Fossway), with the (by then) extensive excavations on the east side of the Rock.

A 30° incline was driven from the Great North Road near Southern Brigade H.Q. to the Dockyard Tunnel. This incline passed close over A.C.H.Q. and some tricky work was required to avoid disturbing the Naval staff working there.

The petrol storage chamber was completed though never used as such and was connected to other accommodation.

Before work on the 6-in. battery had gone very far the plan was modified to suit a 5·25-in. three-gun C.D./H.A.A. battery. No guns of any calibre materialized and this extensive excavation was converted to accommodate a large R.E.M.E. workshop, central bakery and other accommodation. The Fossway mentioned above terminated here.

The work on St. Michael's Cave turned out to be very interesting. The upper horizontal drive broke into an approximately horizontal fissure running north and south. It was not a large fissure but one could with difficulty scramble along. The stalactite formations were different to any others so far revealed and presented some remarkable features. One of these consisted of clusters of pendant leaves up to 8 or perhaps 12 sq. ft. in area and from ½ in. to 2 in. thick and the same distance apart. Some of these gave a good note when tapped and their transluscence gave very fine lighting effects. Another curious formation consisted of capillary vermicular growths rather like the roots of an onion. Round a small pond at the lowest point of the cave the limestone had grown out along the surface of the water just like the initial freezing of a pond. The growth was very thin but would bear the weight of a man treading carefully. A good many of these formations were destroyed by the necessary blasting work, but much remained.

The lower tunnel into St. Michael's cave was successfully driven. The interesting feature of this drive was the very difficult underground survey, involving a large number of stations, some of which were very difficult of access. The whole of this work—benching, building and access—was satisfactorily completed.

The boat hoist never materialized. By the time it came to detailed planning, it was found that spoil, shot into the sea from above, had turned two or three fathoms of water into a beach. This fact is interesting as showing the enormous quantities of spoil excavated.

Water Supply

A system of ring mains was installed entirely inside the rock or on the surface on the sheltered east side. These mains connected up with all sources of supply—Naval, Army and Civil tanks and both the Navy and Army condenser plants. By utilizing external sources—wells on the north front and water imported by barge from Algeciras—to the fullest extent for the current requirements of the garrison and civil population, stocks of water in the rock tanks were kept always at a figure which would tide the garrison, the fleet and the civil population over to the next rains. Although the medical authorities had stated that bacteriological infection of the catchments from the air was impracticable, chlorinators were installed for use if required at all points where water was drawn from the tanks. The civil brackish water supply was also brought into the tunnels, supplemented by a submersible electric pump installed in the sea on the S.E. side of the Rock. Expense tanks for both fresh and washing water were provided in each section of tunnels, to be filled from the mains. These were tunnelled chambers lined with concrete and rendered with " Pudlo " or similar and were of the order of 100,000 gallons each.

In the later stages, when more transport was available and crushing and screening plant had been installed, nearly all spoil was used on Admiralty and W.D. projects.

Phase III

The size of chambers had been progressively increased as work went on and, with the introduction of excavating machinery and five-ton lorries into the tunnels, larger rock could be expeditiously dealt with. These machines required a greater height in which to work and the greater the space the less the concentration of carbon monoxide.

The Tunnelling Coy. left behind during this phase evolved an entirely new method. A heading having been driven the full length of the chamber by normal means this was widened and the roof dropped in successive stages by banks of bore holes driven the whole length of the chamber by diamond drill.

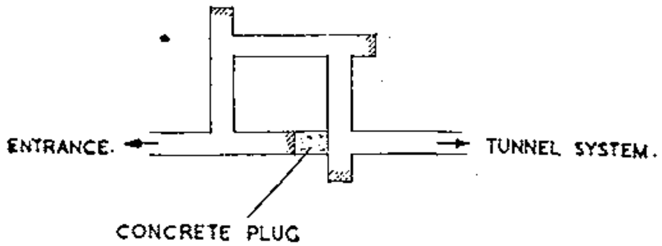
By this means chambers up to 40 ft. wide and 45 ft. high were excavated, the roof being formed to camber for safety. Such chambers were only suitable for stores that could be stacked to this height unless provided with one or more floors. The economy of tunnelling time was great, not only in the excavation of the chambers themselves but also in cutting down unproductive mining for galleries and ventilation.

General

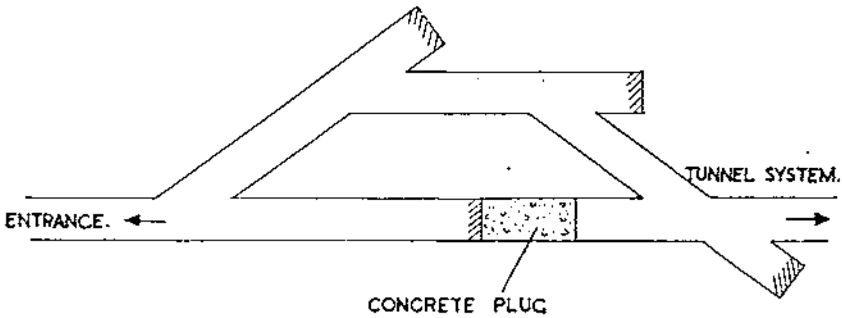
Protection from Blast

For ease of construction all entrances to tunnel systems were straight, there being generally 50 to 100 ft. of straight drive before chambering was started. This being so, although the excavations were to all intents and purposes bomb proof, there was the possibility of considerable damage being done by blast following the explosion of a bomb or shell at the tunnel entrance. The advice of the Ministry of Home Security was sought as to the type of protection which could be provided, it being considered that the conventional blast walls would seriously impede traffic, making the use of lorries underground well nigh impossible.

As a result of experiments carried out by the Ministry a "blast trap" was adopted on the principle of absorbing the blast in soft material and at the same time making it turn corners. The sharper the corners the better, but for a lorry-size tunnel these had to be eased off as shown in the sketch below. These traps were excavated after the internal tunnelling work was finished, the last operation being the insertion of the concrete plug into the original straight tunnel. Traps of this type were designed and constructed to permit the passage of three-ton lorries with little or no inconvenience.



BLAST BLOCK ON PEDESTRIAN TUNNEL.



BLAST BLOCK ON VEHICULAR TUNNEL

NOTE ////// PLUG OF SOFT MATERIAL SUCH AS EMPTY SANDBAGS.

Tunnel Spoil

On the east side of the Rock all adits came out on the cliff face and spoil was dumped in the sea. On the S.E. side the spoil was used to provide parking space for transport between the tunnel entrances and the sea. Spoil from the southern and northern magazines provided road access to the tunnel entrances. Where spoil had to be lorried away timber hoppers were built. In one case rough screening was interposed in order to grade the spoil into a battery of hoppers; this was very useful for surfacing the airfield and saved a lot of crushing.

In the latter stages, when more transport was available and crushing and screening plant had been installed, nearly all spoil was used on Admiralty and W.D. projects.

Nevertheless some nasty scars were made by spoil which had to be dumped down the hill side in the early stages for lack of any other means of disposal.

Ventilation

During actual excavation the normal practice of ventilation was used. Tunnels and chambers were planned to take all possible advantage of natural ventilation ; this was supplemented as necessary by air driven fans and metal or canvas ducting. Much useful experience was gained in this most important aspect of all tunnelling work, but a detailed description would take up too much space for inclusion in this article.

Ventilation for personnel accommodation was provided by electric fans (taking power from the underground grid) and metal ducting. The circulation was designed to assist the natural flow of air, although in practice it was found extremely difficult to predict what this would be. The natural flow was governed by differences of temperature and direction of wind at the tunnel entrances ; these were subject to constant variation, especially between night and day, and the tunnel system had so many entrances at all points of the compass.

Gas filters were fitted on a by-pass at all ventilation intakes and arrangements made for sealing tunnel entrances in the event of a gas attack. How this would have worked in practice it is impossible to say but, since the tunnel entrances were nearly all situated well above sea level, it is doubtful whether any appreciable amount of gas would have tended to find its way in.

In the case of underground engine rooms considerable trouble was experienced in dissipating the large amount of heat generated ; the natural exhaust of engine room air by the radiator fans (ducted to the open) was quite insufficient and considerable forced draught had to be provided. No ordinary gas filter could cope with this and the engine rooms were consequently outside the gas lock.

Except in the case of A.C.H.Q. (built by the Admiralty) no attempt was made to condition the air ; any attempt to do so on such a vast scale would have been impracticable. Due to the cooling of the outside air by contact with the rock and the high percentage humidity, especially during the " Levanta," forced ventilation tended to cause excessive condensation ; it was found that ventilation must be kept down to a minimum consistent with an adequate change of air.

Use of Mechanical Excavators

Excavators (mostly 10 R.B. and some 19 R.B.) fitted with face shovel or grab, and fed by bulldozer, were successfully used in the later stages in large chambers for loading direct into tipping lorries. The layout had to be planned to give adequate through ventilation and, provided this was done, no trouble arose from exhaust fumes. The rough floor was hard on tyres and the dust-laden atmosphere much increased maintenance on the machines, but the enormous saving in labour fully justified the use of mechanical equipment wherever possible.

Accidents

A certain number of accidents, and some serious ones, occurred but, considering the enormous amount of rock excavated and the urgency of the work, these were surprisingly few. One case is known to the writer of a very gallant rescue at the face where at least half the charges were already lit. No doubt other cases of bravery occurred when the writer was not in the colony.

Models

The plaster model of the Rock, used in peace time for the information of visitors, was of great value for indicating works on the ground but it was impossible to show tunnels on it. A new model was made consisting of a framework of plain galvanized wire. Horizontal wires followed the contours at 100 ft. vertical interval, these wires being held together at about 9-in. intervals by wires soldered at right angles to them. The vertical scale was twice the horizontal scale. Tunnels were made of strips of tin plate painted red and soldered to the frame work. The model was made and kept up-to-date by the tunnellers and was a great success. It was quite easy for a newcomer to learn his three dimensional geography of the Rock, and it proved an enormous help in planning. In fact planning for new tunnels was indicated on the model and studied by the tunnellers before survey commenced.

Conclusion

The provision of the Gibraltar Tunnels was an enormous task and involved the excavation out of the solid rock of over a million cu. yds. executed over a period of approximately five years. The start was slow, the early days trying. Then it was a case of "get a hole made" and naturally the easiest places at which to begin were chosen. Plant was practically non-existent, experience of mining in Gibraltar meagre, but lack of both was compensated by the terrific enthusiasm of the tunnellers and all concerned in the job of tunnelling. As the threat of immediate investment of the fortress receded, and with the arrival of more plant and personnel, properly planned schemes were evolved and the "holes" of late 1940 and early 1941 were, on paper at any rate, all connected up by drives and inclines. In due course these plans were executed and further plans were drawn, more ambitious still. Underground storage, workshops, bakeries, roads, hospitals, offices, headquarters were provided, in fact everything which could be done to make possible the troglodyte existence which would have been the lot of the Garrison under seige conditions. Technique improved and, with yet more plant available, what was originally a "wishful thinking" tunnel became quite common place. Tonnages excavated originally measured in hundreds per week were now accepted in thousands, an average weekly heading advance of 180 ft. against the original 30 ft., and so on.

It is not surprising that in such a system there should be technical *faux pas*, but before criticizing these, let the Mining Engineer give a thought to the conditions of urgency and improvization under which the work was done and the purposes for which it was required.

Of all the lessons which can be learned from the task by far the most important is that planning from all aspects must be kept well ahead, and that no tunnel, however desirable, should be started unless it conform to a general plan. Only too often it was found that "highly important" tunnels in the early days were on second thoughts not nearly so important and their presence prejudiced the nice development of the area in which they had been mined.

GODDESS OF THE RIVER

By Jemadar Said Ahmad

SOME time in June, 1942, while on retreat, my company was ordered to halt at Palel river bank till further orders. Another signal followed conveying orders "Bull Dozers should proceed via Kaschim to Imphal." I was detailed as Convoy Commander. The track to follow was shown to me from the survey sheet by the Second-in-Command. All the dozers and vehicle transporters were re-fuelled, maintained and necessary breakdown tackling equipment was loaded in. I, with other 150 strong men and a team of tractors (Dozers) marched off through the jungle. After having accomplished a day's journey, thinking we were away from the bombing area, we halted there, encamped in hutted accommodation, known as Bashers, left vacant by inmates who fled away for fear of air raids by Jap planes. However we enjoyed our hard rations (biscuits, grams) as usual.

At day dawn, the Havildar-Major gave the three long blasts at his whistle and with thunderbolt voice, shouted "Gird-up boys." Soon after the tea a check up on machines was an important factor. This was always done and even a slightest mechanical defect carefully handled. There could then be no reasons to delay our further advancement, hence machines and men streamed in an orderly manner. A distance ahead on a motor cycle I used to recce out the track and found that the track had submerged into Paddy fields which were flooded with rain water ankle deep. It matters not for the Bull Dozers to make way through, but to be sure that we are keeping to the given track a sapper was sent with a flag to act as depth finder, however, it was crossed safely.

It was mid-day when we reached a swiftly flowing stream. Over its narrow width was a wooden trussed bridge. I calculated it too weak to stand against the live load of a D.7 tractor (Bull Dozer). A forced stoppage was made while the depth of the stream was measured at certain intervals to verify the least depth of water and the firm bottom. At last we succeeded and the class operator-driver was singled out to master the fate of the first machine Who with no difficulty had crow flight across.

The others to follow were instructed NOT to follow the same track for reasons of boggy and soggy soil in the river-bed, which is known to be unsuitable anti-grip to track chains of tractors. But the driver operator had a flagrant disregard of instructions and drove over the prohibited track and caught into bad soil. He manœuvered advance and reverse gears but in vain. Through cuts thus formed the silt gave way and the Dozer sank in more. Everybody scratched his head, was grinding his teeth to gums, if someone could play a black witch about its extracting out.

Every attempt with fresh alternatives met the ugly fate. At last an S.O.S. to H.Q. Wing was preferred with the request to send per bearer a winch cable for hauling the dead monster. While sitting for charred tea there appeared a Budh-Priest clad in loin cloth, a tattoo-painted creature. Though of advanced age but well built musculars was evidence to be a strong guy of the village shrine. He poked his nose to smell our ration and glanced all the aspects with eagle eyes and sat near by me on the turf. He acquainted himself to me in priestly fashion giving his faith and doctrines and uttered about the Goddess of river. She is awfully angry. She is raged and will engage her invisible power to kill many of you and you will be men disappeared from human ken. Because you have disturbed her sleeping. No one since ages came with such a heavy monster to cross the river. Even we the apostles when we need to cross the bridge with a cart load, used to lay flowers, betal nuts, sing humble slogans with folded hands and pray safe crossing. You people had committed a sin unpardonable. On hearing all the legends of the Goddess I in a jovial smile which was of course an impression to make him understand " I care a fig for."

I in turn during talk replied that these fairy tales may amuse you or terrify the tiny tots in your village. We are soldiers, we trust our God but not gods in our skill, tackles, shackles and rifles.

My God is more more stronger than your Goddess. You will have to witness in a short while he is flying to me in a Jeep. He have a bull's fight with your diety and smash her down. On hearing about another Goddess or God he with great surprise asked me who is he. I politely said " Major Murray-Lees." It again worried him to understand and he asked " What do you mean ? Is he brother of Muraray Lal " (a holy Ghost in Budh-theology). " No," said I, " he is brother of Captain Bulfe." As it was a puzzle to solve for him we cut jokes at him. With longing eyes towards the road for a whirling Jeep we noticed a Jeep and there appeared Lt. Alexander with a cable length. Out of it a towing sling was made. The first dozer which crossed the river was employed to extract the bogged one. I told the Budhist Priest who was standing amidst his village folks to be ready to witness the show. " My God (Lt. Alexander) is now ready to duel with your's. Soon he will signal with his hat ' Pull.' The dead monster (Dozer) will move out coughing." (The machine was put in gear with the idea when pulled it has to use his own power also). " My God will restore life in it. He knows all the secrets of the black witch." According to necessity towing-slings was coupled in and Lt. Alexander stood on a mound to conduct the operation as pre-arranged. Soon signalled " Pull " the bogged Dozer was dragged out. To great astonishment of the Budh-Padri and the innocent gentry around him, who all took to their heels and ran crying, yelling in a helter-skelter manner for shelter. This sudden flight of them was a cause of anxiety for me as what wrong we did to them. I made up my mind to find out terribly strange action of the villagers. I marched toward their cottages and got hold of the Padri Sahib who was sitting under a tree at his back and shedding tears for nothing. I in sympathizing manner asked about his misery and sorrows. " After all what is the real cause to make you weeping." He in a tattered voice murmured " I avoid the sight of your God (Lt. Alexander). Undoubtedly, he knows the black witch and he may harm us." I laughed. " No danger, do not be afraid of him. He is very kind to human race. He is only annoyed when he do not get tea, otherwise he is quite sober. He will be more glad if you entertain him with a fresh milk." The poor Padri heeded to me and arranged some milk. Thereupon I agreed to introduce him to God (Lt. Alexander) and walked along with other diciples of him to riverside. The tea minus sugar was hailed and served amongst all of us.

I opened with introducing notes and a brief account of the priest to Lt. Alexander and the Budh religion. He rented air with loud laughters and shrugged his shoulders. Remarked " God Save him." I prayed :

God save the King, Defender of Faiths and Religions in India.

THE ENGINEERING RECONSTRUCTION OF CYRENAICA BETWEEN OCTOBER, 1943, AND JULY, 1945

By Lieut.-Col. J. H. Brass, A.C.G.I., A.M.I.C.E. (late R.E.)

1. Purpose of Article

After the axis forces had been driven out of Cyrenaica in the winter of 1942–43 a territory was left behind in which almost every engineering installation had been destroyed or demolished, and the majority of buildings in the towns of Benghazi and Tobruk were in complete or partial ruins.

Much valuable work was done by the 8th Army Engineers, and in the interim period up to the autumn of 1943, to make the country habitable ; but most of this work was essentially of a temporary nature.

It became apparent that the time had come when temporary measures and improvization of reconstruction should give way to more permanent schemes.

The purpose of this article is to describe some of the engineering work done in Cyrenaica by the Royal Engineers between October, 1943 and July, 1945 to render the country more fit for the occupying troops to live in and for the eventual return of the civilian population and the industries of the country.

2. Extent of Territory and Nature of Terrain

Cyrenaica is situated on the North Coast of Africa and, is bounded by Egypt in the east and Tripolitania in the west. Although it extends several hundred miles inland over arid expanses of desert, it may be considered as a narrow coastal strip extending about 600 miles from Bardia in the east to Marble Arch in the West.

Outside this coastal strip there are no surfaced roads or habitation other than wandering tribes and native villages.

The centre third of this strip, from Derna to Benghazi is hilly, fertile country, rising to an altitude of 2,000 ft. It is in this area that most of the native population, totalling 180,000, resides.

The eastern and western thirds, i.e., from Bardia to Derna and Benghazi to Marble Arch are wastes of featureless desert.

3. Importance of Cyrenaica

With the campaign in Italy progressing steadily and the invasion of N.W. Europe not started it will be appreciated that Cyrenaica, with its Naval and Air bases, was a vital link between Egypt and North-West Africa.

The garrison strength varied from time to time, and in any case is immaterial, but its existence, together with that of the native population, depended on the maintenance of the roads, the provision of water, electric power and the clearance of ruins and partial rebuilding of the city of Benghazi and the town of Tobruk.

The engineering aspect of these problems is as follows :—

4. Road Maintenance

Except for two short branches to R.A.F. Stations and a duplication for 90 miles in the fertile centre of the country there is virtually only one road in Cyrenaica and it runs roughly parallel to the coast, from Egypt to the Tripolitanian frontier.

This road is 6 metres wide, with a Tarmacadam surface and was constructed by the Italians at a cost of £1,000 per kilometre. By the winter of 1943-44 disintegration of the road surface, as a result of the heavy traffic it had borne during the previous winter was occurring on a large scale. The edges of the road were crumbling, while large, deep pot-holes made travelling slow and dangerous. To restore the road surface to its original condition for its entire length was a matter of importance. Experience had shown that local native labour was not equal to the task, so the following organization was introduced.

Camps of 100 Italian P.W. were established at intervals of approximately 50 miles all along the road. The two main factors in siting the camps were the proximity of water supply for the personnel and hard limestone for the road surfacing.

Each camp was equipped with the following items of portable plant :—

2 Stone Crushers.
2 200 gallon Tarpots.
2 Tarmacadam Mixers.
1 10-ton Roller.
6 Tipping Lorries.

These plants were set up at suitable quarry sites for the manufacture of tarmacadam, and crushed stone for Bitumen grouting. This material was run out in the tipping lorries where required. In all some hundreds of thousands of large pot-holes were made good with tarmacadam and 25 miles of carriageway was resurfaced with bitumen grouted stone. By the spring of 1945, the whole road surface compared favourably with that of main roads at home, thus effecting a considerable saving in wear and tear on the vehicles using the road, besides safely speeding up their rate of travel.

This road maintenance organization also justified its existence in the spring of 1945, when during a severe gale on 15th February, 1945, a floating dock, capable of taking a cruiser, was wrecked, while in transit to the Far-East, on the rocks at Ras Aamer, the most northerly point of Cyrenaica. The wreck occurred 19½ miles from the nearest road and could only be reached by donkey and camel train. The problem was to construct a road in the quickest possible time to take 10-ton lorries so that the valuable machinery on the dock could be salvaged. A survey revealed that the proposed road would traverse for most of its length an inaccessible rocky surface, crossing several ravines, three of which were over 20 ft. deep with almost vertical sides. A detachment of the road maintenance organization was sent to the nearest town, Apollonia, and equipped with 3 bulldozers, one mechanical shovel, one grader and 18 tipping lorries. A formation was made and surfaced with soil that compacted well under traffic. Considerable blasting was necessary in the crossing of the ravines. This 19½ miles of road was constructed in 7 weeks. The Mechanical Equipment operators were all provided by a Palestinian Unit, R.E.

5. Water Supply

The Axis forces, on being driven out of Cyrenaica completely destroyed all the water producing installations.

The Benghazi water supply is provided by deep well pumps and with the return of the native civilian population in 1943–44 it became desirable to increase the water supply there. Trial bores were put down by Royal Engineers to a depth of 150 ft. and the yield from these varied considerably. The number of deep well pumps installed was 7, giving a total output of 500,000 gallons per day.

In many places the damaged distribution mains were repaired so that a fairly adequate water supply was provided throughout the city.

Several boreholes were also sunk in other parts of Cyrenaica and pumping machinery installed to provide a local water supply to our occupying forces and the civilians. The water supply at Tobruk has a salinity of 360 parts per 100,000 and fresh water is brought to this town from Egypt by rail. The large distillation plants installed by the Italians at Tobruk have been completely demolished and are beyond repair.

6. Electric Power Supply

The Italian power staion at Benghazi was thoroughly demolished by the Axis forces on their retreat, so that neither the building nor the plant could be used again, although certain parts of the plant were salvaged and sent to Tripoli, where they are in use at the power station.

Electric power was needed for refrigeration, lighting, workshops, etc., and also for the slowly returning industries of the city.

In 1944, a new power station was built by Royal Engineers and equipped with two British 175 kilowatt generating sets. The smaller plants that had been left behind by the 8th Army and were dispersed, were brought into the same area as the new sets. This was done as it made for ease and economy in running and maintenance if the sets were all within a confined area and not spread over the city.

At Tobruk, plant totalling 100 kilowatts was installed and at Barce 45 kilowatts. In all these places much work was done on renewing distribution mains and insulation.

The result now is an adequate electric power supply for the necessities of the population.

7. Rebuilding Benghazi and Tobruk

As a result of changing hands 5 times between 1940 and 1942 the City of Benghazi suffered very considerable damage, and Tobruk, although a smaller town, was reduced to ruins.

For sanitary reasons alone it was desirable to clean up the debris from the ruins, and to make habitable all buildings that were not too badly damaged, so that they could be used by the occupying forces and ultimately the other inhabitants of the country.

Many of the damaged buildings were of reinforced concrete. Beams, columns and floors were held together by the steel reinforcement and were hanging at all angles, making their demolition a hazardous procedure. It was found that the cheapest and safest way of dealing with these structures was to attach a small explosive charge to the exposed M.S. bars on each item to be demolished and detonate them simultaneously.

A programme of reconstruction was decided on in the summer of 1944, and with limited supplies of labour and materials, buildings with an area of approximately 500,000 super-foot floor space were made habitable in the ensuing 12 months. The work consisted of plastering and tiling, decorations, the provision of doors and windows and where possible electric light, water supply and drainage. Work was started on the top floor of each building and was completed floor by floor. Special attention was paid to kitchens, kitchen equipment and hospitals.

For all this work little suitable civilian labour existed. It was done by Royal Engineers, assisted by Pioneers, from Palestine, Mauritius, Seychelles, Sudan, West Africa, Syria and Greece, and Italian P.W.

General Remarks

In all the engineering projects consideration had to be given to the labour and materials available, and the strictest economy was observed.

Benghazi is situated by road over 800 miles from the base (Cairo), so the supply of imported materials was a considerable item.

Some projects, for example, the reconstruction of the outer Mole at Benghazi Harbour, which was badly damaged by enemy demolitions and later by storms, were not proceeded with.

Whatever the ultimate fate of Cyrenaica is to be, none of the work done by the Royal Engineers of the occupying forces will have been wasted, and it has been a start in the gigantic task that lies ahead of Engineers in the reconstruction and restoration of installations and property all over the world, made necessary by the war.

PRE-STRESSED REINFORCED CONCRETE

By Capt. M. W. Horne, A.M.I.Struct.E., R.E.

ALTHOUGH the first step in the evolution of pre-stressed reinforced concrete was made as far back as 1888, it is only recently that this system has become appreciated by engineers as a valuable addition to Structural Engineering Science by greatly increasing the scope of usefulness of that important compound building material, reinforced concrete.

The high resistance of concrete to compressive stress is well known, and the application of modern chemical knowledge has served steadily to increase this resistance. However high the compressive resistance may be made, the tensional resistance remains at the very low value of between one-tenth and one-fifteenth of the compression strength and it is usual, therefore, to insert steel in areas subject to tension forces, so effecting a balance ; steel in tension comparing most favourably with concrete in compression.

In the design of reinforced concrete members it is usual to neglect the tensional strength of the concrete and assume that the steel reinforcing takes the whole of the tensional load. This assumption very nearly becomes a fact when it is considered that the ability to withstand tensional strain of even the very best concrete is quite small if compared with that of steel, and even under small loads, tiny hair cracks will appear in the concrete. The rules given in the Code of Practice do not exclude this fact and, it is obvious, that when these conditions are reached the steel reinforcing does literally take the whole of the tensional load, the concrete having actually failed in tension.

Concrete is a " compound " building material and its formation depends upon a chemical reaction. As a result of this chemical reaction, the concrete, whilst setting and hardening, shrinks. The shrinking sets up important internal forces in the member. In contracting, the concrete is put under tension and by the bond, or grip, between the steel and concrete, the reinforcing members are compressed. Thus, contraction fissures are caused and make the concrete itself unreliable with regard to its further resistance to tension which may be caused by either primary or secondary forces.

What, then, is the remedy for disadvantages which may be caused by this cracking of the concrete under tension? In simple terms it is this: any plastic deformation of the concrete in tension must be prevented by reinforcement which has been pre-stressed and which holds the stress while the concrete is setting and is released after hardening has been sufficiently completed.

This principle was partially investigated by C. F. W. Doehring in 1888 when he patented, in Berlin, mortar slabs reinforced by steel wires which were pre-stressed and thus produced compression on that part of the slab which was later to be under tensional load. Doehring failed because the bond between his mortar and the steel wires was insufficient and slip took place.

It was not until some twenty years afterwards that Lund and Koeneu made experiments with pre-stressed reinforced concrete beams using a mild steel with a yield point of about 34,000 lb. per sq. in. This steel they pre-stressed up to 8,500 lb. per sq. in. Anchored to steel plates at each end of the beam, the steel, when released, introduced pre-compression into the concrete of the beam. Their experiments showed that cracks appeared at higher loads than for ordinary reinforced concrete beams but that, after a certain lapse of time, the pre-stressing disappeared due to shrinkage and plastic creep of the concrete. The trouble here was that the steel they used allowed of an elongation almost identical with the value of the average amount of shrinkage and creep in the concrete.

The famous pioneer of reinforced concrete, Considere, also made experiments but from published results it seems that his idea failed to reach success because of the difficulties arising during the execution of the work rather than anything else.

It was not until early on in this century that the first really practical step in pre-stressing concrete structures was taken. This pre-stressing was done with a view to eliminating shrinkage stresses and was carried out during the construction of the Albert Louppe Bridge, at Plougastel in France, and the bridge across the Rogue River in the United States.

In each of these cases, pressure was exerted by means of jacks at key points along the arches. In these and many other subsequent cases, shrinkage stresses were cancelled and thus the dimensions of the arches could be considerably decreased.

Up to this time the phenomena of creep had not been catered for: indeed, although its presence may have been noticed, its nature and effect had not. The building research station at Watford is still conducting experiments in an attempt to arrive at exhaustive data concerning this property which all materials, and not only concrete, possess when subjected to a load. From consideration of this phenomenon and its connection with shrinkage and the release of the pre-tensioned reinforcing bars it may be shown that only a high tensile steel is practicable as a pre-stressed reinforcement. Such reinforcement must also possess sufficient residual pre-stressing to counteract those stresses produced by both dead load and super-imposed loads.

There are a variety of methods of pre-stressing reinforced concrete, many of which are covered by patents and about which little is known, and still less has been published. One or two more important methods have been put on record, however, and a word or two about them may be of interest.

The first really practicable method of pre-stressing reinforced concrete came in 1928 and was devised by Freyssinet, who combined the properties of high tensile steel and high quality dense concrete. His concrete was vibrated, subjected to pressure, heated, etc., etc., in order to make it dense, quick hardening and highly resistant and his reinforcement was either silicon or chrome steel with an ultimate strength of about 140,000 lb. per sq. in.

and a yield point of about 110,000 lb. per sq. in. This steel was supplied in the form of wires of up to $\frac{5}{8}$ in. diameter, bundles of which were welded together at the ends. With regard to the concrete, Freyssinet used a special "treated" type which was compact and subject to only slight shrinkage. Deforming at a fairly constant rate, and resisting repeated stresses, it is very suitable for pre-stressing purposes because of its high strength and quick hardening properties. The elastic constants for this concrete are greatly in excess of those of ordinary concrete but the ratio of compressive to tensile stress is almost identical with that of ordinary concrete. Owing to the fact that the pre-stressing forces are so great, the pre-stressing load cannot be transferred to the concrete by virtue of natural bond alone and special anchorages, which are permanent, must be attached to both ends of each reinforcing bar. These end anchorages cannot be removed without nullifying all pre-stressing effects.

Generally it may be said that the Freyssinet method, described above, is the traditional one. The steel deforms with the concrete, and its compound effect with the concrete is ensured partly by the end anchorages, which correspond to the hooked bars of ordinary reinforced structures, and partly by bond.

A further advancement on pre-stressed reinforced concrete was made by Kurt Billig, who arrived at a method based upon the use of high tensile wire reinforcement and the highest quality concrete. These wires consist of single or stranded wires of no greater diameter than $\frac{1}{8}$ in. The wire consists of very high quality piano wire, with an ultimate tensile strength of between 340,000 and 390,000 lb. per sq. in. The yield point is approximately 85 per cent of the ultimate strength. Owing to the fact that a large number of wires are used and the fact that these wires are distributed over the whole cross-sectional area of the member, the load to be resisted is split up and sufficient natural bond is obtained without the necessity for end anchorages. This bond is further increased by the fact that, when pre-stressing is released, the wire expands and thus exerts a pressure against its surrounding concrete. Actually, this expansion is greatest nearest the ends of the wire, where the tensional stresses are least, and the ends, therefore, form an efficient end anchorage. Pre-cast units produced by this method are definitely superior to ordinary reinforced concrete units and compare very favourably with steel units. The initial cost of the unit is cheaper and there is practically no maintenance cost.

Another method of pre-stressing deliberately dispenses with the property of bond between the concrete and steel by coating the reinforcing bars with waxed paper or other insulation. After setting and hardening have taken place, the bars are tensioned and end anchorages provided. This method is now extensively used in America, whilst those methods employing the property of bond are mostly preferred on the Continent. The method described above has been used for the construction of large water tanks in America. The large circumferential ring wall of the tank is fitted with numerous rings with connecting turn buckles. The bond between the concrete and steel is destroyed by coating the latter with a special asphalt compound. The tensile stresses produced in the concrete as the tank fills with water are counteracted by the pre-stressed steel rings.

A good example of the use of pre-stressed reinforced concrete is that of a road bridge at Oelde in Germany for the "Reichsautobahn." It was from exhaustive tests that this bridge was built in 1937 with a span of 108 ft. It is bridged by four pre-stressed girders at 4 ft. 8 in. centres, each 5 ft. 4 in. high at mid-span and 4 ft. 10 in. high at the supports. This was the first time in the history of reinforced concrete that a beam bridge, freely supported, had been built for a span greater than 100 ft. carrying loads equal to M. of T. loads and with a depth-span ratio of only 1 : 20.

Experiments on fire-resisting properties have been carried out and it is of interest that the results proved better than similar tests for ordinary reinforced concrete. It must be remembered, however, that any extreme heat would affect the strength of the high tensile steel and will, in that case, influence the pre-stressing. This question is still the object of much research however, and little definite information relative to fire-resistance is available.

Pre-stressed reinforced-concrete has been used with great success and to great economic advantage during the last six years in the construction of shell structures such as barrel vault roofs, airplane hangars which are hyperbolic in shape, cone shell roofs, chimneys, towers and silos.

Although at first sight pre-stressing seems a costly method of construction it has, on the whole, a favourable effect upon the costs of the structure because an infinitely better use may be made of the high qualities of both materials in the permanent structure. The cost of complicated moulding and scaffolding required for shell structures is reduced and, in some cases, entirely cut out.

Considerable research has been made during the war years on pre-stressed reinforced concrete sleepers for permanent way construction and a factory employing mass production methods has been running for some considerable time. The author understands that cost is high, but that, after exhaustive tests by railway companies on main line traffic, they have proved to be equally as good as wooden sleepers and vastly superior to the ordinary reinforced concrete type.

In conclusion, it is hoped that the foregoing will serve as an introduction to a method of construction which the author firmly believes will eventually become as common to the structural engineer as ordinary reinforced concrete is at present. For those who would wish to delve into the design of pre-stressed reinforced concrete he can suggest no better text book than that of Kurt Billig, *Pre-stressed Reinforced Concrete* (second edition, published by Knapp, Drewett and Sons, Ltd., 30, Victoria Street, London, S.W.1, 1944, price 21s. 0d.).

JEEP RAILWAY IN BURMA

By Lt.-Col. P. A. Easton, R.E.

In July, 1944, 36 Div. landed on the airfield at Myitkyina with the task of advancing via Mogaung down the railway towards Mandalay. This phase was completed early in December by the capture of Katha, where a spur of the railway rejoins the Irrawaddy. During the whole of the advance down this "railway corridor" roads were either non-existent or, at best, unmetalled cart-tracks of very limited capacity. The Division was therefore on air-supply (from Ledo) throughout; but in order to economize in air-lift as much as possible it was decided to use the railway as a ground L. of C. This article gives a brief account of the Engineer work involved in opening and operating the line.

Opening the Line

The 150 miles of single track metre-gauge railway between Myitkyina and Katha had suffered considerable mutilations at the hands of the R.A.F. Special Force, and the retreating Japs. Most bridges over 40 ft. span had been demolished (often with trucks cast into the gap), craters were frequent, points were usually either missing or blown, and long stretches of line had been removed into hiding or used elsewhere.

This was bad enough, but to make things yet more difficult no item of equipment larger than a fishplate could be flown in for the work and existing material had to be used throughout. Missing rails and points were supplied from stocks captured from the Japs, or by demolishing unwanted sidings and spurs; bridging was in framed timber trestle construction; bearers were improvized variously from 60 lb. rail (five per girder), R.S.J.s out of an old sugar factory (Sahmaw), girders from a demolished road bridge (Mohnyin), and finally baulks of local teak. The line was made good to Class 24 single track, with passing places (single siding or loop) from five to seven miles apart. In all some twenty-eight bridges were built, with spans ranging from 20 ft. to over 200 ft., numerous craters were bridged with timber cribs, and ten miles (at least) of track relaid from scratch. Finally turntables for Jeep locomotives were improvized, telephone cables connected and the line was opened, normally only ten days behind the forward brigades. The whole railway was open, to Katha, by the middle of December.

Rolling Stock and Locomotives

Sufficient rolling stock was captured, in working order, to carry the stores' lift required. All stock was carefully overhauled before use by R.E.M.E. and faulty wagons pushed off the line. Box cars and flats were both employed and a passenger coach was taken over for use as the general's caravan.

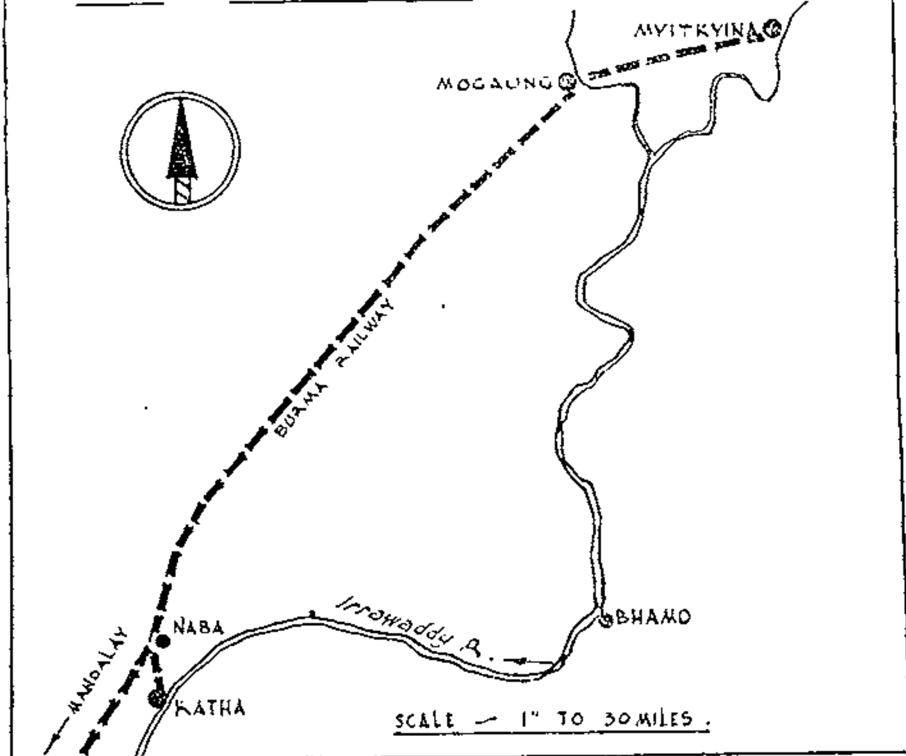
Locomotives, however, were not so easily come by—none were captured that were serviceable or repairable—and once again improvization was required. One form of locomotive consisted of a box car with a lorry engine connected by chain drive to one of the axles. This did function, but a more economical, reliable and useful kind of railway engine was found in the converted Jeep. Owing to the large number of these that were used the whole project came to be known as the " Jeep Railway."

Basically, the transformation from Jeep to loco consists in the substitution of suitable rail wheels (two designs are shown in Diagram) on to the existing axles. The Jeep was then coupled to a train, comprised usually of two ten-ton box cars. A timber sleeper was fastened as buffer over the bumpers back and front, and the Jeep securely attached to the front wagon by a chain and shackle, any slackness being liable to cause bumping and damage to the rear of the Jeep.

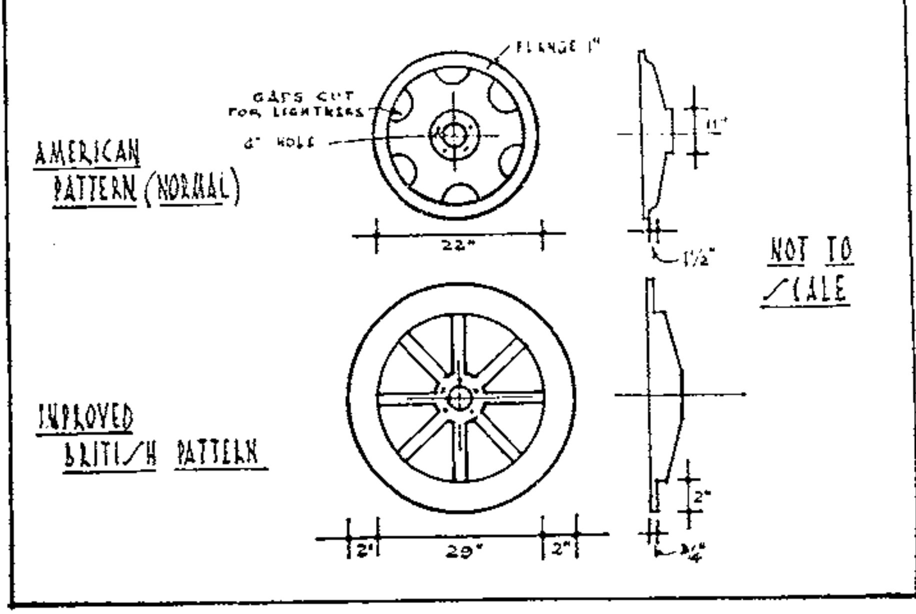
Jeep trains are not easy things to drive. Starting is done by engaging low gear (four wheel drive) opening the throttle and letting in the clutch with a bang. The wheels spin, but the train moves off slowly (unless the load is too great, in which case another jeep or some men are required to push) and the engine speed can then be reduced until the wheels stop spinning. This method preserves the clutch plates and does not damage the wheels. It is fatal to slip the clutch.

Gear changing is carried out normally, but stopping is again a skilled business. Due to its comparatively light weight the Jeep brakes are totally ineffective, and trains have to be rolled to a standstill on engine compression, starting about 500 yds. or so from the halting place.

THE RAILWAY CORRIDOR



JEEP RAIL WHEELS



By these methods satisfactory running was achieved. A speed limit was imposed of 25 m.p.h. on the Jeep speedometer (in reality about 15 m.p.h. only, due to reduction of wheel diameter). The trains could negotiate inclines of up to 1 in 100 and would average from eight to ten miles in the hour over moderately hilly sections. Light rain or mist caused wheel spin and so restricted early starting, but heavy rain had little effect and no substantial delays were caused for that reason.

Jeeps needed frequent overhauling. Excessive vibration tended to loosen the nuts and bolts in wheels and chassis, steering would slacken, oil seals leak and wheels rapidly become elliptical. By prompt attention to these failings R.E.M.E. managed to keep a high proportion of Jeeps in working order.

Organization

The running of the railway was controlled by C.R.E. 36 Div. This proved the most satisfactory arrangement, firstly because running was so closely connected with the repair progress ahead and secondly because the C.R.E. could then co-ordinate the normal railway service with trains carrying Engineer stores for the work. He appointed as his executive a " Divisional Traffic Manager " and this officer was responsible for attending " Q " conferences, arranging train time tables, liaising with sapper parties on the line and administering railway personnel.

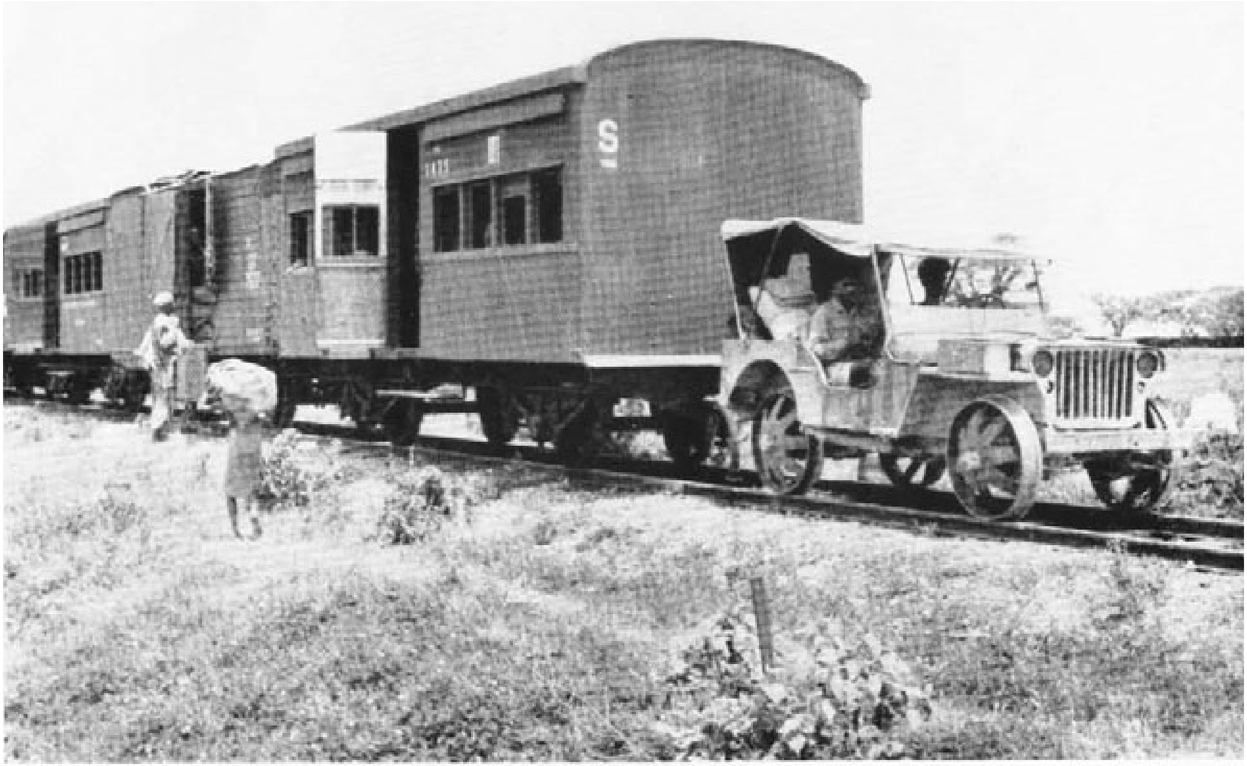
Station staffs consisted of an R.T.O. with an assistant and a pointsman. They were responsible for marshalling trains and checking loads (with inexperienced drivers only half loads were allowed) and were in communication by phone up and down the line. The R.T.O. in his own area was all powerful and had to be a man of personality—being required to co-operate with several nationalities.

Driving a Jeep train is tiring work, and a tired driver may cause an accident through no fault of his own. Accordingly two drivers were provided per train to work in shifts, and close attention had to be paid to their food, sleep and welfare during the advance. Night driving (unless lights could be used) was avoided whenever possible. In doubtful country a railway patrol was sent out with the first trains of the day to cope with possible ambushes, and two guards accompanied each subsequent train if Japs were suspected in the area.

An emergency repair party of sappers was held ready to deal with derailments and hasty repairs to the line. At railhead there was a R.E.M.E. detachment for servicing and repairing locomotives, who gave invaluable assistance throughout.

Performance

The largest lift in one day was 230 tons over a twenty mile stretch of line. The greatest number of trains on such a stretch at one time was eight ; four in each direction with possibly one or two double trains among them. No figures are available for the total tonnage lifted, but the line stayed in operation for five months. By mid December the Americans had got steam locos on to the line and the project was turned over into their hands.



Train drawn by Jeep.

Jeep rail in Burma

Major General Sir Henry F E Freeland

MEMOIRS

MAJOR-GENERAL SIR HENRY, F. E. FREELAND, K.C.I.E., C.B., D.S.O., M.V.O.

HENRY FRANCIS EDWARD FREELAND was born at Charlotte Town, Prince Edward Island, Canada, on the 29th December, 1870, the son of Col. R. G. Freeland.

He was educated at a private school in England and entered the Royal Military Academy, Woolwich, in January, 1889, where he was Captain of the Rugby XV, a member of the Cricket XI, won several events in the athletic sports, and played a good game of rackets. In fact he was a first-class all round athlete. He was the acme of smartness on parade. At work he was well up in his batch among those who secured commissions in the Royal Engineers on the 13th February, 1891. Add to these qualifications a sterling character and sound judgement and it is not surprising that he was appointed S.U.O., in which capacity he gained the respect and affection of his batch.

At Chatham he played for the R.E., both at "Rugger" and "Soccer" and also Cricket.

In March, 1893, he proceeded to India where he was employed on Military Works Services at Madras.

Between March and October, 1895, he was on active service with the Chitral relief Expedition, attached to the 4 Coy. Bengal Sappers and Miners. Among other work he was responsible for the construction of a suspension bridge with composite cables of telegraph wire and timber obtained by felling Deodar trees in the forest. It is believed to be carrying traffic to this day.

From October, 1895, to September, 1897, he was employed on Military Works at Madras and Quetta including four months special duty on famine relief work. At Quetta he was in charge of the construction of defences of the Bolan railway.

In September, 1897, he proceeded home on leave. On the 22nd of the same month he was married to Ethel Louise Walker, daughter of Colonel T. Malcolm Walker, R.H.A., later Inspector-General of Ordnance.

Returning to India in January, 1898, he was again employed on Military Works at Bombay and Kamptee. In June, 1898, he received an offer, which he accepted, to join the Indian State Railways in the traffic department. This decided the course of the whole of his future career.

In 1900, he had become a District Traffic Superintendent on the Oudh and Rohilkhund railway. In the same year a Field Force was despatched from India to deal with the Boxer rebellion in China, and Freeland was posted to the Force. On arrival in China he was appointed military Traffic Manager and Deputy Director in Tientsin. In 1902 he was British Representative for railway matters in Tokyo, Japan.

A spell of leave in England followed, after which he joined the North Western Railway of India, and was posted to the Traffic Department in the Head Office. In 1905 he was appointed District Traffic Superintendent of the Karachi District, the most important District charge on the N.W. Railway, including the Port of Karachi with its heavy grain export. He was also a member of the Port Trust and of the managing Committee of the Chamber of Commerce 1905–7. This experience of the working of a large Port was valuable to him later in his career.

In 1908 he was sent to America and Canada to study and report upon railway practise in those countries. On return to Europe he represented the Indian Government at an International Railway Conference in Paris.

In 1911 the Prince of Wales (later King George V) held a Royal Durbar at Delhi, for which preparations on a large scale were necessary. New railway connections, stations and yards were built. Freeland was selected to organize and manage the traffic. He introduced for the first time in India a very complete system of telephone train control, which was an outstanding success. For these services he was awarded the M.V.O. An officer who worked under Freeland at Delhi writes, "He had a most difficult and trying job, but had the complete confidence and affection of his staff, no worry could ruffle him—all went well." Later he was in charge at Karachi, from which place the Prince of Wales departed to England.

About 1912 Freeland was a member of a committee, of which the President of the Indian Railway Board was Chairman, to enquire into measures of reorganization to relieve the congestion on the Indian railways due to recent enormous expansion in the volume of traffic. The Committee was divided in their views, and Freeland was among the minority, who were at first not supported by the Chairman, but Freeland developed the minority scheme, and presented the reasons for it with such clarity, that he succeeded in converting a minority into a majority which included the Chairman.

Thus between June, 1898, and August, 1914 (16 years) Freeland had acquired a great deal of valuable experience and expert knowledge in the management of both military and civilian traffic on railways in India, China, Japan, America and Canada.

He was convinced that Germany would declare war in the summer of 1914, so he contrived to be on leave in England in August of that year. On mobilization he was ordered to the R.E. Railway Depot at Longmoor Camp. At the end of September, 1914, he arrived in France at a time when military railway traffic was in some confusion. He was appointed A.D.R.T., later D.D.R.T., with the temporary rank of Lieutenant-Colonel, at the headquarters of the Inspector-General Line of Communications, where he opened a traffic office. In the month of October the control of military railway traffic began to shift from the I.G.C. to the Q.M.G. at G.H.Q., so Freeland reported to the Q.M.G. for special duty in liaison with the French Railway Directorate for the strategic railway move of the whole B.E.F. from the Aisne to Flanders in "the race to the sea," which culminated in the first battle of Ypres. This work proved to be of great importance and brought Freeland to the notice, not only of British, but also of French Hd. Qrs. As a result in June, 1915, Freeland (having been promoted Major in 1911) was awarded a brevet Lieutenant-Colonelcy, and about the same time he was given the temporary rank of Colonel. The Generalissimo Joffre personally presented him with the French Legion of Honour.

In September, 1916, the Cabinet deputed Sir Eric Geddes to reorganize Transportation in England and France, furnishing him with unusually wide authority, power and resources. Sir Eric Geddes proceeded to France accompanied by Colonel Freeland and Colonel O. Mance (also R.E.) to tour the lines of communication, and to conceive and execute his scheme for reorganization of Transportation at home and overseas.

Sir Eric Geddes has expressed his appreciation of the help he received from his guides on this tour. He wisely encouraged them to express their views freely, and gave serious consideration to their suggestions in drawing up his scheme.

In his reorganization he at first appointed Freeland to take charge of the "movement control" staff at G.H.Q., under the title of D.R.T. Later he was appointed Deputy-Director-General Transportation in the forward area of the Southern Armies. In December, 1916, he was awarded the D.S.O. and in June, 1917, the C.B. for this work. He was also promoted Brevet-Colonel in 1916 and given the temporary rank of Brigadier-General in 1917. Between November, 1917, and March, 1918, he was employed on a mission to Mesopotamia concerning the reorganization of transportation in that country, covering rail, river, docks, harbour and inland water transport.

In March, 1918, the C.-in-C. India applied for Freeland's services at G.H.Q. India to prepare a Railway concentration scheme for a war with Afghanistan which seemed imminent. He was appointed a member of the Indian Railway Board and Director-General Military Transportation with the temporary rank of Major-General, and carried out those duties during the Afghan war for which he received the K.C.I.E.

An officer who served for some time as Freeland's Deputy writes that "He was a charming Chief to serve under, as he always listened to the views of his Deputies, and often accepted them." In June, 1919, Freeland was approached by the Government of India to accept the presidency of the Indian Railway Board, but almost simultaneously he received offers from both the East Indian Railway, and also from the Bombay, Baroda, and Central Indian Railway to be their Agent (General Manager). His choice between these three offers was the last named.

He retired from the Army on the 28th July, 1920, with the Honorary rank of Major-General, after having taken up his new appointment at Bombay. He was also a member of the Bombay Port Trust, and of the Managing Committee of the Bombay Chamber of Commerce.

From 1920 to 1921 he was a member of the Governor of Bombay's Committee on Industrial disputes.

He was responsible for the initiation of very large development of the B.B. and C.I. Railway by much new construction of many large works of various types.

In 1925 he reached the retiring age (55) from Indian State Railways and returned to England.

In England Freeland was appointed Director of the B.B. & C.I. Railway Home Board, Director of the Madras and Southern Mahratta Railway Home Board, and Director of the Barsi Light Railway Board.

In November, 1929, the survivors of Freeland's batch (Sappers and Gunners) celebrated the 40th anniversary of sitting at the examination for "The Shop" in 1889, by a dinner in London which was very well attended. Of course they put their S.U.O. in the Chair.

Ten years later, in 1939, the dinner was repeated by a somewhat diminished number. Again Freeland was in the Chair still retaining his hold over the batch, but, in the intervening ten years, his physique, hitherto so remarkable, had begun to fail him, perhaps the worst affliction being failing eyesight. His friends were grieved to see this quondam athlete enter the dining room very slowly with the assistance of two walking sticks, his eyesight obviously causing him difficulty in recognizing his friends. He carried on bravely without complaint.

He used a typewriter for his letters, which his friends noticed continued to be cheerful, brave and uncomplaining. The increasingly difficult conditions of life imposed on everyone by the recent war bore heavily on such an invalid, and perhaps especially upon his devoted wife, who bravely did everything for him until he passed away at his own home on 29th March, 1946, aged 74.

H.L.P.

BRIGADIER-GENERAL E. P. BROOKER, C.B., C.M.G.

EDWARD PART BROOKER was the son of Captain E. W. Brooker, R.N. and was born in May, 1866. The father died when E. P. Brooker was very young. After going to a preparatory school, E. P. Brooker was sent to Merchant Taylors'. He obtained a direct commission in the R.E., his commission being dated 18th February, 1886, so that he was then nearly twenty years old. His first foreign station was Malta and after five years there he was posted to Chatham, and then, in 1895, he joined the Ordnance Survey and remained in charge of the Bristol Division of that Department until 1900. Whilst there he earned the gratitude of his successors in that Division of the Survey by persuading the Office of Works to build a suitable drawing office, in spite of very luke-warm support from headquarters. However, the office was built and remains to this day.

He then went, with the 5 Fd. Coy., R.E., to the South African War; served throughout the war, and afterwards was Division Officer, Cantonments, in Pretoria. He there had plenty of scope for his organizing and administrative ability. It was there that he had occasion to order some trucks for construction work and received a certain number of tenders; one was of such a fantastic price that he did not trouble to answer it. In reply to a reminder from the would-be contractor, Brooker replied that the fault was, no doubt his, Brooker's, in that he had omitted to mention that he did not require the trucks "to be encrusted with gems!" It was in Pretoria that he came into touch with Fowke and they remained friends for the rest of their lives.

He resumed his acquaintance with surveying in 1905 when he was appointed Chief Instructor in the Survey School, S.M.E., and here he did useful work for the next four years. On completion of his tour in this appointment he was posted to Jersey and spent rather more than two years in that delightful island, where he became popular with all sorts and conditions of people. His infectious cheerfulness and ready wit made him much sought after and he thoroughly enjoyed his time there, though he realized that, from a service point of view, it was just a pleasant backwater. Indeed, he used to repeat a remark made by another soldier in the Island, "Why have you been sent here? There must be some reason; we shall know some day!"

He rejoined the Ordnance Survey in 1911, at Southampton, and was put in charge of the largest branch of the work, the Publication Division, and he was still in charge of that Division when the first World War broke out in August, 1914, and for the next two years he was responsible for the printing of war maps, which were issued by the million. In 1916 he was appointed C.R.E. of the 32 Div. (Glasgow), of the Expeditionary Force, and he shortly became Brigadier-General, Chief Engineer of the XIII Corps. His next appointment was to the important post of Deputy Engineer-in-Chief, Expeditionary Force, in which appointment his ability in administration and organization had full scope.

After the War he served, from 1919 to 1923, as A.D.F.W. in the War Office. He retired in January, 1923. After leaving the service he used to spend his winters abroad, coming back each year for the fishing of which he was very fond. He kept up with his old friends. He was one of those men whose presence cheers up any company; always a good talker, but not one who reduced conversation to a monologue; a man of excellent sense and judgment. For the last five or six years of his life he lived at Bude. He had no long illness, but had failed greatly in health during the last few months, and he died on the 3rd July, 1946, aged eighty. And so, farewell to a man of happy temperament, cheerful, capable, considerate, and a good friend.

C.F.A-C.

Brigadier General Edward P Brooker CB CMG

Maj-Gen Charles S Napier CB CBE

MAJOR-GENERAL C. S. NAPIER, C.B., C.B.E.

THE news that "Dome" Napier had died very suddenly in London on 16th June, 1946, came as a great shock to many Sappers, particularly to those who have served in the Movements branch of the staff or with the Transportation Service, for it was to those branches that Napier devoted the last years of his life and it was his work for them that brought him high rank and honours.

Charles Scott Napier, the son of Archibald Scott Napier, a civil engineer, was born in India on 3rd February, 1899. He was educated at Springfield Park, Horsham, and Wellington College, whence he passed direct into the R.M.A. in 1915, being awarded a Prize Cadetship. At school he was of the studious rather than the athletic type and soon showed an aptitude for mathematics which enabled him to secure second place in the Army entrance examination at the early age of 16. He was never particularly proficient at games, though he wielded a useful cricket bat, both at school and later in the Army, and his departure from Wellington at such a comparatively early age gave him no opportunity to attain that eminence in college affairs which might have been expected from a boy of his intellectual ability and strength of character.

He received his commission as Second Lieutenant in the Royal Engineers on 26th May, 1916 (aged only 17 years and 3 months) and after a short course at the S.M.E. was attached to Eastern Command, being under the minimum age permitted to proceed on overseas service.

On 26th November, 1917, he was promoted to Lieutenant, and on attaining the age of 19 in February of the following year was posted to India, whence he joined the Egyptian Expeditionary Force in October, 1918. In 1920 he was commanding 18 Coy. of the 3rd (now Royal Bombay) Sappers and Miners in the Palestine Force when recalled to England to undergo a Supplementary Course at Cambridge University. During his year at the University he took part in various intellectual activities and had no difficulty in securing a First Class pass in the second year course of the Mechanical Sciences Tripos. On completion of his Supplementary Course at the S.M.E. he was posted in October, 1922, to Longmoor for a Railway (Operating) Course, which included a one year's attachment to the Great Western Railway. It was at this time that the first inklings of Napier's future career appeared, for, while his colleagues were struggling with the intricacies of platelaying and locomotive performance, he was studying the theory of operation and the higher direction of transportation policy, and it became evident that, though he was no mean technician so far as railway operation was concerned, his real interest lay in the direction of policy rather than in the technical details of the work.

On completion of his railway course he was appointed Adjutant of Supplementary Reserve (Railway) units in June, 1925, being promoted to substantive Captain on 13th January, 1926. In September, 1926, he was transferred to H.Q. Eastern Command and in January, 1928, returned to India where he was employed as an Assistant Executive Engineer with the Eastern Bengal Railway, and later as G.E., Murree, before joining the Staff College, Camberley, as a student in 1932. On obtaining his p.s.c. in 1934 he was employed as G.E. Colchester and then as D.C.R.E. on substantive promotion to Major on 5th March, 1935. After two years as G.S.O. 3 in the M.I. branch at the War Office he was appointed Brigade-Major 1st A.A. Group, Blackdown in September, 1937, until November, 1938, when he returned to the War Office as D.A.D.Tn. in the Q.M.G.'s Department, where he formed part of the special staff responsible for planning the move of the British Expeditionary Force to the Continent, his particular subject being the movement of personnel and vehicles. On the outbreak of war he was transferred to the Directorate of Movements to supervise the execution of his plan. That the move of the B.E.F. in 1939 from the U.K. to France was a model of efficiency and smooth working is now a matter of history, and it is to Napier that much of the credit for this is due, for it was he who worked out every detail of the plan and guided it through to a successful conclusion.

For the next four years he remained at the War Office building up and supervising the organization that was responsible for moving millions of men to all parts of the world. His output was tremendous. No problem was too great nor too small for him and all were tackled with a logical brain, and insistence on absolute accuracy, coupled with practical commonsense, that were almost overpowering in their intensity. It was the rule, rather than the exception, for him to work far into the night and few of his colleagues or subordinates were able, or even attempted, to keep pace with him. He once informed the writer that his only relaxation during this period was a twenty minutes' nap after dinner following a hard day's work, to refresh himself for the evening's labours.

By the end of 1943 his task at the War Office was finished and much to his own satisfaction, he was appointed Chief of the Movements and Transportation Division of Supreme Headquarters Allied Expeditionary Force, charged with invasion of the Continent. In this appointment he was magnificent. His great brain, unrivalled knowledge, determination and prestige were outstanding. His allocation of joint allied resources, often in the face of conflicting claims, was made in a remarkably tactful manner, and though some of his decisions were naturally unwelcome to one or other of the allies they were seldom questioned, for it was generally recognized that any decision made by Napier was the result of careful and detailed investigation and analysis and was sure to be a wise one, however unpalatable it might be.

The movement problems connected with the launching and subsequent maintenance of the allied forces were immense and it was principally due to Napier's firm guidance that they were so successfully resolved.

By the end of 1944, to the surprise of none, the strain of his labours and responsibilities made itself felt and he had a serious breakdown necessitating two months absence on sick leave. He returned to S.H.A.E.F. in time to see the end of the war in Europe and to set up the organization for control of German transport, but the old power and drive were lacking and it was evident that he was a very sick man. He relinquished his appointment in July, 1945, and after a period of sick leave he retired on 11th April, 1946, being granted the honorary rank of Major-General.

He received substantive promotion to Lieut.-Colonel on 14th November, 1941 and to Colonel on 8th August, 1943, and was made acting Brigadier on 4th August, 1941, and acting Major-General on 29th December, 1943. In addition to his rapid advancement the vital part played by his services in the conduct of the war was recognized by the award of six honours between 1940 and 1945—O.B.E. in 1940; C.B.E. in 1944; and C.B., Legion d'Honneur, Croix de Guerre and Legion of Merit in 1945, the last named being a notable tribute to the esteem in which he was held by our American Allies.

After retirement he accepted an appointment with the Control Commissions for Germany and Austria, for he was inspired by the belief that agreement among nations on problems of international transportation might pave the way for agreement on wider issues. It was soon after commencing this work that he suddenly passed away.

In 1927 he married Ada Kathleen, daughter of Mr. V. N. Douetil who survives him, as does his son, born in 1929.

No memoir on Napier would be complete without reference to his devotion to classical music. Though no musician himself, his principal, and latterly his only relaxation was the study of good music and whenever his work permitted, which it seldom did, he would take the opportunity of attending an orchestral concert.

Napier's name appears in no casualty list or Roll of Honour, but those who knew him best will always regard him as a war casualty for they believe that he literally worked himself to death in his determination to give of his utmost in the prosecution of the war.

The shock caused by the news of his death was felt as deeply in Washington as in London and his past associates immediately sent the following message :

> " U.S. Transportation Corps express feeling of great personal loss in the passing of a man who earned the deep respect of all Americans who ever met or knew him. The tremendous contribution he made to the successful solution of our combined movement problems throughout the whole course of the war is well recognized in U.S.A. and it is felt that truly he died a soldier's death as a result of unparalleled devotion to duty."

In the memory of his colleagues probably his most prominent characteristics were his great brain and his absolute selflessness. Though he was not an unusually quick or brilliant thinker he was a regular encyclopædia of knowledge, and to every task that confronted him he brought from the vast storehouse of his brain an array of facts and figures so arranged in logical sequence that the most abstruse problem was soon reduced to manageable proportions. He had no time for self-seekers or ulterior motives ; he always pursued the course of action which he believed to be the right one, irrespective of whether it was the easiest way or of any unpleasant consequences that might be brought upon himself. To him the cause was everything and self was nothing.

Those who had the privilege of knowing and working with Napier will not easily forget it.

R.F.O'D.G.

BRIGADIER-GENERAL U. W. EVANS, C.B., C.M.G.

On the 5th June, 1946, after two years of rapidly failing strength, Usher Williamson Evans died peacefully in his sleep in a nursing home at Clifton. So ended the strenuous life of a man of outstanding ability and force of character who, with better health and a happier fate, might have achieved high distinction as a soldier or as a scientific engineer.

He was born in Jersey on the 26th June, 1864, second son of Deputy Inspector-General U. W. Evans, A.M.D. Both his parents belonged to old Irish families and he, being a delicate child, was allowed to run wild in County Westmeath during all his early boyhood. His family migrated to England in 1876 and he was, soon after, sent to Clifton College. Afflicted by asthma, he was unable to take part in any school games; but he did well in the classroom, especially in French, mathematics and science, and passed second into the R.M.A. in December, 1881. Bad health, however, continued to dog him. He had to drop a whole year at "The Shop" and did not gain his commission until the 9th December, 1884. The rigorous life of a cadet and of a young officer, however, temporarily banished his delicacy. He rapidly developed great physical strength and even became a very formidable boxer. At the S.M.E. he devoted much of his spare time to studying French and electricity and to making himself a good shot and a good yachtsman.

Early in 1887, he proceeded to India and was posted to the Q.O.S. & M.* His company was ordered to Burma in 1889; but Evans, suffering from an attack of dysentery was unable to accompany it. At the end of the year, however, he was passed fit and rejoined in time to take part in the Chin-Lushai expedition of 1889–90; but not for long. He soon fell a victim to the malaria which laid low some fifty per cent of the South Burma column and was invalided home. He took the opportunity to rub up his knowledge of mathematics, construction and photography and spent some happy months hunting in Ireland. On his return to India in 1891, he went to the headquarters of the Madras Sappers at Bangalore and, apart from some special services on the North-West Frontier, he continued there until 1908. During this long spell, he was employed successively as Company Commander, Superintendent of Park and Train, Superintendent of Instruction and Officiating Commandant.

In 1897, he was selected to command the one and only Divisional Field Park mobilized to serve not only the Tirah Expeditionary Force but also the many other smaller forces then actively employed on the N.W. Frontier, a total of some 50,000 men. It was a Herculean task; but Evans carried it out with marked efficiency. His services were rewarded with a Mention in Despatches.

In 1902, he was in command of No. 5 Company, Q.O.S. & M., during its employment on railway construction between Khushalghur and Kohat. In 1903, he attended the "Wild East" course at the S.M.E. and here he made his mark in the Electrical School and was reported by the Senior Instructor to have been the keenest student he had ever had under him. In consequence, Evans was allowed to spend two additional months in the School to continue his study of electrical generators and motors and of internal combustion engines. About this time, he wrote several pamphlets on service subjects which were smiled upon by Indian Army Headquarters. In particular, he compiled a text book of instruction for Pioneers, which was printed by order of the Adjutant-General in India and issued to all Pioneer Units.

In 1908, he was transferred to the Military Works Service and, in January,

*Later entitled "Queen Victoria's Own (Madras) Sappers and Miners."

1909, became Officiating Assistant Director-General, Military Works, at Simla. Nine months later, he was appointed Commandant of the Bombay Sappers and Miners and—to quote his own words—the next four years were some of the most interesting and certainly the happiest of his life. At Kirkee he was able to give practical expression to his own very decided ideas about the training of sappers of all ranks. They must be not only first-rate workmen but also first-rate soldiers, and the object of all their training must be all-round efficiency in war. The wisdom of his methods was amply demonstrated by the achievements of the Bombay Sappers in 1914 and after. At the first battle of Neuve Chapelle, at Sahil and at Shaiba they fought as infantry, pure and simple, and covered themselves with glory. In 1911, Evans officiated as A.Q.M.G. of the 6th (Poona) Division for five months. In this and in other temporary appointments all through the early years of the century he was qualifying himself for high army rank. At the same time he was an ardent student of military history and of the science of strategy. Ill-health, however, continued to handicap him. Late in 1899 he was sent home on one year's sick leave. He was again in England in 1903, in 1910 and in 1914.

On his return to India in August, 1914, he was appointed "Divisional Engineer Commander," i.e., C.R.E. of the 6th (Poona) Division, then under orders for Mesopotamia. Characteristically, he immediately started an intensive course in field-works for the Sappers and Miners and Pioneers under his command and conducted two staff rides for their officers. As no Field Park was to be mobilized with the division, Evans extemporized one. He did more; he "went to Bombay and chartered a 600-ton ship to carry the materials, timber, cement, wire and paulins which he considered necessary." He also obtained permission from the C.G.S. to form an Electrical Section.

Early in November, 1914, he sailed from Bombay with the leading troops of the Mesopotamian Expeditionary Force. On the 17th he was wounded at Sahil during the advance on Basra; but rejoined a fortnight later. Engineer work in Basra was very heavy; material and labour were at a minimum. Full justice will, it is hoped, be done elsewhere to the achievements of the technical troops on the Shatt-el-Arab in the early days of the war. They drew their inspiration largely from their Commanding Officer, Evans. On the 7th June, 1915, he became G.S.O.I. of the 6th Division and held that appointment until given command of the 17th Brigade in Kut early in 1916. He was General Townshend's right-hand man during the successful Tigris campaign of 1915, which ended so disastrously at Ctesiphon and Kut-el-Amara, and he was mainly responsible for the defensive system adopted by Townshend during the siege of Kut. On the 8th March, he was given command of one of the two brigade-groups organized to break out of Kut and co-operate with General Aylmer in his action at the Dujailah Redoubt. But Aylmer's attack failed and there was then no hope of co-operation. That failure sealed Kut's fate; and the fall of Kut ended Evans' military career. He was a prisoner of war in Turkey for two years and eight months and, on return to England, had to be admitted to Millbank Hospital. In 1920; he learnt that he had no prospect of further army employment. His service in Mesopotamia had won him the C.B., C.M.G., Croix de Guerre (French) and five Mentions in Despatches.

He retired on the 3rd June, 1920; but he had no idea of living an inactive life. He threw himself whole-heartedly into the study of electrical engineering and accepted the offer of a highly responsible appointment in an Indian Hydro-Electric concern. He proceeded to India at once; but was so ill on arrival at Bombay that he had to resign his appointment and return to England.

Thereafter, he continued his study of all forms of engineering, particularly motor, aero and radio; but only as an amateur. He realized that his health disqualified him for any professional employment.

In 1939, however, he became a very active A.R.P. Warden at Clifton until he had a severe heart-attack, which kept him in bed for seventy days. Yet, in October, 1940, he considered himself well enough to undertake the organization of the fire-protection, first aid and welfare of fifty houses and was out all night in all raids. It was only a severe attack of pneumonia after 'flu that compelled him to retire from fire-fighting in 1944. His strength then gradually ebbed away; but he was cheery and chatty to the end.

Evans was always a good sportsman, though not a great player of games. He was a strong rider and devoted to hunting and polo. In the early nineties, he was leader in the renaissance of Madras Sapper polo which paved the way to many successes in South Indian tournaments. He was a crack shot with rifle, revolver and shot gun. As an organizer and trainer of teams for rifle meetings and military athletics of all sorts he was unsurpassed. It was mainly due to his tutelage that the Madras Sappers were so often adjudged "Best regiment at arms" in 9th Division Assaults-at-Arms and that the Bombay Sappers gained the same distinction in the 6th Division in 1913.

He had the gift of tongues to an unusual degree. He read, wrote and spoke fluently French, Italian, Turkish, Persian, Pushtu, Urdu and Tamil, and had more than a bowing acquaintance with Burmese, Punjabi, Arabic and many European languages. He learnt languages not for the pecuniary rewards which his proficiency might have brought him but for the sheer joy of making use of that proficiency, and nothing pleased him more in his last years than to "listen-in" on a wonderful receiver, largely made with his own hands, to the broadcasts of all nations. He did much valuable work in the review and translation of foreign books, notably in his translation of the Turkish Official Account of the War in Mesopotamia. His English vocabulary was unique: but that is another story!

Evans was essentially a good companion and, in his prime, full of *joie de vivre*. He did not suffer fools gladly; but was quick to recognize and encourage a trier. He was always keen on the job in hand and thorough in his execution of it. It was only natural, therefore, that he should inspire confidence and devotion in his co-workers. Though the very reverse of a carpet knight, he was popular socially, a good conversationalist (when he chose), full of quaint tales and shrewd comments, and he possessed a great sense of humour. He was, indeed, a man of many parts.

He was twice married, firstly in 1907 to Julia Gertrude, second daughter of the Rev. W. S. Davis, who died in 1918 during Evans' captivity, and secondly in 1921 to Flora, widow of Lieut.-Colonel C. Sandes, who died in 1925. There were no children of either marriage.

T.F.

Brigadier General Usher W Evans CB CMG

Major General William Huskisson CMG

MAJOR-GENERAL W. HUSKISSON, C.M.G.

WILLIAM HUSKISSON was the son of Francis H. Huskisson, a member of the Civil Service employed at the Royal Naval College, Greenwich, where Huskisson was born in February, 1859. He was educated at Crompton House, Brighton and was commissioned in the Royal Engineers from the R.M.A. in January, 1878.

In 1882 he elected for Indian service and served in India at Umballa and at Quetta, working on the Bolan Road. In 1889 he returned home to command the 5 Coy. R.E. at the S.M.E. till at the end of 1890, he was made Professor at the Royal Military College, Kingston, Canada. Home again in 1895 he was employed at Chatham in the Thames District and in 1898, in the rank of Major, he became Professor of Fortification, R.M.C., Sandhurst.

In 1903 he was ordered to India and was C.R.E. Presidency District, Calcutta, being promoted Lieut.-Colonel in April, 1904. The next year he was made C.R.E. 9 (Secunderabad) Div., this was a Colonel's appointment and in April, 1907, on completion of three years' service as Lieut.-Colonel he was promoted Substantive Colonel. He continued in this job till he left India in May, 1911, when after a few months of unemployment he was made Chief Engineer, Scottish Command, Edinburgh, where he was serving on the outbreak of war in August, 1914.

Up to this time his work and service had followed the routine of many senior officers of the R.E., a record of good work carried out with zeal and efficiency in many parts of the world. He had not had the good fortune to see active service, but the fact that he had been twice selected for an appointment as Professor of Fortification showed that he had not neglected the military side of his duties.

On the outbreak of the 1914 war his first job was the Engineer work connected with mobilization in Scotland, especially the preparation of the defended ports. In January, 1915, he was selected for active service on the Lines of Communication in France. As the British Armies moved to the north it had been intended to divide the work on the L. of C., then under Brigadier-General A. M. Stuart, into two parts and Huskisson was chosen as Director of Works for the Northern Line, with headquarters at Boulogne, but it was finally decided that Stuart should remain Director of Works for the whole area and Huskisson became Deputy Director at Boulogne, where he took up work in February, 1915.

During the early part of the year the Force in France was gradually reinforced by new Divisions from England, which were grouped into Corps and Armies, and when the VII Corps was formed in July, 1915, Huskisson was selected as Chief Engineer with the rank of Brig.-General. At the same time this Corps and the X Corps were formed into the Third Army, under General Sir C. C. Munro, and a little later this Army with the XII Corps added, took over from the French a portion of the line astride the Somme and south of the French Army. Preparations were in progress for the battle of Loos, which began on 21st September and lasted till 4th November. This battle was fought by the First British Army and the Tenth French Army, under the command of General Sir Douglas Haig, but the Third British Army was to support the French, if they succeeded in their attack, by the advance of all nine Divisions. This involved much Engineer work in the advanced trenches, but as the French attack was not successful, this advance did not take place.

On 3rd October, 1915, Huskisson was selected as Chief Engineer, Third

Army, with the rank of Major-General, in succession to Major-General J. E. Capper who was given the command of a Division.

At the end of 1915 plans were begun for a combined attack on the Germans which later developed into the Battle of the Somme, but these plans were delayed by the attack on Verdun which was opened by the Germans on the 21st February, 1916, and continued for several months. This caused the withdrawal of the Tenth French Army and the gap was filled partly by an extension of the First British Army to the south and partly by a move of the Third British Army, under Lieut.-General Sir H. E. Allenby, to the north.

The methods of trench warfare adopted by the French were on a much lighter scale than the British, so there was a great deal of Engineer work on the new front of the Third Army. This included, in the words of the *Official History*, Vol. VI, " a desperate struggle for mastery below ground " in which no less than ten British tunnelling companies were engaged. The whole of the work was further complicated by movements of Divisions and Corps in connection with the formation of the new Fourth Army. As a consequence of the success of the British mining operations, the Germans launched an attack in May on the Vimy Ridge at the junction of the British First and Third Armies and were successful in overrunning the British mine-shafts, but were eventually checked and a new defence line was established a little further to the west. During all these operations Huskisson was very fully employed; he was mentioned in despatches and in 1916 was given the C.M.G. Meanwhile the preparations for the battle of the Somme were proceeding and the opening of the Allied offensive was fixed for the 1st July, but Huskisson's share of the work came to a sudden end; he had been overtaxing his strength for some time and on 16th July, on the recommendation of a Medical Board, he was ordered home and had to give up his appointment.

When he recovered from his illness, there was no appointment vacant in England for an officer of his seniority, so he accepted the position of Chief Engineer of the Thames and Medway Defences under Major-General H. Mullaly. Most of the defences had been prepared but there was considerable work in hand in connexion with the expansion of the Electric Light and Anti-Aircraft defences against Zeppelins. In October 1916, he had the bad luck to fall when inspecting trenches and broke an arm. Though this mended eventually it brought his military career to an end, as he was past the age for a further Colonel's appointment, so in November, 1917, he retired with the honorary rank of Major-General.

He had married in 1890 the second daughter of Colonel David Ward, late Royal Bengal Engineers and had three daughters. The eldest who is unmarried has just returned after spending twenty years as head of a Native Mission School in South Africa. The second is the widow of Lieut.-Colonel P. T. Birch, D.S.O., R.A., who died in 1939; they had two sons, both of whom have done good work in the R.A. during the last war. The third daughter has also done useful work as Secretary of the Hampshire Women's Land Army.

After his retirement the family settled down at Alverstoke in Hants, where Huskisson busied himself with many local affairs. He was local Secretary and Chairman of the St. John Ambulance Society, and received the medal of the Order of St. John of Jerusalem in 1938; he also served on the Committee of the Gosport War Memorial Hospital, was for twenty years churchwarden of the Church of St. John the Evangelist at Forton, was Chairman and Secretary of the Sailors' and Soldiers' Institute and a member of the British Legion. He passed away on 24th July, 1946, in his 88th year.

W.B.B.

BOOK REVIEWS

STANDARD MILITARY RAILWAY BRIDGES

By F. S. Bond

(*Railway Gazette*. Tothill Street, London, S.W.1. Price 5s. 0d.)

During the late war destruction of communications by air bombing and enemy demolitions reached a degree of intensity previously unknown. Bridges suffered particularly badly, and consequently there was an unusual output of inventive effort devoted to bridge repair and replacement. For roads the Bailey Bridge became world famous, while for railways results equally useful, though not so well known, were achieved by Lt.-Colonel Everall, R.E. An account of his work is given in the pamphlet under review, which deals with bridges, piers, and foundations designed for rapid construction in the field. These designs were adopted without hesitation by the Americans, despite their own inventive genius, which was no small compliment to the designer.

The first chapter describes the Unit Construction Railway Bridge or U.C.R.B. This was for spans of 45 to 105 ft. and was the type of bridge most commonly used. It was employed in the British built bridges over the Seine near Rouen and over the Rhine at Spyck. An account is also given of the light standard steel trestle, adjustable to any height, width, or length, and the "camel foot" which could be fitted to the lower end of each trestle column, and adjusted for depth from above water level. In many cases this arrangement avoided the necessity of driving piles. The steel trestles were found very useful for bridge repairs by British railways during the blitz.

Chapter 2 deals with the Standard Through Truss Bridge for spans of from 90 to 150 ft. It was found specially useful in Italy for bridging deep ravines where the use of U.C.R.B.'s would have entailed the erection of unduly high intermediate trestles.

Chapter 3 describes a sectional plate girder for 40 ft. spans. To facilitate transport, each unit was supplied in three sections, the heaviest component weighing 1·6 tons.

Chapter 4 gives an account of the Everall Sectional Truss Bridge for use over spans of from 80 to 400 ft. In spite of its size, the length of span can be varied in increments of six inches. It is made of small parts, all of which can be manhandled, and may be erected as a cantilever up to 300 ft. span. This design was first used for replacing three girders, each of 230 ft. span, at Deventer in Holland. Large quantities have been acquired by foreign governments for the replacement of long span bridges.

Chapter 5 is a short account of American bridge work. In some cases they used material locally available in the shape of rolled steel beams, one metre in depth and up to 95 ft. in length, which were manufactured in Luxemburg for German use. They also produced an unorthodox design called the Demountable V Type Railroad Bridge. In this type Warren trusses splay out from what is, for all practical purposes, a single bottom chord member forming a span with a V shaped cross section. It can be used either as a deck or a through span for gaps from 30 to 90 ft., and much weight is saved by the elimination of all bottom chord bracing.

The inclusion of a large number of illustrations of bridges actually erected in the field adds considerably to the interest of this pamphlet, which is an excellent record of railway bridge types used during the war.

H.L.W.

THE STORY OF GIBRALTAR

By H. W. Howes, M. A., M.Sc., Ph.D.(London)
(Director of Education, Gibraltar)

(Published by Philip and Tracey Ltd., 93 pp., 16 photographs and 2 maps. Price 4s. 0d.)

This short history, which contains a foreword by H.E., The Governor and C.-in-C. Gibraltar, written primarily to give the young Gibraltarian a pride in his community and in its importance to the British Empire, will be appreciated by those interested in military matters as a concise account of the vital part this outpost has played in the history of Europe. To the many soldiers, sailors, and airmen who were stationed on the Rock, or were there in transit, during the war years, this little book, with its many photographs, should be a valuable souvenir.

Dr. Howes traces, in a few chapters, the story from the eighth century, or Moslem period, through the days of Ferdinand and Isabella; Charles V (whose name still lives in the wall); Philip II to the "Prelude to British Occupation." At chapter V the story has reached the stage where, in 1713, the Rock becomes British, by the Treaty of Utrecht. The Great Seige, 1779 is allotted one chapter, just a fair share in a story of this length. The next phase covers Napoleon to the Suez Canal and the history ends with the period of the two World Wars, see chapter IX which many will find the most interesting in the book. The photograph of the American War Memorial furnishes a reminder that Gibraltar served as an important base to our allies in the War of 1914-18. In the second World War the Mediterranean highway became of supreme importance. Hitler, as his plan "Felix" proves, contemplated bringing Spain into the war, and then attacking the gate, Gibraltar, to gain control of the Straits. Ambassador Hayes considered that Germany made a grave blunder by not putting the plan into operation at an early date, because the major defences of the "Rock," including the tunnelling, were not nearing completion until 1942. Mention is made in this chapter how the need for air cover, and for a transit station for Egypt, led to the building of an aerodrome 800 yds. out to sea, described in the Sept. *R.E. Journal.*

The final chapter deals with Gibraltar as a Colony rather than a fortress. The development of the Central and local government, and its position to-date, is here clearly given.

H.M.F.

SHEET PILING, COFFER DAMS & CAISSONS

By Donovan H. Lee, M.Inst.C.E.

(Published by Concrete Publications Ltd., Price 10s. 0d.)

This book will provide a very useful text-book for students and engineers who wish to study the type of work described in the title. It gives a very clear picture of the theoretical problems to be considered as well as details of a number of practical examples of work carried out in various countries. In the latter cases the reasons for adopting special methods are explained.

The calculations for assessing both active and passive pressures on the sheeting under different conditions are discussed at some length. This chapter is well illustrated with diagrams of pressure curves and of practical design. By their very nature these calculations are of necessity complicated and require considerable practical as well as mathematical knowledge, and for any large or important work they are essentially a matter for experts.

The same can be said of the actual design of the sheeting, etc., required to resist the pressures which have been calculated. Here, although the general principles are clearly described and easily understood, the detailed design is not described so fully.

The book is very fully illustrated, both with photographs and line drawings. The latter have been greatly reduced for reproduction, but the lettering is in most cases clear and they are easy to follow. They show clearly all the points being discussed.

The chapters on Coffer Dams and Caissons contain details of several intersting works carried out on such varying subjects as the foundations for the new Waterloo Bridge in London, the very large piers for the San Francisco Bay Bridge and the remodelling of the Assiut Barrage, on the Nile, amongst others.

There is a chapter on Pressure Work in Pneumatic Caissons, with details of the necessary air locks and particulars of working conditions under different pressures.

The final chapter deals very briefly with the Box Caissons used for breakwaters in the Mulberry Harbours during the Normandy Invasion.

Throughout the book any subject which is dealt with by another author is clearly numbered and a useful reference table is provided at the end giving full details of the name of the book and the author. This numbering enables the reader to see at once where he can obtain further information on any particular point of detail.

In his preface, the author states that his intention is to provide a concise modern treatment that can be read with interest and also serve as a reference book. These objects have undoubtedly been achieved.

C.C.P.

PLANE AND GEODETIC SURVEYING FOR ENGINEERS

By the late David Clark, M.A., B.Sc.

Vol. I., *Plane Surveying*, Fourth Edition revised and enlarged by James Clendinning, O.B.E., B.Sc.(Eng).

(Constable and Company Ltd., 1945. Price 30s. 0d.)

Clark's two-volume text book on Plane and Geodetic Surveying was first published after the first world war, and its usefulness and popularity are attested by the number of editions and reprints. For Royal Engineers its principal virtue is that it is complementary to the Text Book of Topographical Surveying and to Survey Computations, taking one further into the survey problems of the forest belt, than they do. This fourth edition retains the matter, save for minor corrections, and the paging, of the third edition (1940), but adds five new and valuable appendices. The first on "Some recent small Theodolites with glass circles" will be particularly useful.

This is certainly a book for one's survey bookshelf.

H.S.L.W.

MAGAZINE REVIEWS

GEOGRAPHICAL JOURNAL

(Published by The Royal Geographical Society, London)

January—February, 1946.—Brigadier Bernard Fergusson gives a most interesting account of two military expeditions into Upper Burma, the first of which, in 1943, was in the nature of a foray, and the second, in the following year, was in much greater strength and better equipped, and had the assistance of an American Air Force. He is somewhat apologetic for the fact that in addressing a geographical audience he is unable to give much new geographical information: but the interest of his narrative of arduous operations in this difficult country far outweighs any lack of geographical matter.

Professor H. W. Ahlmann gives an account of " Researches in Snow and Ice " carried out in the period 1918-40 in Norway, Iceland, Spitzbergen and Greenland, which show that a remarkable climatic change (in the direction of greater warmth) has been taking place in the Arctic since the middle of the nineteenth century, at first very slowly and of late rapidly.

P. B. Cornwall contributes a long account, of a great archaeological interest, of exploration and discoveries in the province of Hasa in Saudi Arabia.

J. A. Steers gives an interesting continuation of his previous account (pub., 1944) of " Coastal Preservation and Planinng."

There is an obituary notice, by the President, of Ahmed Hassanein Pasha, a distinguished Fellow of the Society and a well known traveller and explorer.

E.M.J.

EMPIRE SURVEY REVIEW

(Published by The Crown Agent for the Colonies)

July, 1946.—N. B. Favell, in Suggestions for speeding up Topographical " Surveys," gives various methods of saving time on rapid or reconnaissance surveys, as the result of his practical experience. He lays particular stress on the use of slide rules for computations, and describes two types which appear to have special value for survey work.

H. A. S. Smith describes " Some Surveys of Rivers in Ceylon," and gives an interesting account, illustrated by photographs, of large scale models of rivers made from these surveys for the purposes of experiment.

B. Goussinsky discusses " implicit " condition equations in the adjustment of figures, and L. P. Lee has an article on the convergence of meridians.

There is a note on the recently formed Directorate of Colonial Geodetic and Topographical Surveys, to which Brigadier M.Hotine has been appointed, and an obituary notice of the late Captain John Calder Wood, who succeeded Captain McCaw as Mathematical Adviser to the Geographical Section, War Office.

E.M.J.

JOURNAL OF THE UNITED SERVICE INSTITUTION OF INDIA

(Published by the Civil and Military Gazette, Ltd., Lahore.)

April, 1946.—*Selection or Personal Prejudice* is a well thought out defence of the selection board system of choosing candidates for commissions in force in India. The system differs little from that in use in the U.K., which has been described in this Journal (Dec., 1944). It is noteworthy that an overwhelming majority of candidates, whatever their province, religion or language, preferred both written and verbal tests to be in English.

Malaya Campaign ; the first and last weeks. The author, Staff Captain in a Gurkha brigade, tells the unvarnished tale, melancholy but very interesting, ending with his being marched off into three and a half years' captivity. He makes no recriminations, and praises Indian and Gurhka troops, and especially the Chinese, who helped us at the risk of death and torture. The only bitter note creeping in is our lack of aircraft.

It is good after this to read *Assisting the Malayan Maquis* which was done by B.O's and Gurkhas parachuting into enemy-held territory. They were received by a very useful Chinese force, and their only regret was that they arrived too late for more than one brush with the Japs. There were however ticklish times after the surrender, and before the arrival of the army of Occupation, when they were outnumbered by 1000 to one. They had magnificent welcomes from Chinese and Malayans, and above all from P.W's.

India's watchword—Readiness is a well-written essay, beginning with an apt quotation from *Mein Kampf*. What the Indian forces want above all are leaders, and these can no longer be counted on from Britain, nor can the present education system in India produce enough of the right type of man. The author suggests schools, beginning with boys of nine years of age, and going on to the stage where a pupil will be able to take his place in the armed forces, or alternatively join the civil services. The disarmament of the N.W. Frontier tribesmen is the first item in the author's defence programme, followed by the provision of a contingent to help the U.N. ; finally, preparation for World War III, should the U.N. fail to preserve peace. A would-be aggressor must be attacked and crushed and not appeased.

Sinews of War and all that states as one of the reasons for the German collapse, as also that of Japan, the failure, once the great offensive had been halted, to react quickly enough and produce new types of surprise tactics and equipment. We were fortunate enough to be able to do so. The lesson must not however be thrown away ; there must be close and continuous contact between military, technicians and manufacturers to see that the new weapons produced are the best possible and produced in the minimum of time.

India's National War Academy is to be built near Khadakvasla Lake, near Poona. This lake is formed by a dam across the Mutha river, built by Lieut.-Gen. J. G. Fife, Bombay Engineers, and is still sometimes called Lake Fife.

Further Thoughts on Frontier Myths is another rejoinder to *The Frontier Myth* in the July, 1945 Journal. As the author states, a large part of the Indian 4th, 5th and 8th divisions had been trained in frontier warfare, and where could you find better morale, or more dash and initiative than they showed on a hundred battlefields during the late war ?

India's Policy towards States of the Indian Ocean Area by the Prime Minister of Bikaner State, is particularly interesting. The most dangerous points are the Persian Gulf and the Dutch East Indies, to both of which Russia has fairly easy access. Whatever the ultimate form of Indian Government, an offensive and defensive alliance between Britain and India is essential.

The Last Year in Italy. The author has a good many criticisms to make concerning operations up to the beginning of the final push in March, 1945, which, he says, was magnificently run. Among the criticisms is that of the habit of commanders of initiating small offensives with little or no tactical value, simply to keep up morale. This was not done by Canadian and New Zealand troops to anything like the same extent, with the result that they were much fresher on D day.

Our Infantry, compiled from notes left by the late Lieut.-Col. Sarbjit Singh Katha—he was killed in Java in Jan., 1946—is of outstanding interest as showing that infantry work today is every bit as technical as that of other arms of the service.

To get the best men, the Infantry should be paid at much higher rates and draw marriage and children's allowances.

When Expansion again becomes necessary notes the difficulties the civilian is up against when he becomes a part of the war machine. The army should therefore be run on business lines. With this everyone will agree, but it is the getting down to brass tacks that is always the trouble.

F.C.M.

THE INDIAN FORESTER

(Published by the Civil and Military Gazette, Ltd., Lahore.)

April, 1946.—D.D.T. has been so cracked up as a remedy against all noxious insects that a warning note comes not amiss. There are some harmful bugs that it seems hardly to affect at all, such as red spider, and it has no ovicidal properties at all. Its effects on hive bees and useful insects have not been fully investigated.

May, 1946.—*Aerial Reconnaissance for Forest Officers* describes a flight in a Gypsy Moth over more or less desert areas in the east of Sind. In addition to a previous ground recce. on camels, of parts of the area, it gave very valuable information regarding nature of vegetation, drift of sand, etc. The camera used was a Rolliflex 2¼ in. by 2¼ in. roll film (a larger one proving less useful) which was not fixed to the plane, but carried strapped to the observer. The cost worked out at Rs. 250, say £18, and the trip occupied a few hours only, a great saving both in time and money. But, says the author, the preliminary ground recce. was very necessary.

June, 1946.—*War comes to the Doon Forests*, in spite of some technical terms, is of absorbing interest. Covering an area of fifty-five miles by seventeen, the forests lie in the U.P. near Dehra Dun. 1939-45 brought demands for timber of all shapes and sizes far in excess of peace-time procedure. Scantlings, sleepers, *ballis*, bamboos and firewood were produced, and contractors hauled them to railhead on coolies' heads and shoulders, by camels, bullock carts and M.T. Roads had to be improved or made *ab initio*, and existing bridges had to be strengthened. To add to the difficulties, a Tactical Training School was established in the middle of the area. This school, and the presence of the 39 Div., in training just outside the forest, added greatly to the danger of fire, and an improved system of fire fighting was introduced. The blitz, as they termed it, left the forest worked out for many years to come, but with certain solid gains, such as the clearance of otherwise useless trees, which went for firewood.

F.C.M.

THE MILITARY ENGINEER

(Published by the Society of American Military Engineers.)

May, 1946.—*The U.S. Corps of Engineers.* By Lieut.-General Raymond A. Wheeler, Chief of Engineers, U.S. Army. An excellent, short and concise description of the development and organization of the Corps of Engineers. Act of Congress on 16th March, 1802, directed that the " engineers of said Corps shall be subject at all times to do duty in such places and on such service as the President of the United States shall direct." This instruction has resulted in the detail of Corps of Engineers' Officers throughout the Government structure, and their serving in many capacities outside the Army. Within the Army, Engineer Officers frequently fill other than Engineer appointments. General of the Army Douglas MacArthur and General Somerwell were conspicuous examples during the War. The Chief of Engineers has two jobs; to direct the Engineer Technical Service for the Army, and to direct the Engineer Department for Federal flood control and navigation improvements and maintenance. In his first capacity he works largely through thirteen Engineer Divisions and three independent Engineer Districts. Eight of these Divisions and the combination of two Divisions have military boundaries which correspond to the boundaries of the nine Army Service Commands. The thirteen Divisions have under them forty-six Engineer Districts. Post Engineers and Depots, work directly under Divisions and not under Districts. In his second capacity the Chief of Engineers uses the same Engineer Division and Engineer District organization, but not the Post or Military Depot Engineers. In addition he uses a number of Boards and Commissions to help him perform his civil functions. All civil projects are also referred to the Governors of respective States for an expression of their view-points. Many Government Agencies faced with construction programmes turn to the Engineer organization for help. An interesting list of Corps of Engineers Installations is given at the end of the article.

Dozer on Wheels. By Mr. Leighton W. Johnson. An account of experiments carried out for the Engineer Board to fit a T-D18 International-Harvester angledozer with retractable pneumatic tyres for rapid transportation by road and to eliminate the necessity for carriage on a trailer. Three excellent photographs illustrate the article. The experiments are not yet completed.

June, 1946.—*Operation Crossroads.* An interesting editorial dealing with future control of the Atomic Bomb. The arguments put forward are :—

The best way to promote an armaments race is to provide each nation with what it needs to conduct such a race. Although our generation has learned from recent experience that acts of appeasement lead to War, yet the trend toward an appeasement policy, especially in relation to the atomic bomb, seems to be stronger today than ever. President Truman is quoted " The Atomic Bomb is too dangerous to be loose in a lawless world." The atomic bomb can, and should, be used as an instrument to preserve peace. The people of the United States wish so to use it, but if they give away their military secrets, they may create chaos.

Peacetime Duties of the Civil Engineer Corps of the Navy. By Rear-Admiral John J. Manning, U.S. Navy, Chief of the Bureau of Yards and Docks. Deals with the problem of the future design and maintenance of naval shore installations in the light of new methods of destruction introduced by the Atomic Bomb or rocket. Factors to be considered in future installations are, greater dispersion of facilities, the construction of duplicate facilities, the design of sturdier and radiation-proof structures, and the feasibility of underground facilities. Also, the important possibility that the best defence for naval shore installations lies not in making them bombproof, but in perfecting their offensive character. The Maginot line philosophy should be avoided at all costs. For the word "defence" should be substituted "preparedness." The responsibility of the Engineer in the face of the uncertainties of the future, and what countermeasures will be most effective, is to keep his eyes open and his mind alert, and to ensure that by research, imagination and experimentation he keeps ahead of the game.

Development of the Atomic Bomb. By Major-General Leslie R. Groves. An interesting and detailed article on this £500,000,000 project which was organized and developed under the direction of the Manhattan Engineer District of the Corps of Engineers. A masterpiece of co-ordination of the activities of hundreds of thousands of Americans by the Corps of Engineers who were first brought into the work in August, 1942, and achieved success by July, 1945. The Manhattan District was a special District, and it was charged with the direct responsibility of carrying forward to completion the Atomic Bomb Project, and nothing else. It had special powers and all the facilities, not only of the Corps of Engineers, but of the War Department as a whole, were available to assist it.

The work of the Manhattan Engineer District was divided into four major classifications :—

(*a*) The further research and development work required, including the production of U-235 and plutonium.

(*b*) The design, construction, and operation of plants for the full scale production of the required fissionable materials.

(*c*) The design and construction, to be followed later by the test and use, of the atomic bomb itself.

(*d*) The maintenance of security and absolute secrecy in all phases and all details of the work.

The author was Deputy Chief of Construction working under the Chief of Construction and Deputy Chief of Engineers, when on 17th, September, 1942, he was placed in charge of the development of the atomic bomb. He was commissioned in the U.S. Corps of Engineers in 1918. An interesting comparison would be the appointment of a D.D.W. or C.E. Works to control the National Housing Programme or the development of Atomic power in this country, should urgency ever require these projects to be handled as military operations.

July, 1946.—*Operation Crossroads* by Major Philip G. Kreuger (under the supervision of Major-General Leslie R. Groves), deals with the detailed organization and preparation of the stage for the atomic bomb test at Bikini, and covers the composition of the task force, preparation of the areas, assembly of the force, layout of the target, conditions required for the operation and delivery of the bomb. An interesting point is that coral heads or peaks, in the target anchorage were blasted off to a depth of forty feet in preparing the target area prior to the test. The atomic bombs for the tests were delivered to the Air Force by Manhattan Engineer District. The author emphasizes that the test is a joint operation of all services to test the atomic bomb, the product of the Manhattan Engineer District. This is the first of a series of three articles prepared by Officers posted to the Manhattan Project of the Corps of Engineers.

N.W.

REVUE MILITAIRE SUISSE

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May, 1946.—*Le Problème du Haut Commandement.* (contd.) Col. Anderegg continues his study of the questions which now arise in the Swiss High Command. The desirability of keeping the number of high functionaries to a minimum makes it necessary to have a very clear definition of duties and responsibilities. The growing power of the Administrative side of the Army tends to overtake the prestige and importance of the Chief of the Military Department, who is the highest official, but need not necessarily be a soldier. When a strong personality has been at the head of the Army, he has usually been succeeded by a committee rather than by a single head. This is an age-old experience and is not confined to Switzerland.

Une Offensive Pacifiste contre la défense nationale. (contd.) by Major P. de Vallière. The Communist attack on the Swiss measures of national defence is countered by further strong arguments. The author points out that during the troublous period since 1930 all the chief military powers were interested to know what were the Swiss ideas on the defence of the Alpine bulwarks, and he quotes French, American, and Polish opinion on the Swiss system. Undoubtedly, the safeguarding of the Alpine passes was a matter of deep concern to peace-minded nations ; and it still is. Not even the experiences of the small nations over-run by Germany seem to deter the sinister critics of military service.

Le Tragique du Coup de Main by Captain Allgöwer, describes the series of military *coups de main* perpetrated by the Germans, from Ludendorff's onslaught in the West in 1918 to the series of Hitler's lightning attacks of 1939-43. Germany's recent leaders have tried to excuse themselves by claiming that they had no part in the Nazi doctrines of aggression, but they played their part in the policy which seized the opportunities given to them to avenge the Treaty of Versailles. Hitler's Munich Putsch in 1923 was backed by Ludendorff. It failed to overthrow the Government, but it created the spirit of revolt. When Hindenburg, as President, had to accept Hitler as the leader of the best organized party, the way was open. Thereafter, whatever hopes there were of Germany settling down as a peaceable partner in Europe were swept away by the sequence of increasingly successful *coups de main* which carried Hitler forward in his mad career.

June, 1946.—*Le Problème du Haut Commandement.* The conclusion of the articles by Col. Anderegg. He lays emphasis on the necessity, now greater than ever, of selecting the Commander-in-Chief in time of peace, and of giving him full scope to study his problems, his staff and his means. In other words, the High Command must be prepared, from day to day, to function as a war machine. This selection of the High Command cannot be left to the eve of war. The team must exist and have as long a preparation as possible. It is easier to select the right men in time of peace than to choose them under the pressure of violent events. Yet is it not very often the case that it is the pressure of war which produces the man of the hour ?

Une Offensive Pacifiste contre la défence nationale. Major de Valliére continues his refutations of the pacifists' claims, He describes the development of the Pan-German doctrine and the growth of the German ambition to absorb most of her smaller neighbours, Switzerland among them. He reminds his readers that Swiss independence dates from 1291. The Germanic connection is linguistic, not racial. The Helvetians were a Celtic people, attached to Gaul. The German overtures were illusory ; the Swiss have no desire to be drawn into the Teutonic bosom, and since their national spirit has preserved for centuries their independence, to the great benefit of the rest of Europe, the argument for maintaining the integrity of this brave people is scarcely to be challenged.

Le Tragique du Coup de Main. Captain Allgöwer continues his article, pointing out that since the days of Moltke, the German High Command has devoted itself to systematic preparation for war; not war as a means of safeguarding the nation, but as an instrument of aggression, a means of imposing the Teutonic will upon all and sundry. The methods of war were constantly under review, in the search for new surprises. With every stage in the German military development, a new feature was sought for, and prepared so that attacks could be made without warning. Such methods will always attain some initial success.

July, 1946.—*Le Rapport du Général Guisan sur le service actif* 1939-45. By Major P. de Vallière. General Guisan was Commander-in-Chief of the Swiss forces throughout the late war. In his report to the Federal Assembly he has given his impressions, criticisms and proposals for future consideration. Each time that Switzerland has mobilized her forces in face of threatened danger (there have been ten previous occasions) the Commander-in-Chief has rendered a report, and each of these documents has been the starting point of important military reforms. No exception is likely to follow in the present case.

Until the fall of France in June, 1940, Switzerland had to keep her defences prepared for action in the north and the west. The remnants of the French 45th Corps, the 2nd Polish Division and a Brigade of Spahis—in all, some 40,000 men—crossed the Swiss frontier and were interned.

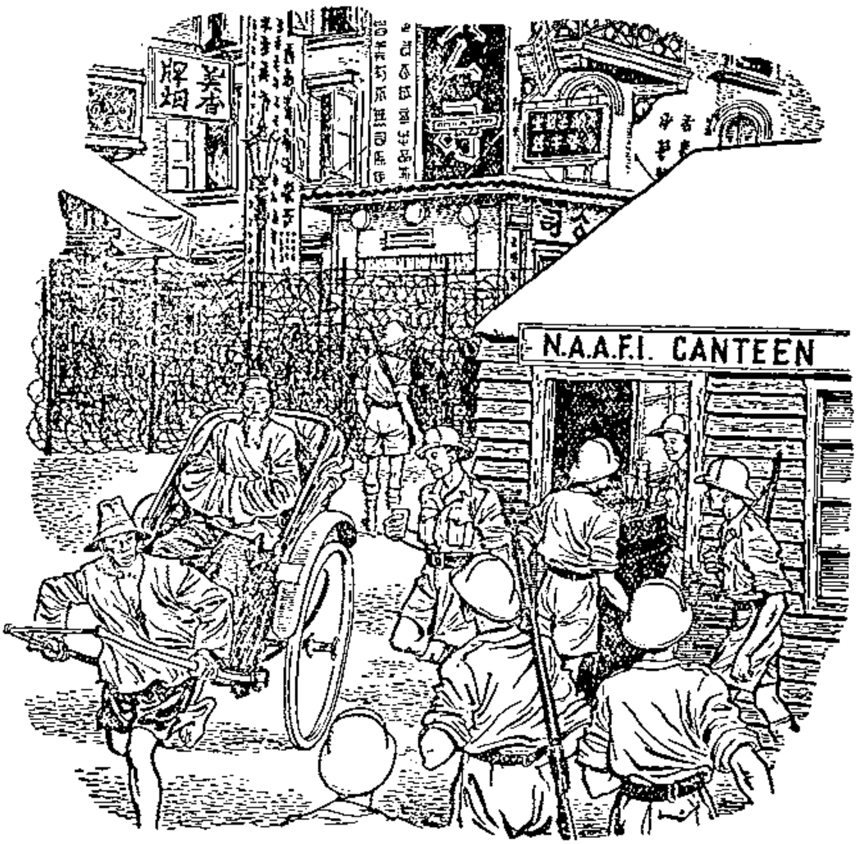
When Italy entered the war, the encirclement of Switzerland became complete. Fresh dispositions had to be made. Fortifications were vigorously pressed on. The Alpine passes were prepared for demolition and total obstruction. Great magazines were carved out of the rock.

The Allied invasion of Normandy, and more particularly the Franco-American operations in the south of France once more affected the western frontier of Switzerland. From Bale to the north of Berne, the Swiss placed five divisions, two light brigades and three frontier brigades. Two Corps watched the north and north-west, and elements of two more Corps watched the south. It was always possible that the Germans might try to break through Switzerland. The possibility that they would make a last stand in the Black Forest, with a bolt-hole through to the south, kept the Swiss on their toes until the end.

Le Tragique du Coup de Main. Hitler's will had to be unchallenged. While his successes lasted he could dispense with the old school of military leaders: he found a sufficient number of subservient soldiers, even among the proud Prussians. But when he came against the hard core of resistance which his enemies still preserved, he had to fall back upon traditional military science. German *Kultur* was not equal to the task of re-organizing Germany on humanitarian lines. The great Juggernaut of war was the sole instrument of the maniacal painter who seized the leadership.

L'engagement des troupes aeroportées. by Lt.-Col. Nicolas, introduces an article by Lt.-Col. J. G. Cornett, reprinted from the American *Military Review*. The air attack on Crete is described as the prototype of air-borne tactics. The first occasion on which parachute troops were used in the war was the attack on Rotterdam on 10th May, 1940. As with all the German surprise-methods, the Allies soon improved on the technique and surpassed the innovators, both in scope and daring.

W.H.K.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